

Linguistic Approaches to Literature 16



Creative Confluence

Johan F. Hoorn



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Creative Confluence

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Creative Confluence
by Johan F. Hoorn

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Venus Rose
(a cyborg poem)

A rose is like Venus

A rose is joy:

You celebrate the moment

A lily is like the sun

because both are full of beauty

The day is like love, starting afresh

by the end you're tired

Sleeping is like the sun

and death is like winter:

Every ending

brings a new beginning

Introduction

“Our problems are manmade; therefore they can be solved by man. ...
Man’s reason and spirit have often solved the seemingly unsolvable,
and we believe they can do it again.” (Kennedy, June 10, 1963)

1. Puzzled

The other day, I held a seminar on creativity with a group of about thirty university professors from different disciplines: Law, history, art, engineering, computer science, etc. They were sitting in a rectangle with a wide open space in between. I handed each a box containing a 50-piece jigsaw puzzle. The puzzles were all different: A landscape, a painting, cuddly animals, an airplane. They started to work and the professors were satisfied for having finished in time although they wondered what this had to do with creativity. “Is it the scattered representation of the work?” the art historian asked. “Is it about restoring harmony into the system?” the student of law inquired.

I then asked them to take their completed puzzles and throw them on the floor in the open space between the tables. There was some hesitation and some protest of why they had to do all this work in the first place but after pushing them a little, everybody had fun smashing the puzzles against the carpet. Then I started walking through the broken puzzles, disassembling each part and mixing the pieces until one big pile emerged. “What a mess,” the computer scientist remarked. I invited her to leave her table and sit on the floor to work together with the others on this pile of pieces. “But that is unfeasible,” the professor of business administration said, “we will never be able to single out all the different pictures that make up this pile.” “Start putting together a new 1,500-piece jigsaw puzzle” I replied. Now there was despair and anger. “What do you mean? These pictures do not belong together. They will never fit! You cannot have a kitty cat with the tail of an aircraft carrier! Even the joints and the holes of the different pieces do not fit together! They have different forms and sizes!”

Then the professor of mathematics, whom we nicknamed Mad Maths, came up with the following idea: “We can make a new pattern by joining and contrasting line and color.” To which the engineer added: “Yes! And we can make the pieces fit

using the design professor's nail file!" And so the different disciplinary professors did not care anymore about following the templates on the cover of the puzzle boxes. Instead, they started to cooperate and created a dazzling mosaic of a person running after the sun. This new picture did not keep to the obligatory rectangular frame that puzzles have (how could it?) and in fact it could not be called a puzzle any more. I ended by saying that this was the transformation society would be going through in the coming years.

2. Urgency of creativity

Civilization is humanity's greatest invention. We have created our own world and with it, our own freedoms and limitations. This means that most of the large-scale challenges that we face today are human-made. Here is the good news: Humans should be able to resolve them. In order to do this, civilization is in need of a grand new scheme. This is why we should gather bright people from all walks of life to take the lead in its design by way of combining creative exploration with scientific rigor, in an attempt to answer the questions of our modern day world.

Science, technology, arts, design, business, and governance. These are the disciplines that can make a real difference in creative cooperation: From idea to implementation and from a local to a global scale. People from these very diverse backgrounds combined will be able to generate a collective capacity to solve genuine societal challenges, while respecting the insights of each other's disciplines as well as those of co-creating stakeholders. Harnessing curiosity and novelty, balanced by analytical and conceptual thinking, is what captains of industry, political leaders, artistic icons, and scientific geniuses should do together and they should do it on an equal footing, because all of them are connected by one thing: their creative ingenuity.

The new businesses, new knowledge, and new designs that will be generated by these versatile minds will additionally greatly impact those who work with their leadership. Because creativity is fun, it is contagious – and this quality will eventually lead to a redesign of society and a deep change of culture that is carried by a multitude of people. A new global mentality will emerge, which will be characterized by individual contribution – whether spiritual or material – of a new kind, and which is in balance with responsibility for what surrounds us. At least, that is what we hope for...

3. Creativity in theory

The concept of creativity involves a great number of theories and ideas, all of which seem to have a point; they are at times in conflict with each other, and at other

times seem to be complementary. There is the idea of creativity as a socially-driven, evolutionary process that allows co-creation (e.g., Surowiecki, 2004/2005; Brabham, 2008), building upon prior ideas (e.g., Tapscott & Williams, 2006/2008), and favoring user-generated content (e.g., Anderson, 2006). This line often coincides with a more-or-less deterministic world view (cf. the Marxist view on technological innovation). New technology always has its predecessors; science merely ‘discovers’ what is already there, independent of the individual. There is also the idea of the disruption of a grand tradition, the paradigm shift, forced by the individual psychology of the one unique genius who at a flash of insight sees what others do not see (e.g., Hausman, 1984; Simonton, 2009, p. 14). And then there is the role of chance, probability, ‘serendipity’ (e.g., Baines et al., 2010) or systematically adding noise to a pattern (cf. fractals), the results of which may be interpreted as an artistic *objet trouvé*.

Science, technology, arts, and business thrive on creativity. Yet, are we talking about discovering or about constructing novelties? And what is the creative process actually about? Preparation, incubation, insight, evaluation, and elaboration are often-mentioned ingredients of the creative process (e.g., Csíkszentmihályi, 1996, p. 79) but can easily be extended by association, integration, abstraction, adaptation, etc. How do these concepts relate to one another?

This book is meant not as a mere inventory of perspectives on creativity but as a serious attempt to evaluate the meaning of the different concepts, to define the different mechanisms, and to try to come to a level of scholarly discourse that escapes the narrow practices of individual areas of inquiry: a confluence theory (Sternberg & Lubart, 1999, p. 4). According to Basalla (1988/1999, p. 134), such a theory should address issues of play and fantasy, science, materialism and economy, as well as social and cultural diversity. I wish to attempt the layout of an integral theory that in the long run is confronted with real people to verify its empirical value and that can be implemented as a computer model to validate its logical consistency. That would be a step forward to turn the ideal of a unified explanation of creativity into reality (cf. Basalla, 1999, p. 65).

3.1 Creativity in the humanities

As a theory, *Creative Confluence* may revitalize certain areas of scholarship, which began their long malaise as fields that once were richest in creativity. The products of creativity are the core of the study of literature, and of the humanities in general. Because creativity falls inside the scope of scientific investigation (see Lowcre, 2013), this means that as fields, literature and the humanities do so as well.

Gottschall (2008, p. xi-xii) claims that the humanities (i.e. the study of literature, arts, and culture) are in crisis whereas the sciences flourish. He wonders what

science is doing different from humanities and why the humanities are unable to shrink the possibility space of explanation (ibid., p. 1). In the same vein, Van Peer, Hakemulder, and Zyngier (2012, pp. 23–30) reply to 23 (*sic*) complaints that traditional scholars have with the science of culture. These authors observe that there is no inherent difference between doing research in the sciences or in humanities.

Gottschall wants to accumulate more reliable and durable knowledge by emulating science with “new theory, method, and ethos.” He searches for a paradigm shift (Gottschall, 2008, p. 1, p. 6). Deep change is urgently required, he avows. There are elementary weaknesses in the Marxist, feminist, structuralism, and post-structuralism theories that guide (i.e. literary) investigations and in the methods that explore and validate hypotheses (ibid., p. 3). His cure is to move the humanities closer to the sciences and leave the “impressionistic study of the landscape of make believe” (ibid., p. 4). He states that “The literary scholar’s subject is ultimately the human mind” (ibid., p. 17). Gottschall advances a quantitative turn (e.g., word-frequency analyses), trying to relate phenomena such as adoration of the protagonist to a cognitive-evolutionary, almost Darwinian, paradigm such as sexual selection theory and studies of mate preference (ibid., p. 94, p. 102). In this respect, Van Peer, Hakemulder, and Zyngier (2012) offer clear-cut examples of how empirical methods and data collection support our understanding of literary texts.

Creative Confluence attempts to formulate an encompassing theory that connects the humanities to the social sciences *and* to the sciences as well. It attempts to show how quantitative and empirical studies supplement historical and interpretive scholarship. It is not only that the humanities can incorporate the results of scientific studies into their own scholarship; *Creative Confluence* provides the means how to produce them – if they want to. This way, the humanities gain “the ability to systematically and decisively narrow [their] allotted portion of possibility space – to zoom in toward truth in the immense, multidimensional hyperspace of error and vacuity” (Gottschall, 2008, p. 9). Based upon this theoretical foundation, the humanities may finally develop ways of putting their ideas to rigorous tests (ibid.).

4. Creativity in application

The attempt for a trade-independent theory of creativity is timely because, for good or for ill, our future is closely tied to human creativity in facing the challenges that lie ahead (Csíkszentmihályi, 1996, p. 6). Creative thinking is “the engine that drives society” (Pfenniger & Shubik, 2001, p. xi). The post-industrial “creative class” (Florida, 2002) is growing and expanding into areas that traditionally are

not seen as creative (e.g., governance, business, education, healthcare), blending in with creative core domains such as arts, design, science, and technology. Established formulas for decision making do not count anymore in a continuously changing open information society (Williams & Yang, 1999, p. 374). Increasingly, policy makers and classical industry seek the help of creative professionals to broaden their scope, find new possibilities, and new ways of solving their problems. Attempts are being made to introduce “design thinking” (Brown, 2008; Martin, 2009) into business and governance. So-called “Living Labs” are initiated as open platforms to learn, co-create, and investigate creativity and innovation in solving pressing societal issues (e.g., Chesbrough, 2003). In addition, the creative community seeks to corroborate artistic ideas and design decisions with scientific evidence, for example, to understand the impact and effectiveness of innovations and to make creations that are more valuable socially and economically.

From a theoretical point-of-view, it is debatable what the right approach to creativity is. Does the creative genius take the lead and the others should be seen as ‘apprentices’ or more egalitarian, do all ideas count equally, irrespective of the credibility of its source? Again, taking a theoretical position has its impact on practicalities such as legal issues (e.g., copyrights, intellectual property) and on the choice of a business model while a solution is under development. Social co-creation may favor creative commons, whereas individual genius may call for a more neo-liberal approach. A social, individualistic, or serendipity approach to creativity puts different demands on the management of creative people or even the lay-out of an office. It may be obvious that the management of groups differs from the coaching of the lone high-potential.

Demands of freedom and/or restriction cause a true challenge to the study of creativity. The process of creativity should occur in an ecologically valid setting, whereas scientific rigor should be maintained by a controlled environment and the systematic manipulation of factors. Heisenberg’s (1930/1949, p. 3) observer effect already implied that when you look at something, you change it. To measure creativity you must affect it. Apart from discussing what creativity is, then, we should focus on what it needs to be manifested in reality, and how to approach it non-disruptively.

5. Heading for common ground

If governance, business, science, technology, and the arts are to work together, there should be a common ground in language and concepts regarding creativity. That aim demands something of an integrative approach in which the various fundamental perspectives are represented, that can be verified and validated,

and that in applied settings can count as the blueprint for a creative workflow that all stakeholders can relate to. It is essential, then, whether one takes the ‘individual genius’ position, the ‘social evolution and co-creation’ stance or the ‘lucky coincidence’ approach. In sum, this book on creativity wants to instigate and accelerate:

- the confluence of theories of creativity throughout disciplines
- the establishment of a common ground in language and concepts regarding creativity
- the production of computer-generated creative output that can be tested against real users
- the dispersion of the knowledge economy by providing a general theoretical basis for activities in the Creative Industries

6. The Confluence Theory of Creativity

The remainder of this book addresses the explication of the Confluence Theory of Creativity. This theory explains that the three views on creativity (evolution, disruption, and serendipity) can be connected if we respect the three planes they focus on: the masses, the individual, and the materials, respectively. At a macro level of data aggregation, individual outliers vanish as minor variations in an ongoing line of greater or smaller increments. At the meso level of individuals, deviations from tradition seem much more disruptive than from an overall point of view and, indeed, when the sample size is smaller variance becomes more pronounced. Serendipity is most likely to occur at the micro level. The smallest units for creativity are the single pieces of material that one works with: artifacts, features of artifacts, ideas, words, images, sounds, lines, curves, etc.

During the evolution of a line of innovation, serendipity leads to a disruption that is the beginning of a new evolution. This is why the development of creativity is non-linear and follows an S-shaped curve of innovative growth. That curve is sensitive to a plethora of factors that bend and mold its form, from inspirational conversations to occupational stress.

7. About this book

Creative Confluence is a follow-up and counterpart of *Epistemics of the Virtual* (Hoorn, 2012). Like before, my use of reference works is not strictly scientific. Where science shies away from answering pertinent questions, I refer to websites,

comic books, television programs, newspapers, and poems. Examples in this book are just as eclectic: They are drawn from paleontology and particle physics as well as painting and pop music and many more.

Because the sources used are so diverse and so many disciplines are included, Chapter 1 provides a concise display of the entire theory that the book advances and will explain. The journey starts with physics (thermodynamics), passes through biology (evolution), physiology (brain), psychology (problem solving), philosophy (epistemics), geometry (fractals), and computer modeling (simulation) to explain the relationship between physical and organic creativity and how these forces shape the world about us.

Chapter 2 points out that in the wake of orderly Classicist philosophy and the rise of task specialists during the Industrial Revolution, rule-based problem solving became the dominant culture in the West. It also argues that creative problem-solving styles and the yield of chaos emerged with early Romanticism and later modern and postmodern undercurrents. Basically, whether one turns to a creative mode of thinking or a rational mode is related to having an optimistic outlook on life or a pessimistic outlook, respectively.

Chapter 3 starts from classical problem-solving theory and decision making. In business, governance, and science, rule-based problem solving strategies are dominant, reasoning from premises to conclusions. So it seems. When problems become ill-defined and underspecified, the number of unknowns becomes so large that we can speak of a challenge instead of a problem. In arts and design, people are used to deal with such underdetermination and their strategies for solutions have an associative and similarity-driven thrust. In other words, rule-based problem solving is most applicable to deterministic problem spaces whereas creativity is required in more probabilistic settings.

Chapter 4 shows that although rule-based problem solving and logics are the preferred mode of thinking, creative insight does not come from reasoning. In science as in the arts, creators make unwarranted leaps to bridge the underdetermination gap, sometimes arriving at the right answers from the wrong premises. Chapter 4 delves into the creative process and presents the ACASIA framework, which describes how familiar entities may lead to original blends through Association, Combination, Abstraction, Similarity, Integration, and Adaptation. It also shows that the first half of this model is responsible for the disruptive side of creativity whereas the second half takes care of the incremental improvements – the peripheral creative activities. Additionally, Chapter 4 offers a simulation model that shows that combinatory creativity yields professional designs.

ACASIA is a self-propelled combinatory process that in the long run produces the well-known innovation growth curve. In Chapter 5, the theory behind this

growth curve is adapted such that it accounts for evolution, disruption, and serendipity. Because of its extra features, the curve is rebaptized the Creative Sigmoid, from which specific predictions on creative development can be derived independent of scale size. To test the logical consistency of the theory and to improve the precision of prediction, Chapter 5 also presents a simulation model of the Creative Sigmoid.

Chapter 6 discusses the conditions under which people flourish so to make them creative and what puts them down and keeps them from being creative. Such conditions have a distinct impact on the way the Creative Sigmoid develops. This chapter is particularly of concern to those who wish for leadership that unleashes creativity and that is itself intrinsically creative. Many people thinking of themselves as creative leaders will find out that they are not even halfway this trajectory.

Chapter 7 is an integration of ACASIA and the Creative Sigmoid with the perception of the fiction that creativity inevitably produces. *Epistemics of the Virtual* (Hoorn, 2012) is a theory of how perceivers deal with fiction, how they attribute truth to direct and indirect observations, how they handle metaphors and fictional characters. In Chapter 7, that framework is enriched with the ACASIA process of creativity from the assumption that creators start out as perceivers and after creation again are the first perceivers of their work. Figure 1 shows that perception of fiction plus the creative act upon that fiction contributes to innovation development, which in turn is perceived as fiction that can serve as input for creation. Thus, the Creative Sigmoid that is produced by ACASIA loops back into *Epistemics of the Virtual* (Figure 1). Creation constructs its own perceptions, making epistemics itself a virtual product of creation.

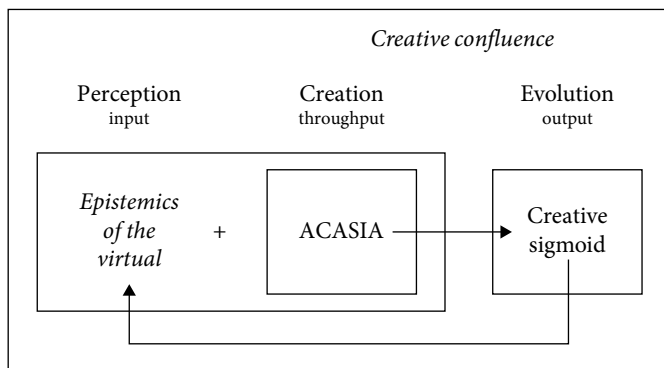


Figure 1. Loop between fiction perception, creativity, and innovation development

Similar to its counterpart *Epistemics of the Virtual, Creative Confluence* is an eBook that also is available as a hardcopy. The hyperlinked images, video clips, and other text satellites in the eBook are readily accessible. You just click the figure captions. With respect to the paper version, URLs are published on the book's website. This is to avoid copyright issues and to keep the book affordable.

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Confluence

“A confluence is a joining together of rivers. I enjoy many creative outlets, and they all inform and build on one another.”

(Quinn Ainsley, Feb. 23, 2011)*

Where many rivers come together and the salt water of the sea mixes in, the most awesome life forms appear. Confluence. As an outline to the theory, the current chapter provides the rationale of this book. The unifying principle it advances is that of combination making, visible in the formation of matter, in the genesis of organisms, in the novelty-accelerating function of the brain. It is a somewhat neglected area in the traditional, read rule-oriented, problem solving literature and it has genuine consequences for our philosophy of truth and reality. We will find that in its most premature stage, human creative insight pertains to quantum behavior at the synapses while in later evaluative stages, fractal emergence plays a role. In all, building up and breaking down combinatory creations seem to be the doing of the two laws of thermodynamics.

1. Cooling down

This book is about creativity but until we are talking about brain architecture, you will find that this word is not mentioned on the next couple of pages. In the humanities, psychology, and the social sciences, creativity is unequivocally ‘human.’ Only occasionally will there be recognition of animal creativity, let alone plant creativity. *Creative Confluence* goes further and will speak of creativity of dead matter. This is also why computers can be creative and conjure up poetic sentences such as “The wind is like a pencil,” while providing an explanation: “Because both are sharp.”

In the wake of Lowcre (2013), creativeness is inherent to physical nature and creativity in organic forms such as plants, animals, and humans are purposeful applications of that general faculty. Therefore, in this chapter, we will pursue the manifestations of creativeness in physics (i.e. thermodynamics), biology (i.e. evolution and mutation), human physiology (i.e. brain), psychology (i.e. problem

* <http://quinnainsley.com/2011/02/confluence/>

solving), philosophy (epistemic theory), geometry (i.e. fractal emergence), and computer modeling (the simulation of the creative act). In other words, this is a story of genesis, starting when all of nature was empty.

When the universe was born, there were no people to observe it. Even with our most sophisticated equipment of today we are not able to replicate the extreme conditions of those very early moments. Therefore, theories of how matter came into being are necessary speculative. Certain authors state that before the universe came into being there was nothing. Without a specific cause, the universe emerged from this nothingness through the act of quantum vacuum fluctuations (Vilenkin, 1982). Others say that the universe always existed and goes through a cyclic motion from the Big Bang to the Big Crunch. Ashtekar (2005) proposed that the universe “bounces” back into a new Big Bang just before reaching singularity (i.e. the complete universe packed into an infinitesimal small point). The Many-worlds interpretation posits that the universe is one of an infinite number of universes (Everett, 1957). Parallel universes come into existence at every point where a quantum superposition is present (*ibid.*), which means that more interpretations of an observed entity are likely. For example, energy may assume a particle form as well as a wave form for which the Many-worlds theory presupposes that the world splits in two and that there is a universe for each interpretation. Note that this is a mere conceptualization and not something supposed to be real, reminiscent of possible-worlds semantics (e.g., Divers, 2002). According to Verlinde (2010), there has never been a ‘beginning’ but there always was an everlasting entropic force from which particles, space, and gravity surfaced. This underlying chaotic system is thought to be busy recapturing its thermodynamic balance (*ibid.*).

One thing many theorists do agree on and that can be observed experimentally is that slowly, very slowly, and with all kinds of fluctuations up and down, on the whole the temperature of things is declining. One could reason that in its infancy – if you believe in that at all – the universe must have been in a tremendously high-energetic state. While cooling down from higher to lower levels, energy condensed into matter. Different particles emerged from that energy in the form of protons, electrons, and atoms. The universe cooled down and took shape. When the turmoil of extremely erratic heat motion came somewhat at ease, gasses, liquids, and solids emerged. Over an astronomic period of time, atoms assembled into different kinds of molecules, molecules into dust, dust into rocks, and rocks into planets, stars, galaxies, or even bigger systems (e.g., Silk, 1994, p. 87).

From chaos came order through the combination of increasingly larger constellations of matter. While cooling down, on the one hand, the universe diversified from ‘amorphous energy’ to ‘all kinds of substances’ and on the other hand

evolved from less complex structures (e.g., atoms) to more complex ones (e.g., clusters of galaxies). If this process continues without disruption, the universe would aggregate into a super-cold homogeneous state of perfectly aligned solid matter: A gigantic block of crystalline inertia, that is, given that degeneration can be expelled.

2. Thermodynamics

The universe cools down because it is expanding (Christian, 2011, p. 507). Expansion causes a decrease in pressure so that particles move less and hence things cool down. This means that between moments in time, temperature differences exist, earlier being warmer than later. Yet, temperature wants to reach equilibrium. *Conservation of energy* states that where there is a difference between energy levels, the energy from the higher level will flow to the lower level. Formulated as the *first law of thermodynamics*, the convection of heat (Q) goes from the warmer to the colder object, which is why we can boil an egg. In other words, heat balance follows Black's principle that $Q_{up} = Q_{down}$: Within the boundaries of our universe, the amount of warming up equals the amount of cooling down.

The first law of thermodynamics can only be seen in action if temperature is not equally distributed over the universe. The borders of the universe expand and therefore become cooler. However, local areas within that same universe are contracting and heating up. Sometimes gravitation pushes matter so hard together that it starts burning again, becoming stars, which are hotter than their surrounding space (Christian, 2011, p. 508). After that, energy starts to flow freely from hot to cold: The sun shines on Earth. Black's principle is the engine of change. Or even of complex life forms (Davies, 1989, p. 119). While things cool down, they become stable and take shape. This is the driving force of order formation.¹ However, this must be at the cost of increasing chaos elsewhere, that is, something else has to be burned for it. What loses temperature (Q_{down}) gains order, what takes up energy (Q_{up}) becomes chaotic. Whereas Q_{down} is clotting, Q_{up} is falling apart.

Any supply of heat (e.g., setting things on fire) increases the turbulence of heat motion, increasing disorder (Schrödinger, 1944/2010, p. 63). The moment of creation, of confluence, takes large amounts of energy to melt entities together and then needs to cool down to hold the new structure together. It is like welding (Figure 1). The spark of insight can be materialized only by cool deduction but keeps radiating its warmth for a long time.

1. Which we later on shall see, follows a fractal patterning.



Figure 1. Creation

After the high energetic moment of genesis, in which all structure is reshuffled, the formation of order, by the first law of thermodynamics, is the result of losing energy to its surroundings, which are heating up (become more chaotic). When this heat loss stops, slowly, very slowly, the structure will fall apart again because the energy it is made of tends to be in equilibrium with its surroundings. Thus, order needs to be maintained. Without maintenance, disorder or “entropy” is the normal state (Christian, 2011, p. 506; Miller, 2000, p. 117). Indeed, the *second law of thermodynamics* says that when left in peace, order turns into entropy, that is, decays into a ‘lukewarm’ energetic equilibrium (Schrödinger, 1944/2010, p. 69).

In other words, there are forces at work that unite diversity into new combinations: A hot collision evolves into cool structure. This is the first law of thermodynamics in operation. But without the continuous presence of such forces, things fall apart and diversify again (the second law of thermodynamics). To bring order, you must cool things down, keep them from moving away, relative to the heat motion of all other things. If you do not keep this relative coolness, things may heat up too much and break loose again. That is why if you want to preserve things, they should be stored in a cool and dry place, potatoes as well as art paintings.

3. Assembling

Over time, molecules not only combined into dust and rocks, they also combined into organisms through DNA. Out of molecular chaos, simple self-organizing principles spontaneously created the diversity of life (Kauffman, 1995). The exciting thing about DNA is that it is one of the few molecules known so far that can reproduce itself. One could even think that due to the second law of thermodynamics, something like a reproducing molecule was bound to come into existence to compensate for its inevitable loss of order. Yet, the copy the DNA molecule makes of itself is not identical; it is near self-similar. That the repetition is inexact opens a wealth of opportunities to develop different variants with only a handful of molecules: First single cells, then cooperating as multicellular plants, sponges, jelly fish, velvet worms, tetrapods, and so on. It is the convergence of broad forms with details left to chance (K. Kelly, 2010, p. 127). The deviation of details, however, can be so large that the DNA branches off into another species.

Schrödinger's (1944/2010, pp. 33–35) theory of life provides a quantum account of genetic heredity. He distinguishes the “continuous transfer of energy” in a genetic lineage from a so-called “quantum jump” into a new variant. Hugo de Vries showed that sometimes jump-like variations (“mutations”) occur in the genetics of certain individuals, resulting into discontinuity with previous generations and siblings. Schrödinger posits that the smaller or larger variations in a continuous line of evolution are not inherited but accidental, due to thermodynamic fluctuation, that is, chance (*ibid.*, p. 106). Such disruptions happen literally owing to quantum jumps in the molecular structure of the genetic combinations.

Normally, certain threshold values avoid that intermediate energies occur between two neighboring energy levels but, under the right conditions of increased heat motion, an atomic electron transition or ‘quantum jump’ may happen in the DNA (Schrödinger, 1944/2010, p. 63). During a quantum jump or ‘leap,’ an electron switches from one energy level to another within the atomic structure. This change is immediate and disruptive. Thus, a chance fluctuation in environmental energy may sometimes lead to spontaneous “jumping variations” with no intermediate forms happening (*ibid.*).

Goswami (1997, p. 90) states that “continuity is not always nature’s way, not in physics, not in biology.” Lumsden (1999, p. 158) explains that natural selection controls systematic change and optimization whereas at the level of molecular physics mutations and recombinations of genes cause sudden change. Lumsden points out that certain unexpected mutations are kept in store: Genetic traits that are latently important only come to expression in certain circumstances and then “can reshape evolution by suddenly opening adaptive opportunities uncorrelated with previous adaptive trends.” When evolutionary circumstances so require,

dormant mutations may come to expression and develop into a new species. Adaptations seem to start as unintended effects that get opportunistically picked up by selective forces in the environment (Dennett, 1995, p. 248).

Schrödinger (1944/2010, p. 80) distinguishes a physical aspect in this system, which he calls “order-from-disorder.” It is the disruptive and chaotic side of creation. The other is the biological aspect, which he calls “order-from-order.” It is responsible for the continuity and hereditary side of creation, allowing for incremental changes bound by set parameters.

Evolution works from simple to complex forms (Christian, 2011, pp. 510–511), from general to specific features. It works towards specialization (cf. Schrödinger, 1944/2010, p. 109). However, high specializations die out when circumstances change, a deadlock that can only be resolved by forcing a breakthrough (K. Kelly, 2010, p. 297). Disruption of a hereditary lineage may help to prepare and adapt to sudden change but for an evolutionary line to survive, continuity guarantees stable conditions within the organism under which the added value of the novelty can be tested (cf. Schrödinger, 1944/2010, pp. 41–42).

Disruption occurs less frequent than incremental optimizations. Allowing many disruptions in a row would ignore the world as is and make the system as a whole unstable and vulnerable to natural selection processes (cf. Schrödinger, 1944/2010, p. 63). In other words, an organism should not be in a rigid cold state to be able to adapt to change; it should neither be in heat because its instability would make it fall apart when confronted with resistance or unfavorable circumstances.

4. Blind variation, selective retention

Darwinian evolution is governed by the principles of blind variation, asymmetric transition, and selective retention (Campbell, 1960). Blind variation takes place at the most basic, physical level, where mutations and recombinations happen at random. The asymmetry in transition indicates that the evolutionary process goes into one direction, from general to specific and from unstable to stable rather than the other way around. Physical constellations created by blind variation transition into biology and random mutations transform organisms into new creatures. At the level of the organism, selective retention favors those features that given the circumstances foster stability of the system. With increasing stability, variation decreases over time. Goswami (1997, p. 99) goes even further when he states that “Darwinian natural selection is the enforcer of homeostasis.” For millions of years, animals such as the Horseshoe crab (Figure 2) and the Coelacanth have hardly developed (cf. Schrödinger, 1944/2010, p. 104).



Figure 2. Horseshoe crab: evolution on plateau. Courtesy Morguefile xpistwv

In studies on human creativity (e.g., Campbell, 1960; Simonton, 1995, 1999; Hélie & Sun, 2010), blind variation and selective retention or “BVSR” is often cited as a model to explain “unity in diversity.” The principle of blind variation would underlie the emergence of novel cultural artifacts while selective retention would consolidate certain continuity within that diversity.

Science in Darwin’s time was still under the influence of Newtonian logic (Gruber & Wallace, 1999, p. 101). This is why Darwin was looking for the rules of deterministic inheritance (cf. selective retention). However, Darwin also saw unexpected mutations arising from a genetic lineage and so allowed for the first traces of probability in his theories (cf. blind variation) (ibid.). Darwin’s blind variation translates into what in creativity later was called “serendipity,” the lucky finding or fortunate invention. Serendipity is creative coincidence that at best can be sensed if it is about to happen (foresight), if at all, and then the right person should be at the right place, at the right time (cf. Csíkszentmihályi, 1996, p. 128; Simonton, 2009, p. 186). Darwin’s selective retention translates into selection and adaptation of features to improve a creation’s ‘usefulness’ (cf. Kozbelt, Beghetto, & Runco, 2010, p. 20). Darwin’s idea of usefulness is what helps the survival of a group.

5. Brain architecture

On the neurobiological basis of creative invention, Damasio (2001, p. 59) remarks that the oldest human decision-making function, residing in the diencephalon and brain stem, pertains to biological regulation and survival. The second function regulates personal and social needs. The youngest function operates on abstractions and symbols and can be found in artistic, scientific, and engineering activities. Damasio suspects that all three are in interaction during a creative act, where the innate biological circuitry largely determines the continuity and similarity of behaviors and the environment largely accounts for the individual variation (*ibid.*) (cf. Lumsden, 1999, p. 158; Dennett, 1995, p. 248).

Pfenniger (2001, p. 91) proposes a hierarchy in the nervous system in which the oldest functions are instinct and autonomous control and the youngest (cognitive) brain function is creativity (Figure 3). Let me state upfront that this “rank ordering” should not be taken overly rigid. It, for instance, may be the question whether “language” is tapping into lower nervous system functions than “intelligence.” Nevertheless, when taking the cascading a bit leniently, one could interpret Pfenniger’s account as a stepwise evolutionary upgrade to deal with increasingly complex problems.

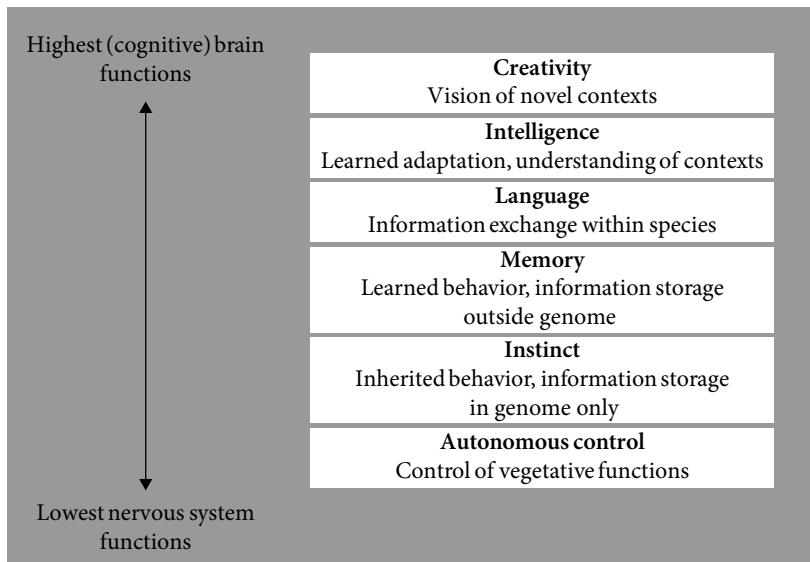


Figure 3. Hierarchy of nervous system functions (Pfenniger, 2001, p. 91, Table 2.2)

Evolving from a simple species that regulated its vegetative system only, instinct became the second step to deal with problems of survival (e.g., eat or be eaten) that were repetitive enough to become hard-coded in the genome. Memory was a major breakthrough because it could use more scripts than just the inherited one and so showed adaptive behaviors in a larger variety of situations. It needed a more advanced brain that could maintain soft-coded information outside the genome. While gaining a competitive edge to other species through group cooperation, language became germane to transfer information from one memory to another and to deal with social relationships. Acquiring intelligence was the next leap forward, making it possible to predict the unknown through reasoning and abstraction from the givens. The ability to deal with the uncertainty of different outcomes culminated in envisioning opportunities and situations never encountered before nor following from the givens, instigating exploratory behavior unprecedented in natural history: human creativity.

6. Selective attention: Survival or opportunities

With the brain's development from a sheer survival machine to an organ that can imagine unexpected possibilities, Csíkszentmihályi's (1996, p. 11) observation gains strength that humans have two innate tendencies, conservative and expansive. The conservative tendency relates to instincts of self-preservation, saving energy, self-promotion, and self-aggrandizement (also Basalla, 1999, p. 73). For survival, a system thrives best in an environment that is fully predictable and under control. Zander and Zander (2002, p. 18, p. 21) call this "survival thinking" and frame it as a fatalistic outlook directed to detecting danger.

The expansive propensity is directed towards novelty seeking, exploration, risk-taking, curiosity, and adapting to change (Csíkszentmihályi, 1996, p. 11). It is the pleasure of play for its own sake (Basalla, 1988/1999, p. 73). In such a state, people care less about being in control and focus less on short-term targets (Zander & Zander, 2002, p. 21). They are willing to take more risks and develop a long view without knowing the outcome: They are oriented to the 'abundance of opportunities' (ibid.). For conservative behaviors, little motivation and explanation is needed, whereas explorative and expansive behaviors are easily resisted (Csíkszentmihályi, 1996, p. 11).

Whereas the survival functions of the old brain are fit to deal with scarcity and threat and lead to risk-avoidance, the creative functions of the youngest brain are geared towards abundance and joy, seeking novel opportunities and taking risks. After a good days hunt, we watch the sunset in reverie, contemplating what new grounds to break (cf. Martindale, 1999, p. 140).

To survive, the limitations imposed by the laws of nature must be respected (Savransky, 2000, p. 33). So far, logics and reason are evolution's best answer to the *mechanistic determinism* of certain problems that an organism faces (e.g., the regulation of temperature). It is a game that should be played according to the rules (cf. James Carse cited in K. Kelly, 2010, p. 353). It has clear winners and losers and prompts a world that is best navigated through measurement and analysis (Zander & Zander, 2000, pp. 17–19).

For expansion, association and insight are the best way to proceed. The *chaotic probabilism* of complex challenges entails many unknowns and triggers high uncertainty (cf. social dilemmas). This is a game that plays *with* the rules (Carse in K. Kelly, 2010, p. 353). It is the world of seeking opportunities (Zander & Zander, 2002, p. 21) and proposing intuitive ideas.

7. Two types of problem solving

In problems of a deterministic nature, rule-based and reasoning strategies yield the most optimal results. Probabilistic problems, however, should be approached with best guesses (preferably statistics) and intuitive associations (at best, analogies). Examples of rational problem solving are goal decomposition, difference reduction, and reasoning backward. Aspects of creative problem solving are ideation and empathic inquiry. In cultural history, the reasoning strategy came to expression in Classicism whereas the intuitive style became prominent in Romanticism, remnants and mixes of which are still recognizable today.

8. Cultural history

In the Age of Reason, the rule-based method of problem solving became dominant. It was visible in the poetics of Classicist verse, in science, as well as in the rationalization of work. By the end of the 17th century, for example, French Classicism penetrated cultural life (e.g., sculpture and music); the main literary and theatrical proponents being Molière, Corneille, and Racine. In opposing the free style and (exaggerated) originality of the Baroque, Classicist poetics was indebted to Descartes in formulating a strict rule-oriented system (e.g., the unity of time, place, and action) that dictated the composition of an individual work (cf. Boileau's *L'Art Poétique*). This was meant to convey complex meaning in a simple way and with great realism (i.e. *vraisemblance*).

In science, Isaac Newton may be seen as the strongest exponent of Classicism in his attempt to formulate some of the fundamental laws of nature. The

‘clockwork universe’ would unfold without any human agency interfering. Beginning and end were predestined and all stages could be deterministically calculated (Westfall, 1980, pp. 1–39; Miller, 2000, p. 14).

In Newton’s wake, the Industrial Revolution took control of the most pressing problems of survival, producing enough food, shelter, safety, and material goods to establish what we nowadays call the consumer society. Problems of organization and work were decomposed into smaller problems until they could be solved mechanically. Adam Smith (1776) created a work force of task specialists, Frederick Taylor (1911) bred a class of scientific managers for task planning and the optimization of efficiency, while Max Weber (1922) organized the process of control as a strict hierarchy of power relationships and command lines. The individual was subordinate to the system, whether natural or societal (cf. Rousseau’s “social contract”).

By contrast, the Romantic counter-movement forwarded the unique individual as the focal point of attention because God was inherent in every person’s soul. Intuition would establish a divine connection to the inspiration of God. In opposition to Rousseau’s social contract, therefore, each individual should be treated as special and of the utmost value, his interests never to be traded for the common good. Civilization, urban life, and the mechanistic factory approach to society would lead to dehumanization, fear, mistrust, and consumerism (cf. Shelley’s *A Defense of Poetry*). In their original, natural state, humans would be morally “good” and control would not be needed (cf. the ‘noble savage’). Spontaneous feeling, self-analysis of psyche, passions, and emotions defined the romantic hero (e.g., Wordsworth’s *The Prelude* or Byron’s *Childe Harold’s Pilgrimage*).

Imagination and creativity replaced logics and reason as the prime faculties of the mind. Human agency with its dramatic, dynamic, and creative powers would equal the wonders of nature or even God (cf. Nietzsche’s “Übermensch”). Not only would imagination constitute art but also construct a large part of our perceptions of the world: A divine vision that created reality (cf. Coleridge, Blake) (Hart, 2010). This mentality opened the door to subjectivism and perspectivism in matters of knowledge and truth. Creativity would fuse reason with feeling and resolve what at first seemed contradictions (Hart, 2010). Creativity would be the reconciliation of apparently disparate ideas, a disruptive act of individual genius.

9. Epistemics and perceptual flaws

In the 20th century, a redefinition took place of the way our knowledge and understanding of the world, our epistemics, are achieved. While in search of natural laws (cf. Classicism), scientists came to realize that imagination and perception heavily affected the articulation of such laws (cf. Romanticism).

For instance, Poincaré formulated his “underdetermination thesis,” stating that no scientific theory or natural law can describe a set of data such that it excludes an equally plausible rule or explanation describing those data (Miller, 2000, p. 35, p. 79). In theoretical advance, therefore, our imagination has to fill out the blanks that our fragmented observations of the world leave open. Moreover, no matter how advanced our measurement tools, the read-out of these instruments is still flawed due to the biases in our sense perceptions (Schrödinger, 1944/2010, p. 163). The “uncertainty principle” as stated by Heisenberg (1952, p. 30) implies that there is a fundamental observation problem, making it impossible to measure two quantities with absolute accuracy – in his case, simultaneously measuring position, direction, and speed of a particle. In addition, there is an ‘observer effect,’ meaning that the very act of observing changes the phenomenon under observation. Hence, we will never be sure that what we see when we see it is the same as when we do not see it.

This type of considerations made people assert that reality is a mental construction (e.g., Zander & Zander, 2002, p. 12; Stent, 2001, pp. 36–37; Pfenniger & Shubik, 2001, p. 222) and that solving problems of great complexity is intuitive and beyond reasoning (Pfenniger & Shubik, 2001, p. xiii). Einstein stated that “There is no logical path leading to these laws [of nature], but only intuition, supported by sympathetic understanding of experience” (Miller, 2000, p. 369). Poincaré wrote that “It is by logic we prove, it is by intuition we invent” (*ibid.*, p. 351). In other words, people may recognize patterns and structure them with rules and, according to those rules, prove what is correct or not. However, these rules are not an inherent part of nature but to a large extent the products of human perception and creativity. In themselves, data are rule-free.

10. The need for transformation

The early 21st century came to realize that subjectivism and perspectivism had undermined the exactness and solidity of natural science and of scientific management but did not behave accordingly. Instead, society tried to force the factory model onto the arts and sciences (cf. SMART goals, output measurement, Hirsch numbers).

This period faced a legacy of the Industrial Revolution that consisted of a neo-liberal demand of consumerism, unlimited growth, and performance measurement and a socialist insistence on job security, social welfare, and leisure time. The intertwining of these claims drove factor prices to such a height that the workforce could no longer pay for ever-increasing demands.

Developing countries, still struggling for their survival, understandably rationalized their production processes: The factory model fitted their situation. Yet, the managerial solution to Western crisis to outsource and offshore production work to low-cost countries turned out to be a two-sided sword. It made factory workers of the developed economies superfluous and, hence, their cry for restoration and conservatism. It urged their managers to reluctantly change the business from producing and servicing mass consumption goods to an information society of concept development and creative ideas (cf. the program *Developing Creative Economies* by the British Council).

Advanced economies had to shift focus: From oil refinery to informed creativity. This endeavor was bound to fail, because the new raw materials and processes (i.e. information and creativity) were approached with classic industrial concepts (e.g., profit, private property, competition, hierarchy, efficiency, cf. Moore, 1996). Beer (2003) posed that “It is hardly news that in this environment firms will have to possess the capacity to adapt or suffer the consequences – low performance and ultimately death and destruction.” Fukuyama indicated that “The adaptive organization can evaluate a changing external environment and modify its own internal procedures in response.” “... adaptable organizations are the ones that survive since environments always change” (Fukuyama, 2011, p. 450). Taleb (2010) proposed that organizations should get used to crises and disruptions and envision this as a normal situation in which doing “business-as-usual” is the exception. However, despite early warnings by Masuda (1983), Williams and Yang (1999), Florida (2002), and Zander and Zander (2002), to date a mentality and a way of being that is adapted to the new situation is still wanting.

Tolle (2005, pp. 20–21) argues that if a life form faces a radical crisis, it can choose to seize to its insurmountable problems and become extinct or to make an evolutionary jump. For Tolle, that crisis is the supremacy of the ego focused on survival and empowered by reasoning and affect. His alternative is to regress back to a state of being that once preceded thought and feeling, a state in which all energy still is unarticulated and ‘shapeless.’

Where Romanticism emphasized feeling and Classicism reason, New Age thinkers such as Tolle opt out of both: He envisions reason and emotion as instruments of mere survival. Instead, he argues, that a state of mindful “being” would foster human creativity (Tolle, 1997/1999, p. 19). This state of heightened attention to the here and now is somewhat comparable to ‘flow’ (Csikszentmihályi, 1996, p. 110, p. 112). In abandoning emotion and ratio from the focus of attention, Tolle proposes to retreat into quiet attention and open perception of the world about us, irrespective of purpose or evaluation. Things are neither good nor bad; they simply are. Just like dead matter simply is.

As I see it, we are neutral “data” in connection with all other “data” in the universe, amorphous pre-creative energy that came to expression in a particular molecular form (Tolle, 2005, p. 132, p. 146), filling up a niche in evolution (K. Kelly, 2010, p. 113), where other niches are waiting to be filled up through creativity. Those neutral “data” can be viewed from multiple perspectives (cf. Poincaré) by formulating different theories and hypotheses (ratio) and that can be colored subjectively by our fears and desires (emotion).

11. The creative process

There are two sides to the creative process, coinciding with the expansive and conservative tendencies, the new and old brain, opportunity seeking and survival thinking, inspiration and transpiration, association and evaluation, mutation and reproduction, breakthrough and incremental change, unfocussed attention versus control, “being” versus ratio and emotion, Buddha versus Newton and Blake.

The core of creativity is *insight* (Wallas, 1926, p. 80), the knack of the luminary, the conceptual generalist, making the unique combination of disparate domains (e.g., Poincaré, 1913, p. 286; Csikszentmihályi, 1996, p. 9; Albert & Runco, 1999, p. 25; Ward & Kolomyts, 2010, p. 101). Insight concerns the reconciliation of an apparent contradiction. Although a wine press is unrelated to writing, Gutenberg saw it as a printing press (Simonton, 2009, p. 123). Although prickly shrub is unrelated to metal wire, Michael Kelly (1868) combined them into barbed wire (Basalla, 1988/1999, pp. 51–52). Although a snail is unrelated to industrial engineering, a cutter suction dredge was modeled after its abrasive tongue (Van der Wal, Giesen, & Videler, 2000) (Figure 4). It is a measure of similarity in contrast to a measure of dissimilarity between unassociated entities, which the creator detects or constructs whereas others do not (Hoorn, 2002).

Figure 4. Cutter suction dredge, mimicking a snail’s tongue. Photo from *Natura Artis Magistra* (2012), 58(3), p. 3

The preparatory state to creative insight is free association, taking place uninhibited, unrestricted by control processes. In Martindale’s terminology, this is a state of ‘defocused disinhibition’ (Martindale, 1999, p. 143, p. 149). Tradition, morality, rational choice, or emotional preferences are de-emphasized at the stages of free association and insight: The latter produce the creative jumps that are typical for the expansive tendencies.

In Chapter 4, insight is explained from the first-time information exchange takes place between neurons coming from a previously unconnected association



area ('seeing similarity'). That chapter explains how the conceptual creative jump coincides with a molecular quantum leap (cf. Goswami, 1997, p. 90) between synapses, the ensuing photon emission of which is interpreted as 'seeing the light.'

After insight, the labor, skills, and judgment of the specialized artisan are needed for *elaboration* and *verification* (Wallas, 1926, pp. 85–86). The novel idea is scrutinized for originality, usability, emotional impact, etc. This side of the creative process is concerned with the optimization of the idea, adapting features, abstracting certain aspects, selecting what is useful, evaluating its relation to the outside world. Selection and evaluation represent the conservative propensity, focused on survival and success of the creation. The improvement of known practice is manifested in incremental change (Basalla, 1988/1999, p. 24; Friedel, 2007, p. 10).

Here is where reason and emotion return to the creative process. Reason is to define purpose and optimize survival chances, whereas emotion is a rapid diagnostic of purpose. Vanguard art will lay emphasis on insight and hence be condemned as 'useless,' whereas industrially produced creations will accentuate usability and applicability and hence are condemned as 'cliché.'

Chapter 4 offers an analysis of the creative process, ACASIA, including an expansive, intuitive side (i.e. Association, Combination) and a conservative, rational-emotional side (e.g., Abstraction, Selection, Integration, and Adaptation). When combination stays within the bandwidth of accepted behaviors, change will be incremental and continuous; when going out of bound, change is disruptive and may start a new development. Chapter 5 demonstrates through computer simulations that the ACASIA model as a self-propelled combinatory process results into the Creative Sigmoid as its output.

12. Conditions of creativity

Inducing or relieving stress is the most important regulator of creativity. Under high stress conditions, the focus of attention narrows down to survival (old brain dominance) while increasing stimulus discrimination and performing stereotypical behaviors. Brain plasticity and the formation of new connections can be impeded by severe stress and arousal. Therefore, high stress levels hamper free association and insight (e.g., Martindale, 1999, p. 140; Heilman, Nadeau, & Beversdorf, 2003; Schweizer, 2006; Kaufman et al., 2010, pp. 222–223). Mild levels of stress may become conducive the more the creative process moves to execution and reproduction and precise targets need to be met. In its conceptual phase, inducing stress may foul up creativity; in its industrial phase *mild* levels of stress may help to make ideas concrete.

From this, a host of factors that impinge upon stress and arousal may count as moderators of creativity. Rules, regulations, protectionism, fixed formats, process management, pre-set goals, instructions, evaluative yardsticks, competition, selection procedures, negative mood, and external motivators such as financial reward, punishment, and fame are part of the conservative propensity, provoking stereotypical behaviors and tunnel vision. The evidence ranges from cultural, technological, and economic history (e.g., Chua, 2007, p. xxi; Davids, 2008, p. 464; Mokyr, 2004), to leadership (Zander & Zander, 2002, p. 31), management and organization (e.g., Williams & Yang, 1999), design (e.g., Ward, Smith, & Finke, 1999), scientific peer review (e.g., Chubin & Hackett, 1990), and neuroscience (e.g., Subramaniam, et al., 2009).

Openness to experience (e.g., Csíkszentmihályi, 1996, pp. 52–53), on the other hand, as well as tolerance (Chua, 2007, p. xxi) and internal motivation (Beghetto, 2010, p. 456) are part of the expansive tendencies. They exert a fueling effect on creativity. Insight happens when formats are as open as possible, mixing a large diversity of people and types of information (cf. Brown, 1995), which should be freely accessible. To make novel combinations, people should be allowed to take different perspectives (e.g., Gruber & Wallace, 1999, p. 109). To make connections across disparate domains, a diversity of information should be freely accessible (cf. Damasio, 2001, p. 65; Basalla, 1988/1999, p. 78). Freedom, tolerance, openness, diversity, joy, playfulness, and an exploratory mindset, appreciative attitude, and visionary leadership breed a culture of creativity.

However, there is no either-or in creativity; it is rather a balancing act. The creative process has two sides. The expansive side is related to solving underdetermined problems through insight and the conservative side relates to solving more specific problems through reasoning. Dependent on the situation, the solver alternates between one and the other strategy (Hélie & Sun, 2010; Kris, 1952). In the early stages of creativity, everything should be as open as possible and without stress and then gradually close in on a specific solution at the end: From rule-free to rule-oriented.

13. Probabilism, determinism, and the rule of rules

Classic scientists are focused on making rules and have a hard time when there is an exception to that rule. They assume a deterministic universe in which exception is a flaw in our understanding of all the variables that should go into the equation. However, the only way to get to that perfect self-contained rule without exceptions is to assume a rule of rules stating that there is always an exception to any given rule. If that is the case, then in applying that rule reciprocally, that

is, applying it to itself, there must be at least one rule that has no exceptions. Total randomness allows at least one constellation of elements that has perfect order. Snowflakes are crystalline and therefore, supposedly show perfect order (e.g., the typical six spokes radiating out from the shared middle). Hardly ever, however, are the two halves exactly the same and only rarely are two snow crystals identical (see Knight, 1988). All the different forces that impinge upon their formation disturb the perfect order that may be potentially there. In other words, we have to assume a probabilistic universe in which deterministic states happen occasionally and locally. Thus, nature capitalizes on chance to achieve pure perfection. Every now and then and only by coincidence, it seems as if God does not gamble.

From idea to concrete manifestation, creativity develops from rule-free to rule-oriented, from hot disorder to cold order, bringing what was first in motion to a standstill. Entropy or utter chaos is about the physics before things, where anything can happen. Human creativity cannot handle total entropy. Coincidental order – no matter how fragmented – should help human ingenuity to make new connections. In entropy, there are serendipitous findings only.

When fragments of form and patterning have formed, certain humans are better equipped to handle probabilistic problems than others. Probabilism spins out from the physics of very small things (e.g., sub-atomic particles), where many things can happen but not all. Whereas entropy entails complete probabilism, deliberate creativity takes place in situations of near-probabilism. Certain forms have taken shape and already came to expression and do obey some non-absolute rules: Humans do not create out of nothing (cf. Simonton, 2009, p. 141).

When things cool down, assemble, and thus acquire more mass, probabilism decreases and the world becomes more deterministic. The unsuccessful strive for determinism rules the world of organism and biology (cf. Schrödinger, 1944/2010, p. 80), the physics of medium-size things. Some things can happen but most options are excluded. Creativity has filled certain niches in a particular and specialized way, needing a lot of maintenance work to keep it like that. Survival of a system is guaranteed in an environment that does not change and that requires standard behaviors only. This also means that other niches are left open (cf. K. Kelly, 2010, p. 113). Biological cross-breeding (e.g., Kozo-Polyansky, 1924/2010) or conceptual blending in creative fantasy (e.g., Sci-Fi) disrupt deterministic rules to bring yet novel combinations to light that can fill up evolutionary niches. Variation is limited by biological or behavioral rules and is quickly treated as deviant. Despite Classic attempts to formulate natural laws and rigid rules, determinism is not absolute, at least not for long; else variation, adaptation, mutation, errors, or fantasy would be impossible. Only when creativity narrows down to implementation or mass production, systems become near-deterministic.

If it is possible at all that systems become absolutely deterministic, they would enter a state of complete inertia. This is the physics of extremely large things, where time and space collapse together with gravity and mass and nothing happens anymore. The universe would freeze (cf. cosmic ‘heat death’) and come to a halt.

14. Creative output: Sigmoid accumulation of innovations

Creativity is about the novel combination of associatively remote entities and there seem to be three universals in the systematic of combinatory patterns, predicated by three interacting characteristics of nature: *continuity*, *discontinuity*, and *chance*. This triplet is responsible for the traces that creativity draws in history: A series of Creative Sigmoids.

Near-determinism of a creative system constitutes conservation, evolution, and incremental optimization. It reasons from the givens. Near-probability of a system gives way to expansion, disruptive insight, and breakthrough change. It associates what is not obvious. Chance helps to ignite disruptive thought through serendipity to start a new evolutionary line.

Chapter 5 explains that the medium in which creativity happens is a universe of free floating information of the most diverse kind. Diversity is necessary; otherwise, there would not be a discrepancy to reconcile. When the combination of unrelated entities develops into an evolutionary line, the shape of accumulative growth is a sigmoid or S-curve (cf. Verhulst, 1838); its *x*-axis being time, the *y*-axis being the accumulation of ideas. In its infancy, the problem space is probabilistic and can only be approached through association and insight. Lucky coincidence that is picked up by a creative mind will start the innovation line. In the acceleration phase, when the flank of the sigmoid rises steeply, the problem space exhibits mixes of probabilistic and deterministic issues. Matters of implementation of the novel idea ask for more reasoning and rule-based solutions. In a mature state, at the asymptote of the sigmoid, creativity declines at the cost of reproductive behaviors. Rationalization of work becomes germane.

Through an increase of choices already made, determinism of the system becomes stronger, and thus, rule pressure becomes tighter (e.g., the demand of originality or the application of safety regulations). Therefore, the bandwidth of possible behaviors of the Creative Sigmoid shrinks from infancy through acceleration to maturity. To avoid homeostasis or even inertia at the asymptote, disruption of the evolutionary S-curve can be achieved by being exposed to unrelated information (increase of diversity), a change of perspective so to make a new combination with a previously unconnected domain. This way, every new

creation builds on older combinations (K. Kelly, 2010, p. 8, p. 38). Combinatory explosion results into the final combination of all the combinations made earlier and then the system comes to a halt. Its only way out is to diversify again and to deliberately demolish or stop maintenance of the definite system so that it decays into entropy again.

15. Creative Sigmoid at three scales

The Creative Sigmoid develops over three levels of data aggregation. At its infancy, a chaotic assortment of ideas, features, and loose entities show irregular behaviors and it is the creator who first discovers similarities among the different pieces. In the acceleration phase, features and entities group together, establishing an intermediate level of coherence. When the line of creative development grows mature, connections are well established and show a systematic. There are hardly any loose ends and the latest developments incorporate the largest number of prior ideas. In terms of information saturation, the first ideas are aggregated over lower numbers of data than the last ideas, because the latter incorporate the first.

This pattern can be recognized at different scales and in different domains but the build-up of the Creative Sigmoid stays the same at all levels (Chapter 5). In atoms, for example, we find complete irregularity cooperating to produce regularity on average (Schrödinger (1944/2010, p. 78). Order happens only at larger sample sizes, whereas variability increases at smaller scales (*ibid.*, p. 18). With respect to the evolution of species, Goswami (1997, p. 88) declares that variability takes place at the level of the genes, whereas selection into a stable feature takes place at the level of the organism. Variability and chances for change are found at the smaller scales; stability is gained over larger constellations. The firing of a single neuron is quite noisy; a bundle of neurons constitutes robust processes (Hélie & Sun, 2010).

In other words, association and insight take place at the lower and more chaotic levels of data aggregation (cf. Schrödinger's physical "order-from-disorder"). Verification and selection happen for the larger bodies of data, when already some coherence has been established (cf. Schrödinger's biological "order-from-order"). Coincidence is forced out by taking ever-larger samples. The same pattern is found in behavioral statistics. A stable mean is established by sampling many data points and ruling out incidental outliers. In other words, zooming in on smaller groups or individual behaviors will increase the variability of the data, some people showing more within-variability than others.

The said characteristics of nature, *continuity*, *discontinuity*, and *chance*, underlie three visions on human creativity: *evolution* (e.g., Basalla, 1988/1999), *disruption* (e.g., Hausman, 1984), and *serendipity* (e.g., Roberts, 1989) respectively, which coincide with the three scales of data aggregation: Macro, meso, and micro – the masses, the individual, the separate materials.

If one looks at cultural history, all developments seem incremental and individual contributions seem to be of equal importance. If one looks from the perspective of individual psychology, associative leaps seem bigger or smaller as compared to others. This instigated the idea that positive outliers might be geniuses whereas negative outliers were mad. In looking at the raw materials from a stochastics or particle physics perspective, all the building blocks (atoms, molecules, features, ideas, entities) seem to be in chaos and patterns seem to form by chance, picked up by the lucky person who happens to be prone to see such coincidences. A computer can do that too. The three lines of thought about creativity – evolution, disruption, serendipity – seem to relate to three scales of data aggregation, becoming more jittery the smaller the scales.

16. Fractal recursion of the sigmoid

Patterns repeat over many different scales, whether they are patterns that lock quarks into protons and neutrons, social structures, or galaxies (Christian, 2011, p. 506). The trace of combinatory creativity has an S-shape. Because new ideas combine earlier ideas, each S-curve should consist of smaller S-curves (cf. Savransky, 2000, p. 340). The S-shape is a geometrical figure that when repeated in itself becomes nearly self-similar, albeit on a different scale. However, an S built of smaller Ss shows a bumpy line, becoming smoother the more saturated it gets by more Ss (cf. maturity). Self-similar repetitions of rough geometrical shapes suggest that there is a fractal Hausdorff dimension to creative growth (cf. Savransky, 2000, p. 347). Fractals consist of almost endless self-similar details and patterns can be repeated on increasingly smaller or larger scales (Mandelbrot, 2001).

Nonetheless, recursion of the sigmoid may occur independent of scale but it still has a lower and an upper bound. In entropy, no sigmoids will develop or only seldom, by coincidence. If these accidental coherences are not picked up, no creative development happens. In inertia, all combinations of combinations have been made and the overall sigmoid cannot be part of an even larger sigmoid any more. In other words, fractal recursion of the Creative Sigmoid develops within a universe from near-probabilism to near-determinism.

Due to its jagged surface, the dimension of a fractal shape cannot be measured by a natural number. Fractals consist of an infinite number of points, which have a

dimension of zero, along a line with a dimension between one and two (e.g., 1.1, 1.2, etc.). Chapter 5 shows a range of simulations of the Creative Sigmoid of which we logically can predict the fractal nature of creative advance.

Acknowledgement

I would like to express my gratitude to Desmond Germans for reviewing an earlier draft of this chapter.

CHAPTER 2

Two world views

“Without order nothing can exist – without chaos nothing can evolve.”
(Unknown)

Being creative depends on our outlook on life. If we believe or frame our world as a continuous struggle for survival, old brain structures become dominant and offer us standard solutions proven by millions of years of evolution. They ultimately lead to rational types of problem solving, reasoning from the givens, resulting into an almost Classicist desire of a predictable, deterministic, ordered world. If we conceive of our world as a treasure chest of unexploited opportunities, the younger brain structures become operative and more associative types of problem solving are activated in which the fixed classifications of how the world ontologically is or should be are transgressed through epistemic appraisals of what the world might be or could be like. Disruptive ideas conjured up by bright individuals entice an almost Romantic culture that, when brought back to a survivalist form, worships genius, excellence, stardom, and ego. The postulation of a probabilistic universe also allows the incidence of sheer luck or serendipity; the circumstance that in physical as well as in organic nature creations surface from accidental collisions or from sudden patterns coincidentally emerging from randomness. In closure, it seems that creativity balances between probability and determinism with neither state being perfectly freed from the other. In this sense, chaos incrementally grows into evolution, which then is disrupted, triggering chaos again, which in its turn progresses towards evolution, etc.

1. A world view follows from what we believe

In the Introduction, a loop was described between the perception of fiction, creativity, and the development of innovation. For someone who is strict in his or her classification of the world (“*Antigone* is a tragedy, *The Taming of the Shrew* is a comedy”), cross-genres such as tragicomedies may be rejected because they are “doltish,” as Sir Philip Sidney (1909/1914; 2001, p. 79) thought they were in his *Defense of Poesy*. Such people may not accept that innovative forms are made by merging and hybridizing old forms (just imagine what *The Taming of Antigone*

would be about), which is exactly what creativity does. In other words, to be creative entails the acceptance of fuzzy boundaries between known categories – and what categories are supposedly ‘known’ all depends on one’s world view. Creativity blurs the borders between the fictional and the real. It accepts that “envy” as an emotion can be epitomized as “a forest,” because you can get lost in both. Therefore, this chapter is devoted to two outlooks on life: survival and opportunity thinking. I will argue that the first leads to crisp categorizations and realistic accounts but hardly to any creativity; the latter to fuzzy categorizations and conjuring up new fictions.

In *Epistemics of the Virtual* (Hoorn, 2012), I discuss that what we believe the world is about depends on an *a priori* system of beliefs that is installed in childhood by all kinds of authorities in upbringing, education, culture, science, and so forth, including our parents (pp. 20–28). This belief system is updated through personal experience – directly or through hearsay (e.g., media messages).

So-called dualists hold absolutist beliefs that knowledge is right or wrong. They focus on facts and truth and believe that authorities have the correct knowledge (Perry cited in Jonassen, 2000; also Hoorn, 2012: Chapter 1). Multiplists accept different views and are skeptical about expertise in general. They try to find truth through tests and empirical verification. Relativists acknowledge the cultural context of truth and rely on their judgment and wisdom to deal with uncertainty. Relativists acknowledge that experts may have better answers but that ideas should be approached from the cultural and intellectual perspective in which they function (Perry cited in Jonassen, 2000). Thus, dualists work best in a problem space that has deterministic rules (e.g., classic mechanics) whereas relativists are better off in a probabilistic context (e.g., relation therapy). Multiplists occupy the middle ground.

No matter how strict or volatile, a belief system determines the way we conceive of the world, the perspectives on the universe we cling to, the interpretations of life we reject. When a world view is collective, most of the beliefs and ideas, fundamental insights, and existential convictions are shared. Derived from that, people share their rules of conduct, their norms and behaviors. A world view determines the way we approach each other, our environment, and the way we solve our problems. Even the acknowledgment of a problem depends on the beliefs we build our lives on. For instance, if you believe in knowledge sharing and open innovation, then how can the protection of intellectual property be an issue?

A world view and the belief system it evolved from is but partly verified through science and logic. Actually, science and logic themselves are rooted in fundamental convictions that cannot be verified. We work from a constellation of assumptions from which we reason, infer, and argue rather than providing the arguments for them. A world view follows from what we believe and what we

believe is arbitrary; a false syllogism of authority (Hoorn, 2012, p. 25). Beliefs cannot be proven; therefore, a world view is axiomatic.

2. Survival versus opportunity thinking

By and large, world views have a cognitive-affective orientation more directed at survival or more directed at opportunity seeking (Chapter 1, Section 6). These biases do not exclude one another; it is a matter of emphasis and over time this emphasis switches. In all possible variants, survival thinking and opportunity seeking maintain a delicate balance in individuals, groups, or even cultures. Survival thinking is more conservative and pessimistic (Zander & Zander, 2002, p. 18, p. 21). Its main emotion is fear. Opportunity seeking is more expansive and optimistic (Csíkszentmihályi, 1996, p. 11). Its main emotion is joy.

Even apart from the instability due to speculation, there is the instability due to the characteristic of human nature that a large proportion of our positive activities depend on spontaneous optimism rather than mathematical expectations, whether moral or hedonistic or economic. (Keynes, 1936/2008, p. 144)

Accepting the instability of a system is a matter of mind set and a matter of what people feel is required given a situation. Savransky (2000, p. 135) lists a range of about 30 reasons why people do inventions: from threat, obligation, legal matters, and competition (typical survival issues) to sheer fun (a typical opportunity motivation).

Basalla (1988/1999, p. 2) argues that anything more complex than strictly necessary for existential survival does not come from need or utility but rather from other motivations such as curiosity and playfulness. As a case in point, Basalla offers the invention of wheels on an axis by native meso-American people (Figure 1).

Figure 1. Pottery toy with wheels from Tres Zapotes, Veracruz (100–200 AD) (Pettit & Pettit, 1978, p. 14)



Due to the rugged and mountainous terrain, the wheels from Tres Zapotes (Figure 1) are useless for the transport of goods and people; probably they were used for rituals or toys (Basalla, 1988/1999, p. 10). Sometimes, utility or need does not demand but follows from the supply of innovations, where Basalla points at the emergence of cars that were first used as toys for the rich (ibid., p. 2).

2.1 Old brain, young brain

Both Damasio (2001, p. 59) and Pfenniger (2001, p. 91) relate aspects of neuronal architecture to creative invention. The oldest parts of the organism's control system such as the vegetative system, diencephalon, and brain stem are directed at sheer survival. They are related to instinct, inherited behavior, and sustain the continuity of the organism under deterministic situations of biological preservation (e.g., temperature regulation, oxygen intake, fight or flight). The youngest parts of the brain such as the frontal cortex are specialized in concept formation and mental flexibility, appropriate for opportunity seeking in highly probabilistic situations (also see Chapter 1, Section 5).

However, the brain does not live in isolation. According to Damasio (2001, p. 59), "creative artifacts cannot be reduced to neural circuitry of an adult brain or to the genes behind the brain." The genome-specified brain circuitries as well as the activity-specified brain circuitry are in constant interaction with physical, social, and cultural environments. From that interplay between individuals and environment social and cultural artifacts emerge.

Which part is dominant during those interactions, the old brain or the young brain, brings forth which mode of thinking is employed when being confronted with a problem: If life is a rat race of survival, more repetitive solutions will surface, leaving less room for creativity. If the world unfolds as a prosperous vista of wealth and possibilities, higher risk-taking results into top-rate innovations.

3. Ontological classification, epistemic appraisal

In a survival mode of thinking, the way we process information is to relate incoming data to known categories: A duck bill belongs to a duck; therefore I deal with a bird. A flat tail belongs to a beaver; therefore I deal with a mammal. In Hoorn (2012, p. 45), I called this process *ontological classification*. It is a quick and dirty, fast and global way to monitor and navigate the world. It necessarily assumes a more-or-less fixed ontology of 'the way the world is.' Ontological classification takes little effort to execute and hardly can deal with unexpected inputs.

While performing ontological classification, the encounter with something novel or creative has a disruptive effect: Exemplars do not match to known categories so that a more elaborate process comes into operation, known as epistemic appraisal (Hoorn, 2012, p. 46). A platypus combines a duck bill with a beaver's tail. Tuatara is an animal in between lizards and snakes on the one hand and crocodiles, birds, and dinosaurs on the other (Box 1). *Procynosuchus* is a crocodile-dog, a mammal-like reptile from the Late Permian.

Box 1. Hard-to-classify living fossil

Tuatara (*Sphenodon punctatum*, Figure 2) is a living fossil from New Zealand, dating back 18 million years and still existent today. It has a third eye on top of its head, a slow metabolism, and breathes once per hour. It feels fine at low temperatures and may reach the age of 100. Sometimes Tuatara shares its den with nesting storm birds.

Figure 2. Tuatara is not a lizard



For someone unfamiliar with natural history, ontological classification goes astray in these cases. Epistemic appraisal verifies at a local level whether the features of the hard-to-classify exemplar can be seen as belonging to the observer's notion of reality or not. In a mode of epistemic appraisal, disbelief is suspended, options are explored, and strange novelties (temporarily) tolerated.

During the appraisal whether features could be deemed realistic or not, certain minds will look for even deeper meaning, accepting that the combination of eagle and lion not merely makes up a griffin but, for instance, stands for a combination of freedom and strength, salvation and loyalty. This is a mode of thinking well-suited for creativity. It allows a wide solution space in which the strangest occurrences and associations can acquire meaning beyond the simple administration into known categories.

4. Determinism, probabilism

The urge to survive is typical for organisms. Organisms have to maintain a steady state in which all of their processes run efficiently and effectively against the least possible effort. Otherwise, they would fall apart or stop working. Change is suspect in this respect because the organism does not know upfront whether the change is a deterioration of circumstances or not and whether it faces a threat to survival. Therefore, organisms will look for a predictable environment, showing little changes, and having the fewest possible unknowns.

To solve existential problems, organisms developed autonomous systems that routinely pump blood around, repetitively inhale and exhale, or show quick reflexes when the pain alarm goes off. For millions of years, these solutions have proven to be effective and they hardly need to evolve – under the condition that the environment does not change too much. As Pfenniger pointed out (Chapter 1, Section 5), for each survival situation that incorporates more complexity (extra unknowns,

dynamic environments), organisms and humans in particular developed more sophisticated layers of the brain: memory for inherited behavior, language for information exchange, intelligence for learned adaptation (Pfenniger, 2001, p. 91, Table 2.2). With increasing complexity (more unknowns, more dynamics), the problem space that organisms could deal with went from more deterministic (e.g., behavior under physical laws) to more probabilistic (e.g., rules of conduct).

It is not hard to see why organisms with an outlook on survival would want to structure their world and the behaviors of others with rules and regulations. Determinism of behavior makes interactions predictable, non-threatening, solutions become repeatable, efficient, effective, against low costs and least effort (cf. Hoorn, 2012, p. 34). The appropriate mode of information processing is that of ontological classification. Intelligence flourishes under deterministic circumstances because in reasoning from the givens, it can predict what a next action should be or how to achieve a desired goal. Figure 3 shows Pfenniger's (2001, p. 91) hierarchy of nervous systems as a function of solving problems of a more deterministic nature or of a more probabilistic kind and where the focus of the two resulting world views lies.

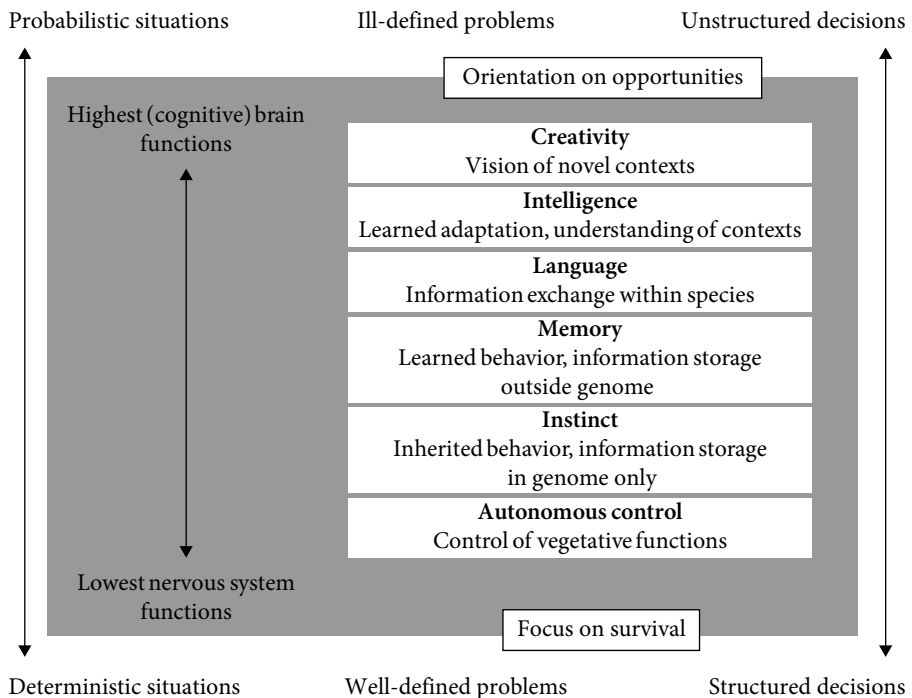


Figure 3. Nervous systems, the problem spaces they cover, and resulting world view

Box 2. Killer rabbits after all

Common duiker (*Sylvicapra grimmia*, Figure 4) eats young plants and leafs and therefore is sometimes short on proteins. Common duiker occasionally behaves as a carnivorous antelope while eating small amounts of fresh carcass or birds that hatch on the ground. It developed intestines that are adapted to meat digestion. Pandas went through a reverse development and made the switch from meat eater to bamboo muncher (e.g., Jin et al., 2011).

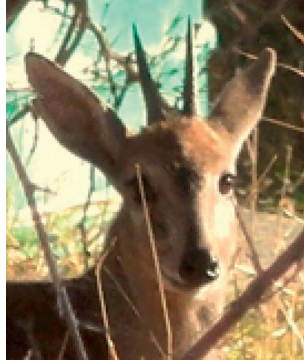


Figure 4. Certain herbivores developed meat eating habits

The only thing that intelligence, instinct, or the vegetative system cannot do, is to escape from the givens and solve an ill-defined problem by illogically jumping to another domain. Creativity can do just that: Bail out from an existing situation and adapt to radical change. It can deal with unstructured, highly complex situations of a probabilistic nature where reason has no grip on. If grass eating is not an option any more, start eating the grass eaters. This is a radical jump for which the complete digestive system needs to be redesigned, teeth included. In information processing, creativity requires doing elaborate and labor intensive epistemic appraisals of a highly imaginative future. One should be willing to consider the idea that rabbits will eat meat (starting with worms); just like impala and giraffes chew on bones for calcium intake and certain antelopes eat small amounts of meat to get proteins (Box 2).

5. Two world views leading to three theories

The previous section argued that an orientation on survival thrives better in deterministic settings, dealing with well-defined problems. Opportunity seeking flourishes under probabilistic circumstances and welcomes ill-defined problems. In thinking about creativity, three lines of thought can be distinguished that correlate with grades of determinism (or probabilism for that matter) with a mindset that is

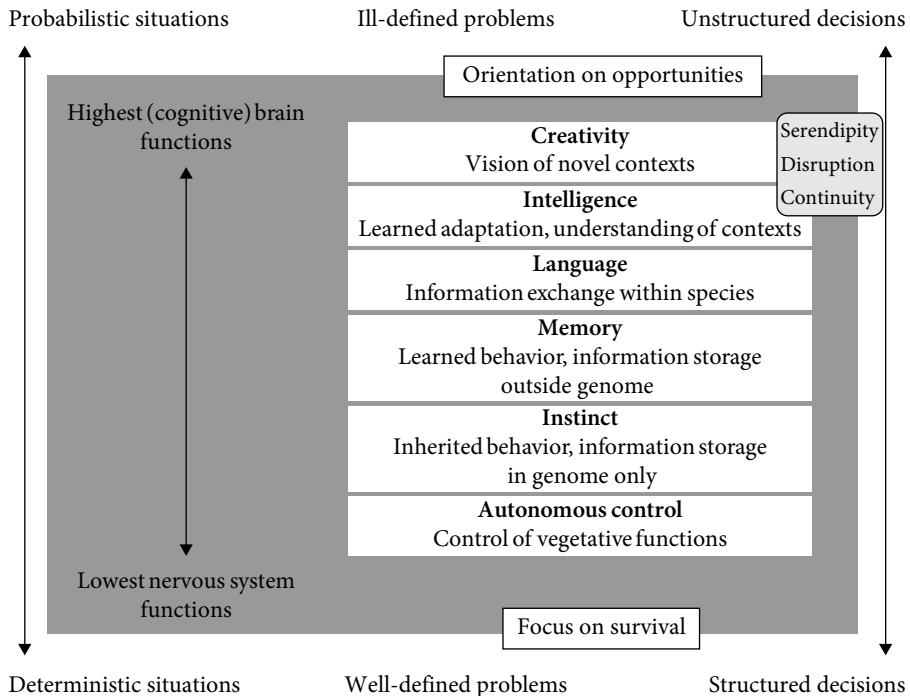


Figure 5. Relations among problem spaces, world views, and creativity theories

more focused on survival or on opportunity seeking, respectively: The *continuity* view, the *disruption* view, and *serendipity* (Figure 5).

Socio-economic and historic accounts usually emphasize the idea of *continuity* and incremental growth (see Simonton, 2009, pp. 136–137). One step follows from the next and although the continuity view does not exclude bigger or smaller variations, slow evolution is what they focus on. Innovation can be reasonably predicted from path-dependency and is mainly based on intelligence (Box 3). The continuity line of thought emphasizes the role of prior experience and recognizes that a multitude of people contribute to big innovations (‘small’ creativity, accumulating). This line follows a Darwinian kind of reasoning of adaptation and selection of novelty.

Individual-psychological and neurological approaches to creativity highlight the *disruptive* insights of gifted luminaries (Simonton, 2009, pp. 136–137). Certain people escape from the mundane by jumping to another domain than the one evolutionary lineage would expect (Box 4). Mokyr (1990, p. 274) speaks of “gradualists” (continuous evolution) versus “saltationists” (disruptive jumps). Intelligence is needed to identify a line of development whereas associative intuition would create the crossover to “break new ground” and “venture into the

Box 3. Graphene: Innovation through incrementation

Andre Geim and Konstantin Novoselov developed a substance called graphene, which promises to be revolutionizing display screens, chips, and solar cells. It is a honeycomb sheet of carbon atoms of only one layer thick, which was previously regarded as physically impossible. It is the thinnest crystalline structure that exists and the toughest and strongest material on earth. The way graphene was developed was stunningly simple: The authors peeled off layers of carbon from the stroke of a pencil by means of adhesive tape. Although extremely clever, this is an innovation attained step by step from a premise to a net result. It is not an associative leap to another domain. Yet, it brought the two discoverers the 2010 Noble Prize in Physics.

unknown” (Csikszentmihályi, 1996, p. 116). The disruptive view believes that creative development is a series of revolutions in which the masses are insignificant bystanders of the extraordinary achievements of a few thought leaders (‘big’ creativity, sudden leaps of the mind). This line is indebted to Nietzsche’s (1888/2008, p. 242) idea of formidable spirits who stand out against the animals and ordinary people (cf. Kaufmann, 1974, pp. 161–167).

Stochastically-oriented views on creativity point at the random aspects of new findings, discoveries, and ideas. The coincidence line of thinking frames creativity in terms of lucky accidents in a universe of randomly floating information, sometimes referred to as *serendipity* (Box 5). Coincidence could be purely physical such as the first formation of water or the first time sodium atoms and chlorine became table salt (Lowcre, 2013). In humans, serendipity may be accompanied by foresight, the feeling that ‘something is out there’ or ‘about to happen.’ Famous examples of serendipity are Newton’s ‘discovery’ of the gravitation law, the Big Bang of Creation, or the finding of DNA. In the technical domain, Savransky (2000, p. 137) provides the examples of rubber vulcanization by Charles Good-year, or the mixing of potassium nitrate with charcoal and sulfur, which led to the discovery of gunpowder.

In the literature, the three views on creativity are treated in many different ways and we will see that the divide is not that strict: Advocates of one view sometimes show traces of the other view as well (e.g., Cartesian dualism, Nietzsche’s coincidental inheritance of excellence). A reconciliation of all three vantage points, however, does not exist yet. An attempt will be done in Section 7. For an overview of how the concept of creativity developed historically, see Runco and Albert (2010). To appreciate the pluralism of creativity theories, see Kozbelt, Beghetto, and Runco (2010). Next, we look more closely into the three approaches to creativity and devote a section to each of their characteristics in the history of culture.

Box 4. Disruptive crossovers

In 1906, Pablo Picasso painted *Self-portrait with Palette* (Figure 6a) in a conventional style. Until then, Picasso had been mimicking the styles of others (Miller, 2000, p. 413). After being exposed to African art and being taught about perspectivism in physics in the salons of Paris (Miller, 2000, p. 421), *Les Femmes d'Alger* (1907) (Figure 6b) introduced (together with Braque's work) a new style of painting derogatorily called "Cubism" by an audience in shock.

Figure 6a. Picasso, P. (1906). *Self-portrait with Palette*. Philadelphia, IL: Philadelphia Museum of Art. <http://www.philamuseum.org/collections/permanent/50947.html>

Figure 6b. Picasso, P. (1907). *Les Femmes d'Alger*. New York: MoMA. http://www.moma.org/collection_images/resized/271/w500h420/CRI_151271.jpg

Box 5. Penicillin: A coincidental finding

At one time Alexander Fleming was sloppy and got lucky. Investigating *Staphylococcus* bacteria, he forgot to close off the petri dish he worked on. After a while, a mold killed the bacteria and Fleming wondered what had happened. It turned out that the bacteria killer was the fungus *Penicillium*. In 1945, Fleming received the Nobel Prize in Medicine for having invented Penicillin.

5.1 The ordered universe: A vision of continuity and determinism

The continuity idea of creativity and innovation is firmly rooted in a Cartesian and Newtonian belief system of a mechanistic clockwork universe that determines the course of events into the future. The world unfolds according to its destiny. Evolution and change are predetermined and can be accurately and securely predicted by the natural laws that govern cause and effect. In reasoning back, it is possible to make an accurate reconstruction of the past (Westfall, 1980, pp. 1–39; Miller, 2000, p. 14). As Leibnitz put it: "Nature makes no jumps" (Miller, 2000, p. 106). It is a Classicist position that gave rise to Newtonian science and in its wake, the Industrial Revolution of the 19th century.

5.1.1 Analytic decomposition

In the Age of Reason, the approach to solving problems is rational, rule based, and analytic. A complex problem is decomposed into smaller parts and then reduced

further to its individual constituents, which are the “indivisibles.” Adam Smith (1776), for instance, drastically rationalized production processes by breaking down complexity into smaller well-defined problems and introducing the division of labor. Highly specialized workers solve known problems without spreading effort and attention over a wide variety of complex tasks. Division of labor brought about a class of top experts with specific knowledge and experience concerning one particular topic. To date, this is still believed to increase productivity. And in a static, mechanistic world, this assumption indeed generates health, wealth, and prosperity. Contemporary problem solving is greatly indebted to this rational approach and speaks of ‘goal decomposition’ (see Chapter 3).

5.1.2 *Hierarchical*

In the slipstream of the Industrial Revolution that unreservedly had incorporated Smith’s approach to labor organization, Taylorian (1911) approaches to business put science at the basis of managerial decision making, instructing the workers to precisely execute carefully engineered plans. Weber (1922) envisioned organizations in general as machines that function or should function according to bureaucratic principles of hierarchical command lines. Responsibilities were taken off the shoulders of the specialists at the bottom end of the command line, executing orders provided by a system of levels of graded authority. Rigid adherence to rule, order, law, and administrative regulations governed impersonalized and precisely formulated functional tasks.

5.1.3 *No free will, no heroes, no revolutions*

In a deterministic universe there is little room for free will, personal goals, mind, or random fluctuation. Invention does not result from the heroic efforts of a few geniuses (cf. Basalla, 1988/1999, p. 21). Optimization rather than revolution would give change its shape and form (Friedel, 2007, p. 3). Thus, the joint transactions of the workforce determine innovation rather than the work of the intellectual elite, each generation building on top of previous achievements. In the spirit of Classic mechanics, human agency is reduced to physics and chemistry (cf. Behaviorism). Evolution cannot be altered or redesigned by human hand nor can humans change the destiny of the world. God is the ultimate creator of the universe; the human is submissive (Westfall, 1980, pp. 1–39).

5.1.4 *Creative drivers*

In a deterministic (social) system, economic drivers such as production factor prices and capital stock are responsible for variation of novelties and for the applicable selection mechanisms. These positions can be observed in, for instance, Marx and Hegel. The economy dictates a continuous stream of technological improvements with a gradual and incremental development in innovation (Mokyr,

1990, pp. 12–13, p. 289; also Davids, 2008, p. 9). Invention is path-dependent, predicting future performance from past performance (Davids, 2008, p. 8). The analysis of two million patents worldwide revealed that very different technical systems and processes show similar ways of development (Savransky, 2000, p. 24).

5.1.5 *Slow evolution*

Basalla (1988/1999) points at the extremely slow development of stone tools, which in the thousands of years of their production across a diversity of cultures and technologies show an unbroken line in size, shape, and materials used (ibid., p. 31). Variation of cultural artifacts often is compared to natural history. Diderot's *Encyclopedia* categorizes artifacts and crafts with the rigor of a naturalist's classification of a species (Friedel, 2007, p. 442). Often, the Darwinian principle of selective retention serves as an explanation of deterministic continuity in a diversity of (once novel) cultural artifacts (cf. Campbell, 1960; Simonton, 1995). A most recent example is the view of technology as a living force (K. Kelly, 2010). At full length, the evolutionary process visible in the advance of technology and culture would be inherited from the molecular organization of the universe itself; repetitively showing similar structures (K. Kelly, 2010, p. 104).

5.1.6 *Invention is social*

Invention is a social process, an accumulation of many minor improvements, which serve as “communal” sources (Davids, 2008, p. 456). Many parallel discoveries occur, and the people who do them are interchangeable (K. Kelly, 2010, p. 133). Simultaneous invention seems to be the rule (ibid., p. 142; Simonton, 2009, pp. 150–153). Csíkszentmihályi (1996, p. 1) argues that creative ideas and products spring from the synergy of many sources rather than the flash of insight in the mind of one single person. Creativity does not happen in an isolated head and does not come from nothing (ibid., p. 29) but happens in interaction with and embedded in a socio-cultural setting, a community (ibid., p. 23). Creative achievement comes after years of hard work (p. 1). Before someone can be creative, Csíkszentmihályi poses, s/he must be trained well in theory and techniques but also in the criteria on which creations are judged (ibid., p. 47).

5.1.7 *Copying from others*

The continuity view implies that no person is so self-sufficient that s/he never borrows ideas from an outside source (cf. Basalla, 1988/1999, p. 78) (Box 6). Shiff (2003, p. 145) states that artists have to begin with what has already been created, entering in historical traditions, “their language of form having already been spoken.” Many artifacts show skeuomorphisms (Basalla, 1988/1999, p. 107), where functional features of older versions are copied into (the material of) the new

replacement. For instance, wooden surfaces and iron nail heads are pressed into plastic boxes without having a function beyond decoration. Another example is the QWERTY keyboard-layout of computers, which was originally designed to keep the letter hammers of typewriters from colliding with one another. The reverse may occur as well: A filokainoism is a dysfunctionally applied or depicted innovation incorporated into prior art to make it look more modern or advanced. Examples are a print magazine with website layout depicting scroll bars; Opel Manta with plastic front spoiler, side skirts, a rear wing, and quadruple air intakes on the grille; or a motor cycle mimicking a B-2 stealth bomber (Figure 8).

Box 6. Shoulders of Giants

In a letter to Robert Hooke, Isaac Newton (Feb. 5, 1676) somewhat mockingly wrote:

What Des-Cartes did was a good step. You have added much several ways, & especially in taking ye colours of thin plates into philosophical consideration. If I have seen further it is by standing on ye shoulders of Giants.

Newton acknowledges the work of Descartes, Kepler, Galileo as well as Robert Hooke but regards himself superior in 'seeing further.' The "shoulders of Giants" later sustained the idea that science is cumulative as visible in endless reference lists of journal articles and the motto of Google scholar beta (Figure 7).



Figure 7. Google scholar beta. Stand on the shoulders of giants

Figure 8. Filokainoism: B-2 Stealth Bike nicknamed "The Spirit of Innovation"



Box 7. The genius is part of creative evolution

Although in history portrayed as a predecessor, in combining the at that time modern Italian style with traditional polyphony, the madrigals of Johann Hermann Schein (Figure 9), German baroque composer, poet, and cantor of the Thomas Church in Leipzig, laid the musical foundation for his later famous successor Johann Sebastian Bach. It is not for the first time and it will not be the last, that a historic development is seen as the prophecy of a creative genius instead of the genius being the product of a development.

Figure 9. Johann Hermann Schein (1586–1630)



Most new ideas and new inventions are disjointed earlier ideas merged (K. Kelly, 2010, p. 45). Even the most inspired creations are firmly rooted in the past (Bailin, 1988). There are many parents for each novelty (K. Kelly, 2010, p. 132). For instance, 23 different examples of working light bulbs existed before Edison invented his. Bach is indebted to Schein (Box 7). Shakespeare copied from Holinshed and Boccaccio. However, in applying corpus linguistics to Holinshed's and Shakespeare's *Macbeth*, Zyngier (2008) concluded that Shakespeare has been much more creative nonetheless.

Shiff (2003, p. 148–149) points out that Classicism made a distinction between copying and imitation. Copying would be the more uncreative mechanical replication of an earlier work. For making copies, a geometric or mathematical algorithm could transform the original into an identical exemplar (cf. mechanical production). Imitation would be a more interpretative act, involving a degree of difference between the model and the new artifact. Shiff states that copying would follow a “predictable rule by system” (cf. Schrödinger’s “order-from-order”) whereas imitation in the Classic sense follows a “spontaneous rule by person” (cf. Schrödinger’s “order-from-disorder”). Shiff (2003, p. 149) explains that copying and imitation limit originality in so far they repeat earlier ideas but the originality is in the effective combinations, hybrid forms, which enhance the Classic imagery. Classic theory calls this ‘invention.’

5.1.8 *Harmony and perfection*

In his pursuit for sheer harmony, the Classic scientist Christiaan Huygens designed a musical system of 31 micro intervals to avoid the atonality that is insidious in the traditional 12 tone system. Keyboard instruments, which use discrete steps between tones, cannot be fine-tuned in octaves of merely 12 tones. Instead, intermediate micro intervals approach the continuous tone transitions of, for example, a

fretless bass.¹ In the 20th century, this system was the basis for Adriaan Fokker (the brother of the aircraft pioneer) to build a 31 micro interval organ (Figure 10) which gave rise to a number of compositions that aspire the complete purity of intonation.

Figure 10. Fokker organ with 31 micro intervals



In the 20th century, the mathematician Milton Babbitt (1916–2011) founded a new genre of serialism in musical composition. In an unpublished thesis, Babbitt (1946) unfolded the principles of *sets* and *pitch classes* in serial music and applied them in his *Composition for Four Instruments* (1948). He regarded the composer as a specialist (Babbitt, 1958) and conceived of his work as science rather than performance art. Babbitt preferred studio recordings to the imperfect and inaccurate interpretation of his work at a concert hall. Oliver Messiaen then gave the clarion call to total serialism in his *Mode de Valeurs et d'Intensités* and the second part of *Quatre Études de Rythme* (1949–1950).

The idea of serialism is to expel Romantic whimsicality from artistic conception (not perception). Serialists devise systems that would produce art free from subjective decisions of the artist. Human choice is ruled out because it interferes with the serial process of the creative system. In the fine arts, Sol LeWitt recommended working from a pre-set plan to explore ideas thoroughly, whereas arbitrary or chance decisions would be minimized. The plan designs the work, LeWitt insisted, avoiding subjectivity as much as possible (Figure 11). The artist merely selects the basic rules and forms that govern the solution to the problem (LeWitt, 1967a) and then functions as a clerk, merely cataloging the results of his premise (LeWitt, 1967b).

Figure 11. Sol LeWitt (1966). Serial Project #1



LeWitt's poetics, Babbitt's musical theory, Huygens tonal system, and Fokker's organ; a Classicist state of mind attempts to expel variation, error, and being out-of-tune from a system that should be entirely orderly and harmonious. For a Romantic mind, this spells utter boredom.

1. <http://www.huygens-fokker.org/microtonaliteit.html>

5.2 A subversive universe: Discontinuity and the outlier

Stent (2001, p. 32) points out that an antinomy exists between the immutable socio-economic forces of history as assumed by the Classicist view versus human agency. If one assumes an inevitable determinism of innovation it is insignificant who the inventing does (*ibid.*) but this stands in sharp contrast to unique achievements, contingent on certain bright individuals.

5.2.1 *Against dehumanization*

The Classicist is prone to establish a harmonious community identity, a bearer of order and hierarchy, basically agrarian, rural, and oligarchic in nature (Shiff, 2003, p. 146). The social consequences of the Industrial Revolution, however, were far from harmonious, rural, and agrarian. The Romantic Movement saw the emergence of an industrial, urban, more democratic world (Shiff, 2003, p. 146; Runco & Albert, 2010, p. 10). In reaction, they longed for natural creativity, individual and unbridled, envisioning humans as autonomous, not as an optimization appendage of machine production (*cf.* Marx' critique). Classicism and its mechanistic manifestation in the Industrial Revolution were perceived as suffocating and inhibiting creativity (*cf.* Shelley's *A Defense of Poetry* but also Giedion's (1948) *Mechanization Takes Command*).

Still under the reign of Newtonian science, Darwinian survival and selection advocated a strongly deterministic universe, which was renounced by Nietzsche on moral-humanistic grounds. Nietzsche replaced selective retention by psychological self-realization (Kaufmann, 1974, pp. 161–167). He suspected that a Darwinian world view would make people succumb to nihilism and shatter human dignity as installed by the Bible. Great Romantics such as Wordsworth and Blake renounced Cartesian dualism that separated mind from matter (Bloom, 2004, p. 6). They emphasized 'wholeness' and 'healing,' so that people could act passionately and purposefully again. And whereas Blake saw that "Natural objects always did & now do Weaken deaden & obliterate Imagination in Me," Wordsworth yet saw nature as the richest fulfillment of his own subjective imagination (Bloom, 2004, p. 216).

5.2.2 *Deviation and disharmony*

Romantic creators prefer the disharmonious, individualistic deviation from cultural norms, while resisting authority and institutionalization (Shiff, 2003, p. 146–147; also Miller, 2000, pp. 164–165). For example:

Blake attempted ... to interrupt the ordinary processes of this central dynamic structure by feeding into it complex information that it could only reject or reconfigure ... His defiance of the institutional structures of knowledge and the technological divisions that correspond to them resulted in unorthodox works that seemed ungainly if not ugly and shocking to his potential audience, who in their aversion have sometimes perceived a mind operating out of control. (Eaves, 2003, p. 8)

In 1786, Robert Burns wrote his ode *To a Louse, On Seeing One on a Lady's Bonnet at Church* only to ridicule the upper class for its pretense. In science, ideas of disruption and deviation can be found with the late followers of Kuhnian paradigm shifts or ideas on the Gestalt switch of theory (Miller, 2000, p. 234).

In countering continuity through natural selection, Nietzsche argued that preservation of ordinary qualities also preserves what has no use for survival (e.g., diseases). He stated that natural selection has no answer to the extinction of successful organisms and that it opens the door to mediocrity (Nietzsche in Schlechta, 1966, pp. 740–748, p. 889). Useful in Darwinian terms is what sustains the survival of a group; Nietzsche's idea of usefulness is what helps a person to gain self-esteem, irrespective of its effectiveness in maintaining the species (Nietzsche in Schlechta, 1966, p. 889). Instead of evolutionary improvement, linear inheritance, natural determinism, and usefulness for survival, Nietzsche emphasizes the coincidental inheritance of superb qualities – thereby unintentionally resonating Darwin's blind variation.

For the Romantic mind, 'the system' is suspect because it limits individual freedom and must therefore be resisted. This position can be observed in US activist poetry from the 1960s on (e.g., Eliot Katz),² "liberationist" postmodern critique (cf. Gottschall, 2008, p. 4), activist protests against the industrial-military complex such as the Occupy movement,³ or in the lyrics of the revolution preaching rap-metal band Rage against the Machine.⁴

5.2.3 *Genius: the freedom of formidable spirits*

Romanticism relishes individual genius (Simonton, 2009, p. 14). Romantics cheer at individual experience, idiosyncratic expression, and growth. They long for open-ended social transitions fostered by a new economy (Shiff, 2003, p. 146). They believe that autonomy and human agency are the key drivers of creativity. Original artists would be the "sons of no one" who "proceed from their own in-nateness" (Thoré, 1893 cited in Shiff, 2003, p. 150). Autonomous creativity would be incomprehensible from known perspectives and is independent of past experience (Hausman, 1984).

On Nietzsche's view, the few people who can escape nihilism are elite individuals or 'geniuses' such as certain artists, philosophers, and saints, who are the true representatives of human dignity and culture (Kaufmann, 1974, pp. 161–167). The technician or the engineer, according to him, is nothing more than

2. <http://blues.gr/profiles/blogs/poet-and-activist-eliot-katz-talks-about-ginsberg-abbie-hoffman>

3. <http://notanalternative.com/blog/oct-20-creative-activism-occupations-spain-w-leonidas-martin>

4. <http://www.ratm.com/>

a super-intelligent chimpanzee (ibid.). Alfred Weber and in his wake Karl Mannheim articulate the notion of ‘free-floating intelligence’ (“freischwebende Intelligenz”), available to an intellectual elite that independently transgresses ideologies, prejudice, and socio-historic determinants so to positively act upon social events (Hoeges, 1994).

5.2.4 *Iconic heroes*

Romanticism replaced the oligarchic nobility of Classicism by the nobility of the individual mind. Looking back at the artistic achievements of the past, the Romantic period deliberately advanced individual heroism even to underscore the superiority of an entire nation. For instance, the courageous and industrious “Byronic hero” became a literary character of its own: “... the Byronic Hero is the one protagonist who in stature and in temperament best represents the [heroic] tradition in England” (Thorslev, 1962, p. 189). The Industrial Revolution created Romantic heroes out of inventors and put them on a par with statesmen and conquerors (Basalla, 1988/1999, pp. 57–59).

Later generations sometimes confuse the size of the societal impact of an invention with the measure of its ingenuity. For example, the germanium point-contact transistor that Shockley, Bardeen, and Brattain invented was initially seen as an oddity. After this device caused an electronic revolution, the inventors were heralded as the inceptors of the information age (Riordan & Hoddeson, 1999).

Sometimes later generations deliberately downplay the antecedents of a great invention (Basalla, 1988/1999, pp. 57–59). In hindsight and with a lack of proper historical knowledge, such developments would qualify as a ‘disruption’ (ibid.). With the current rise of the creative economies, this trend can be observed in fingering all kinds of creative “icons,” with Steve Jobs attaining the status of a pop star.

Arrogance and self-aggrandizement are no strangers to the Romantic creator. The gifted declared God dead and became gods themselves (Nietzsche, 1882/1986, section 125). Although the Romantic mind set resists the suffocation by a rigid system, in disregarding the views of others, the self-centrality of ego can be just as stifling (Box 8). It is a defensive survival reflex not so much directed at group concerns but oriented at the supremacy of the individual. It falls into place with the protection of intellectual property, a liberal market where unlimited profit can be made at the expense of others, and where monopolies are desirable in spite of legislation and restrictions (Box 8).

Box 8. An Amsterdam Symphony

In an attempt to imitate the financial district of New York, a “little Manhattan” was supposed to arise on the South Axis of the Amsterdam metropolis. Yet, the project came to a halt due to vanity and greed, symbolically united in the Amsterdam Symphony, center point of the area (Figure 12). Its architect Pi de Bruijn, who also was the supervisor of the entire South Axis project, wished to complete the two towers with a connection such that the symbol π was formed, a tribute to his first name. Irritation about his stardom and headstrong habits forced De Bruijn in 2006 to retreat from the South Axis (Logtenberg & Soetenhorst, June 25, 2012, p. 9). In addition, fraud and financial crisis popped the bubble of unbridled profit maximization, so that building activities in the area stagnated (*ibid.*). What remained was a pale reflection of a huge ambition and an underdeveloped area with empty offices.

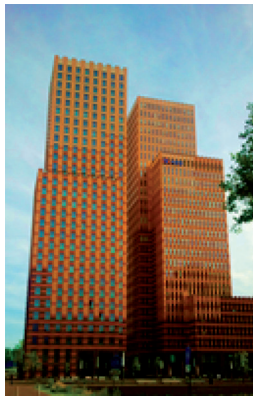


Figure 12. Amsterdam Symphony

5.2.5 Hop, step, jump

In line with the previous, there is an ongoing debate whether creativity develops gradually or disruptively. The continuity line of thought would be concerned with ‘small’ creativity and the discontinuity line would focus on ‘great’ creativity alone.

For example, Friedel (2007, p. 10) points at the historic importance of optimization, which is about short-term and local needs and goals, resulting into micro-inventions. Basalla (1999, p. 24) explains diversity of creative artifacts from continuity in the follow-up of inventions, of which small derivations and optimizations lead to a variety and variance of entities. From this, smaller and larger novelties occur. Selection determines which novel artifacts should be replicated and added to “the stock of made things.”

By contrast, Csíkszentmihályi (1996, p. 26; also Simonton, 2009, p. 24) focuses on acclaimed genius and posits that this is not a matter of being more or less creative but something completely different from everyday creativity. Big creativity would be “to bring into existence something genuinely new that is valued enough to be added to the culture” (p. 25).

Basalla (1999, p. 34) counters that whether an invention can be called ‘great’ is a cultural evaluation, not an inborn quality of the thought or the artifact as the reputation of the creator is tied to cultural values as well. He provides the example of the waterwheel (*ibid.*, p. 145), invented in Antiquity but despite its ingenuity underused until the early Middle Ages. Gardner (2001, p. 131, also Simonton, 2009, p. 24), on the other hand, sharply distinguishes between small departures from everyday routines (“small creativity”) and great people shaping the ideas and standards of a culture (“big creativity”) (cf. Nietzsche’s great spirits).

In reconciliation, Nickerson (1999, p. 399) reviews a number of authors who understand creativity as a matter of degree, which can be expressed by anyone but not necessarily to the same height. From the inventory of problem types by Savransky (2000, p. ii) one can deduce that gradual or radical innovation also depends on the problem space. His classification seems to range from incremental steps in a more deterministic situation (e.g., perfecting an existing artifact, style, or method) to major shifts in a probabilistic setting (i.e. genesis of a new style, technology, or method). Savransky (2000, p. 95) points out that innovation follows an evolutionary line when problems of low complexity are solved and becomes a breakthrough revolution when problems of high complexity are resolved, having many unknowns and contradictions.

There is not much against the combination of gradual and incremental development and the smaller or larger disruptions by the individual (cf. Box 9). Ward,

Box 9. Innovation: gradual intelligence, disruptively creative

In Spain, an extraordinary solar desalination plant is developed, called *Teatro del Agua* (Figure 13). Airborne moisture coming from an array of solar-powered evaporators is collected from the condensers, which in turn are cooled by deep seawater. This desalination method may be regarded as a highly intelligent innovation but even so the creative jump lies in the fact that the half-dome with evaporators and condensers also can be used as a publicly accessible venue for the performing arts: The Water Theater!

Figure 13. *Teatro del Agua* (artist impression)



Smith, and Finke (1999, p. 189) assume a continuum of creativity – from mundane to extraordinary. Also geniuses do not get something out of nothing and are indebted to the incremental work of their forerunners; moreover, they do incremental work themselves before they jump. Feldman (1999, p. 176–177) emphasizes the importance of mentorship and peer discussions and points out how genius, his case is Einstein, is dependent on the state-of-the-art of a domain (i.e. Lorentz, Poincaré) to come to expression and can fade away when the domain evolves.

5.3 Chaos: Coincidence and non-random variance

Coincidence is an alternative explanation for the mechanistic universe unfolding to its plan and for the outstanding construal by the individual genius. Whereas the continuity view of creativity emphasizes the average over time and the discontinuity approach relishes the brilliant outlier, the coincidence point of view works from the assumption that chaos produces creativity as long as every now and then non-random variation emerges from the noise (cf. unpredictable effects). In counting on probability, this line of thought departs from deterministic laws but does not leave determinism behind all together because probability can be estimated and calculated.

5.3.1 *Pure coincidence*

In Lowcre (2013), we took the position that quantum uncertainty dominates the interactions at the sub-atomic level from which the elementary particles result, a process that could be seen as the most rudimentary form of creation. In terms of the Schrödinger equation (a wave function), this type of physical creativity is completely based on chance (Schrödinger, 1926). At the other end of the spectrum, where formations disintegrate, the 2nd law of thermodynamics states that without maintenance, order naturally falls back into its original state of entropy. In human creation, this argument was picked up, for instance, by John Cage, who, in ruminating about his ‘indeterminate music,’ stated that “Chance brings us closer to Nature in her manner of operation” (cited in Lippard, 1999, p. 181). And in quite the same way, Robert Smithson confessed that “On the whole I would say entropy contradicts the usual notion of a mechanistic world view” (Sky, 1973/2010) (Figure 14).



Figure 14. Robert Smithson (1969). Asphalt Rundown

In the arts, Sypher (1962) observed that “During the course of time, entropy increases.” She adds that in most of the literature and arts of the 20th century, the implications of disorder were explored, the loss of structure of artistic systems, sinking back into original chaos (ibid.). Both James Joyce’s *Ulysses* (1922) and T. S.

Eliot's epic poem *The Wasteland* (1922) illustrate the point that after the devastating First World War, "these fragments I have shored against my ruins" (Eliot).

5.3.2 *Mechanized coincidence*

In his treatise of impossible inventions, Basalla (1988/1999, p. 56) mentions Jonathan Swift who introduced Gulliver to a device that could write any book in philosophy, literature, law, mathematics, etc. by turning an array of alphabet blocks with the machine's cranks (Figure 15). The words evolving from rotating the cubes were jotted down and any meaningful phrase that turned up was selected by the author of the new book in the making.



Figure 15. Gulliver's book-writing machine

Surely, Swift was mocking the mechanization of human writing and the role of coincidence in the development of human intellect (Basalla, 1988/1999, p. 56). Little would he have guessed, however, that centuries later this kind of mockery lay at the heart of a new 20th century poetics formulated by the Dada movement, suggesting that original poetry could be made of random samples of newspaper words (see Tzara's recipe in Box 10).

Box 10. To make a Dadaist poem

Tristan Tzara (Figure 16), considered one of the founders of the Dada movement in early 20th century art, made a drastic proposal to let chance determine creativity. In his *To Make a Dadaist Poem*, he wrote the following (Tzara, 1920/1924):

Take a newspaper.
Take some scissors.
Choose from this paper an article the length you want to make your poem.
Cut out the article.
Next carefully cut out each of the words that make up this article and put them all in a bag.
Shake gently.
Next take out each cutting one after the other.
Copy conscientiously in the order in which they left the bag.
The poem will resemble you.
And there you are – an infinitely original author of charming sensibility, even though unappreciated by the vulgar herd.

Figure 16. Tristan Tzara (1896–1963)



Similar ideas gave rise to product innovations later that century such as fridge poetry (Figure 17): A package of magnetic words from which random words can be drawn and stuck onto a metal surface (i.e. a fridge).

Figure 17. Fridge poetry: Coincidence of word choice makes the poem



Currently, Dada inspired a number of poetry generators that randomly change the word order of a paragraph that is put into the system. They output a poem exactly of the form Tzara would have wanted.

In Figure 18, I examined what would be the output of such a system with Tzara's poem on how to make Dadaist poetry as its input. Tzara's poetry and its modern successor occupy an extreme position of allowing chance to the creative process.

5.3.3 Serendipity: The human hunch

Luck is without doubt an important ingredient in creative discoveries (Csíkszentmihályi, 1996, p. 46). In the arts, creativity by coincidence is exemplified by the so-called readymade or *objet trouvé* (i.e. Marcel Duchamp, Tzara). In technology, “*naturfacts*” are found tools such as rocks and sticks that sometimes inspire later

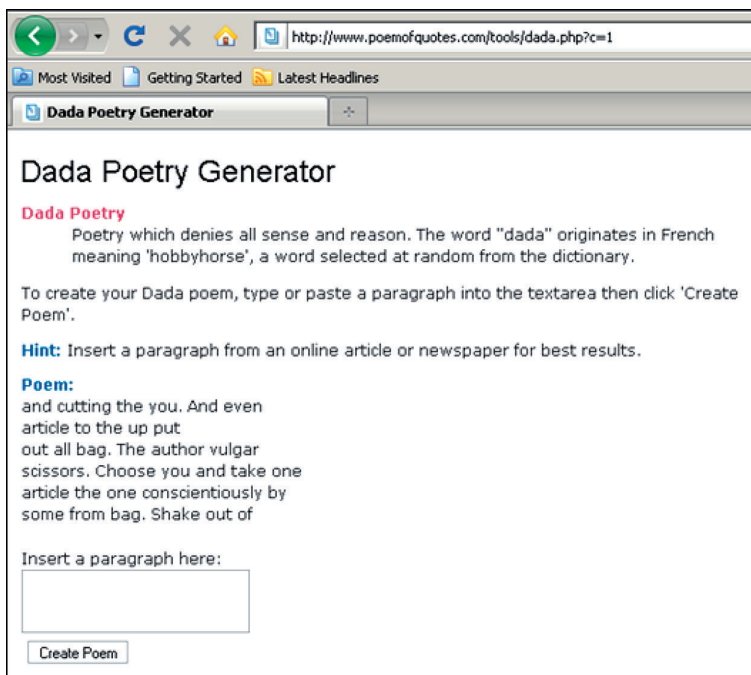


Figure 18. Dada Poetry Generator with Tzara's *To Make a Dadaist Poem* as input. Retrieved Dec. 2, 2010 from <http://www.poemofquotes.com/tools/dada.php?c=1>

inventions (Basalla, 1988/1999, p. 50). Simonton (2009, p. 31) provides a range of famous examples of serendipitous findings through history but argues that those who got lucky worked hard for it. Louis Pasteur (quoted in Cech, 2001, p. 13) asserted that “Chance favors only the prepared mind.” Roberts (1989) contends that the “inquisitive human mind turns accident into discovery.” In other words, although coincidence may qualify the absoluteness of creative originality, discontinuity lines of thought may counter that the luminary anticipates where luck will strike. In such cases, foresight or serendipity is what distinguishes the gifted from the ordinary.

5.3.4 *Mean and variance: Playing with partial determinism*

Whereas a series of replications can be seen as the mean line of evolutionary advance, the smaller or larger variations caused by human or machine deviations can be approached as stochastic variance.

In the wake of Joseph Haydn and Amadeus Mozart who created dice games to make musical compositions (Figure 19), certain 20th century artists made a combination between rigid determinism and random chaos. These people were deliberately seeking the interference of arbitrariness with their systems. So-called aleatory composers discovered the effects of leaving certain elements in a composition open to chance. Those composers left filling out certain parts of their music to the performers (cf. free improvisation) or rolled the dice (hence, “alea”) to decide what would follow. As Meyer-Eppler (1955/1957, p. 55) put it: “a process is said to be aleatoric ... if its course is determined in general but depends on chance in detail.”

The composer and architect Iannis Xenakis (1922–2001), for example, abandoned chromatic serialism but also avoided the pure coincidence that John Cage practiced. He made compositions based on mathematical models such as game theory or Brownian motion of particles but added the atonality of street noise, *glissandi*, or deviant quarter tones. Also the chaotic parts in his music were calculated, rendering so-called stochastic music.

In view of a dice game for making musical compositions, probably everybody can be lucky in finding a number of lines that fit together. Some people, however (e.g., Mozart or Xenakis), will be more fortunate than others because they are better equipped for recognizing original combinations (see previous section).

A literary example is so-called book spine poetry. You take a pile of books and order them such that together the titles on the spines make some poetic sense. Or you just add a few words to let them make sense.⁵ The titles are randomly picked from the shelf but piling up the books one on top of the other is deliberately bringing structure to the chaos of unconnected sentences. This may be done with little

5. <http://www.nataliasylvester.com/wp-content/uploads/2011/09/Books-Poem-N-Sylvester.jpg>



Figure 19. Melody Dicer created by Mozart and implemented by John Chuang (1995). Retrieved Dec. 3, 2010 from <http://sunsite.univie.ac.at/Mozart/dice/>

interference and much coincidence (i.e. blind selection of books and blind stacking) or pseudo-randomly, with much interference and little coincidence (a careful selection of titles in a favored order). Either way, it is a reinterpretation in hindsight of a never-intended combination of textual readymades (cf. Ward, Smith, & Finke, 1999). You may end up with poems like this:⁶

CRASH
 you are here
 Footprints in the Snow
 Say HELLO
 Yum Yum! What Fun!
 JUST TWO MORE BITES!
 THE BEST PICNIC EVER

A computer model that is applied to the fine arts and that explores the variations within a set of rules is AARON created by Harold Cohen. This system is capable of producing museum quality art work (Figure 20), which is enabled but not scripted by the programmer.

Figure 20. Cohen, H. (2003). 0305-03. V&A Museum № E.263-2005

6. <http://blog.susangaylord.com/2013/04/poetry-month-book-title-poem.html>

AARON not only designs the composition of a work but also chooses and applies the colors, which are then printed with pigment inks. As Cohen takes a parental position in dealing with authorship, he insists that the digital print is by AARON, a computer program written by Harold Cohen.

5.3.5 *Fractal recursion*

Benoît Mandelbrot delivered the most profound work in the area of coincidental creativity. From his love for geographical maps and graphic design, he discovered that no matter how someone zooms in or out, the structure of a coast line on a map follows the same self-similar albeit uneven shape. The fractal algorithms he constructed to describe this observation incorporated a scale-independent principle of invariance or statistical self-similarity (Mandelbrot, 2001, p. 196). Fractal algorithms need randomness or non-linearity (that is, ‘deterministic’ chaos), describing self-similarity of a structure with random noise added (Mandelbrot, 2001, p. 201). Fractals describe the “roughness” of shapes (cf. coast lines) or of data patterns (ibid., p. 205). They are line-oriented (ibid., p. 208) and can be used for composition, structure, architecture, organization, and art (Figure 21).

Figure 21. Artificial fractal landscape



Hayles (1989) explains that complex systems are not *completely* random and become chaotic in predictable ways. Hayles (1991), for instance, presents a body of work on metaphor, fiction, and audience reception, in which Newton’s *Philosophiae Naturalis Principia Mathematica*, Ruskin’s memoirs, Victorian serial fiction, and Jorge Luis Borges’s short stories are newly interpreted in terms of chaotic systems that yet have a profound orderly kernel. She and her colleagues use order and disorder even to scrutinize how interpretation itself develops.

So-called “recursive symmetry” in the form of a pattern predicts the unexpected evolutions one observes at the phenomenological level (Hayles, 1991). This recursion is what Hofstadter (2000) called “sameness-in-differentness,” resonating the ancient idea of unity-in-diversity.

6. Classic, Romantic, Chaotic

In the previous (Section 5.1), we saw that an outlook on survival of the group produces a Classicist type of organization of society that guarantees predictability,

taking care of basic survival issues such as food production and mobility for the masses. Romanticism as a counter reaction resonates the spiritual needs of the individual. On the one hand, Romanticism seeks unexpected opportunities and fancies wild ideas; on the other, survival issues yet play a role as the ego wishes to excel, compete, be special, or “iconic,” on the basis of which a privileged position is expected. The “organized chaos” approach capitalizes on chance. It is decoupled from individuals or society as it turns back to the pre-mechanistic creativity of particle physics in which non-human agency (the computerized algorithm) can produce novel conceptualizations and artifacts (i.e. non-linear computational creativity). However, different degrees of determinism and probability are included in the mix, visible in a diversity of expression forms, ranging from aleatoric composition to fractal art.

7. Reconciliation: Serendipity in a partly deterministic system

It is hard to maintain that systems or organizational structures are completely deterministic or absolutely chaotic. We observed creative systems that had a focus on order but could not drive out randomness completely (cf. Sol LeWitt’s seriality). We encountered systems that welcomed as much coincidence as possible without completely getting rid of a systematic (cf. Tzara’s Dada ‘recipe’). We also discussed systems that willingly inserted moments of random variation to explore its effects on strict composition (cf. aleatory music). The focus of these systems may be more deterministic (LeWitt) or probabilistic (Tzara) but this seems to be a gliding scale (cf. aleatory music).

The notion of chaos has undergone changes in meaning such that the categories of order and disorder are not mutually exclusive anymore (see Hayles, 1991). Everywhere we encounter complex patterns that combine structure with diversity (Christian, 2011, p. 505). Christian (1991, p. 237) speaks of “equilibrium systems” that balance order established by creativity with chaos happening through entropy. For complex systems to exist at all, Kauffman (1995, pp. 90–91) envisions an optimum between stability and flexibility “because evolution takes them there.”

Assuming a gliding scale between total determinism and sheer probability is much in line with an approach to truth that has no absolute values (Hoorn, 2012, pp. 42–48). Although an evolutionary line may roughly determine the direction of the next step, standing in a tradition does not mean that someone cannot break with that tradition and simultaneously be an exponent of it (Box 11).

Box 11. Insight sparks from prior optimizations

The Abbey of St. Denis, France, is widely recognized as the gateway to one of the major cultural achievements of the Middle Ages: Gothic style architecture (Figure 22). It was a synthesis of existing architectural elements that sparked this grand tradition of cathedral building (Friedel, 2007, p. 49). Yet, the ‘inventor’ of this style, abbot Suger, did not develop any of the key technical or architectural elements; those had been around for generations. It was the way Suger combined these existing elements which was unprecedented in the history of architecture (*ibid.*).

Small incremental improvements that were developed over many years of religious architecture were synthesized in a new style, opening up possibilities for the “departure from the monumental older heritage.” This flash of insight occurred to only one man, abbot Suger, who had a new requirement on religious buildings, a requirement related to the goal of creating a symbol of divinity, which was to allow more light into the holy place. This requirement put an extraordinary demand on the then available technology and design of large structures. It resulted into major technological innovations such as Gothic arches, the groin vault, and flying buttresses (Friedel, 2007, p. 53). Just to create a symbol.



Figure 22. 13th century nave of St. Denis

Thus, some continuity exists between the breakthrough creation of an individual and the work of earlier contributors. Discovery may happen irrespective of the individual, when someone has all the right pieces of information (*ibid.*, p. 248). Weisberg (1999, p. 226) offers examples of students who without deep knowledge of the domain replicated Nobel price discoveries. This is the near-deterministic aspect of creativity, based on intelligence and reasoning from the givens. In many cases, then, a creation can be assessed as an incremental improvement (‘invention inside the paradigm,’ Savransky, 2000, p. 140) whereas in more rare cases, a disruption occurs (‘breakthrough outside paradigm, and discovery,’ *ibid.*). However, discontinuity does not come out of nothing and is prepared by the continuous line of smaller changes that happened earlier on (cf. Simonton, 2009, p. 141). Smaller creative contributions enhance the output of major creative contributions (*ibid.*, p. 144).

Whereas historic continuity may be envisioned as the mean course of development, variation comes from imperfections or from larger deviations that happen with or without deliberate human agency. Basalla states that even in industrial production processes, exact copies are impossible. There are always slight variations and imperfections. In the made world, variability is the absolute rule (Basalla, 1988/1999, pp. 103–104). Stent also affirms that no two people are the same and none have identical nervous systems. They always produce unique differences even when they replicate things (Stent, 2001, p. 37).

The occurrence of slight variations opens possibilities for individual contributions of a non-deterministic nature, the “spontaneous rule by person” (Shiff, 2003, p. 148–149). Great insight may spark from a continuous line of earlier optimizations (Box 11) where originality is in the unexpected combinations (Chapter 4).

Perhaps we should compare the creative process to a game of chess. In principle, a brute-force system like Deep Blue would know how to make every move that is logically expected in each game that can be played. Given enough capacity to handle combinatory explosion, Deep Blue can calculate in advance all possible chess games that can be played because chess installs a deterministic universe with all rules, situations, and procedures in place. It could also replicate these games time and again without having to know the past games. However, if you bring in the human factor (e.g., anxiety, originality) (cf. Avni, 2001), random variation introduces the unpredictable element and makes chess a game of serendipity-sensitive systematics, deterministic chaos, or orderly disorder (Cox, 2002). Garry Kasparov was able to defeat Deep Blue only because he produced phony strategies and created decoys that made no sense in positional play (Hsu, 2002).

Coincidence in the sense of errors, imperfections, individual differences, or lucky findings introduces variance to the mean line of replications or copies. This is the probabilistic aspect of creativity. In the case of industrial manufacturing, the variance may be small; in the case of breakthrough ideas, the variance is large and forms the impetus to commence a new line of more-or-less deviant replications. This does not mean, however, that the old line completely disappears (cf. K. Kelly, 2010, pp. 50–51). The revolutionary paintings of the 20th century did not prevent certain contemporary artists from painting still lives in the style of the 17th century; perhaps not original but extremely skilled (e.g., Henk Helmantel, Figure 23).



Figure 23. Road to Bhutan. Helmantel (2008)

Incremental change is achieved by the adaptation of a feature that was already part of the work. Disruptive change means that the feature was not contained by the work and that the connection between features was made by association. Incremental change is analytic *a priori* (cf. Miller, 2000, p. 188): The current state contains in potential all future states. Disruptive change is synthetic *a posteriori*. Perceivers record the unexpected in hindsight, through experience. Insight of the creator, then, may perhaps be seen as being synthetic *a priori*?

In a creative mode, the mind may be better equipped to allow (self-generated) chaos, handle randomness, and to sense and monitor the relevant parts. It knows how to orchestrate chaos. It has the ability to organize erratic associations such

that a desired effect or outcome is achieved. Coincidence in the natural world (“physical creativity”) would be sheer luck and selection would be a function of the world surrounding it. In creative humans, however, serendipity or luck would be guided by having a different goal-orientation than other observers, which is followed by a selection and evaluation process that relates the new finding to the continuity principle.

Derived from deterministic rules, creativity seems to be a reciprocal system that hoards moments of coincidence and orchestrated variance ingested from the probabilistic universe. The deterministic aspects produce the average of nearly self-similar replications whereas the probability of random choices produces the variance that leads to novel behaviors. If you take out the randomness, the system becomes deterministic (i.e. mathematical); else it becomes probabilistic (cf. empirical). Serendipity in a partly deterministic system explains the state of orderly disorder that creative systems are in as well as the continuity of change.

8. Creativity on three scales

If creativity produces self-similar entities that are determined in general but turn out to be “aleatoric” in detail (Meyer-Eppler, 1955/1957, p. 55; also K. Kelly, 2010, p. 127), it seems that we have to approach creativity at more levels of data aggregation. At the micro level, coincidence is supreme (the ‘quantum state of creativity’). Differences in size, color, and forms lead to the finding of *naturfacts* and *objets trouvés*. Cutting out words from a newspaper and randomly reordering them stimulates the formulation of an original poetic line. Looking at the changing formations of clouds inspires the molding of a new clay sculpture. While dreaming, coincidental associations that are not repressed by the brain’s regulatory or control systems lead to novel metaphors or scientific analogies.

At the meso level, certain individuals are better equipped to recognize the lucky coincidence than others. These people disrupt known practices because they pre-sense, have foresight, or provoke serendipity. Once they hit luck, they elaborate on the new insight and select properties, evaluate consequences, etc. to optimize the idea or to make the new finding acceptable. In cases of incremental improvements (cf. handicrafts), the creativity may be assessed as ‘small;’ in cases of discontinuity (cf. a revolutionary masterpiece), the creativity may be evaluated as ‘big.’

At the macro level, the creative achievements together produce an evolutionary line (i.e. the average) of bigger or smaller incremental steps. This is the ‘mechanistic state of creativity.’ The occasional breakthrough by an individual or small group of individuals who had an “insight” (i.e. the outliers) starts a new

evolutionary line, which can co-exist, shows remnants of the old (e.g., skeuomorphisms), merges with other developments, and perhaps later crosses-over with the origins again. The evolution of the masses emerges from chaos, is disrupted by some, and becomes chaos again from which evolution emerges.

8.1 The breakdown of determinism or why Rutherford was wrong

Organisms prefer a deterministic world in which predictability increases chances for survival. A Classic Newtonian view on nature is most suited to that purpose because the universe can be known from the early beginning on and all of its results and manifestations can be forecasted:

... it's unphilosophical to seek for any other Origin of the World, or to pretend that it might arise out of a Chaos by the mere Laws of Nature; though being once form'd, it may continue by those Laws for many Ages. For while Comets move in very excentrick Orbs in all manner of Positions, blind Fate could never make all the Planets move one and the same way in Orbs concentrick, some inconsiderable Irregularities excepted, which may have risen from the mutual Actions of Comets and Planets upon one another, and which will be apt to increase, till this System wants a Reformation. (Newton, 1730/2010, p. 204)

However, modern approaches to particle physics tell differently. With increasing complexity or underspecification of a problem (Poincaré), the laws of classical mechanics do not hold. With decreasing specification, increasing creativity is required so that order “might arise out of a Chaos.” A sub-atomic particle is not interested in self-maintenance, primacy, or survival like an organism is. It is energy assuming different forms. Chaos, or entropy, is just a state in which energy may be. It does not strive for anything in a particular sense. It merely is. And undergoes change as is. The quantum jump during DNA mutation (Schrödinger's, 1944/2010, pp. 33–35) is a disruption happening when “this System wants a Reformation.”

The atom physicist Ernest Rutherford once stated that if you need statistics, you did the wrong experiment. A fun aphorism, but it basically presumes that nature works according to regularity and law. Poincaré and Duhem, on the other hand, avowed that, regardless of the data we sample, it is impossible from an epistemic position to decide between competing theories explaining those data. If we were to verify the intertwining of space and time, for example, we should be capable of travelling faster than the speed of light (e.g., Glymour, 1977). Underdetermination may also be temporary. But for that time, which may be indeed very long, people live in a probabilistic universe with an epistemic vacuum that is not solved by logics or reason but rather by pragmatism.

Determinism is an *idée fixe* when interpreted in an absolute sense. Even if perfect order happens, it is a coincidental and temporary event (cf. the rule of

rules, Chapter 1, Section 13). Natural laws are to some extent inaccurate (Schrödinger, 1944/2010, p. 17). Empirically, we may work from the assumption of an almost deterministic problem space of which two-valued logics and classical mathematics are a proxy in a Platonic sense (Hoorn, 2012, p. 20, p. 152). There may be gradations of probability that approach but never reach a deterministic resolution. Schrödinger (1944/2010, p. 10) explains that physical laws depend on particle statistics (cf. Brownian motion) and are thus appropriations: They are statistico-deterministic (ibid., p. 86). Things may be extremely probable but never ‘true;’ they may be extremely improbable but never ‘false’ (cf. Hoorn, 2012, p. 43).

Humans then may try to automate a system and that system surely can deal with most cases. But not with the small percentage of exceptions. As Basalla (1988/1999, pp. 103–104) explains, exact copies are impossible in the human-made world. There are always deviations. Optimization, incremental improvement, and replication may lie within the ordered system but even then there are chances for more dramatic creativity: One can always escape from a system through error.

My proposal would be to speak of a probabilistic universe that becomes more deterministic when problems become better defined but determinism never occurs in an absolute sense. Determinism is imperfect or if momentarily there, it can be degraded. If Platonic or Newtonian truth existed we could not be creative: It would downplay all options in favor of just one.

Error, loss of control, if Newton’s “inconsiderable Irregularities” happen once in a countless number of times, the system is susceptible to “blind Fate;” to chance, albeit infinitesimal. Pragmatically, systems may be approached deterministically. However, to approach a system deterministically is only possible mentally, in the form of mathematics, which is a search for introspectively satisfying structures (cf. Mandelbrot, 2001, p. 191). It is a Platonic ideal, that cannot be and is never demonstrated empirically and that probably does not exist in the physical world, which can always be approached stochastically even in near-deterministic cases. The numerator (the once in a while) of the ratio between incidence (signal) and all other cases (noise) is the slider that goes from ‘very very close to determinism’ to ‘mere chance.’ In other words, God does gamble although not always with enthusiasm.

If God does not gamble, Rutherford should prove that something irregular to a system occurs zero times in an infinite number of cases to decide that deterministic systems empirically exist at all. Until now, it has been far easier to demonstrate exceptions to any given rule than to show that the rule sticks without exceptions. Deterministic systems cannot deal with a joke about erroneous errors (Figure 24). They perhaps can deal with false alarms but not if these are mockingly made on purpose because such jokes confirm the system’s steady state while the joke itself rebels against it. As soon as creativity transpires, systems cannot have been in a fully deterministic state.

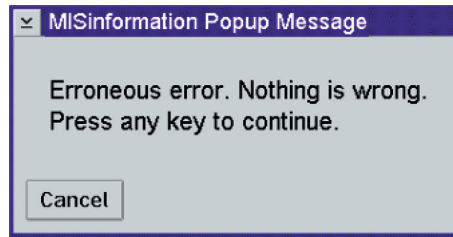


Figure 24. Misinformation popup message

8.2 The law of ‘anything can happen’ or why Rutherford is sometimes right

When elements degrade to plasma or are in a state of entropy, there is no use in looking for a natural law. The absence of regularity is what defines that state. Anything can happen under such circumstances; it is just a matter of chance. Because variability of behavior increases at smaller scales (e.g., Brownian motion of a particle, a neuron firing at random), the applicability of rules and natural laws decreases as it increases when the number of elements that flock together grows (e.g., a planet, an organism, a colony of organisms). Nevertheless, if what occurs in chaos really is completely random then there will be a chance that at one moment in time perfect alignment occurs. Thus, sometimes perfect order emerges from chaos and at that exceptional moment, Rutherford is right. Due to the possibility that order can emerge from chaos, we should not only speak of near-determinism but also of near-probabilism.

However, elements that together form a structure seem to converge in their behaviors. A particle in isolation may behave in many different ways and may become part of many different molecules. Once it is part of a certain molecule, the number of behaviors it can conduct is constrained by the other elements it constitutes a structure with. Molecules of the same kind that interact together also show more coherent behaviors than one of these molecules floating around freely. We could mockingly call this the ‘group think of matter.’ At larger scales of data aggregation, behaviors approach near-determinism in which cases Rutherford is nearly right.

For humans, the same principle applies. Humans in isolation show more divergent behaviors than in a social group. Group pressure unifies behaviors. Larger organizations show more inertia. Therefore, the segregated individual who is exposed to the highest diversity of inputs has the highest chances of doing a creative invention. The masses that do not tolerate deviation hardly have a chance at creativity. Due to their bigger size, they rely on order, rule, and regulation. Co-creation, then, should be a joint effort of highly independent but extremely tolerant individuals.

Problem solving

“Anyone who is technically proficient can solve a problem that is already formulated; but it takes true originality to formulate a problem in the first place.”
(Einstein & Infeld, 1938)

Intelligence is nature’s answer to the logical and inference type of problems. Intelligence complies with the rules, and is perfectly fit for survival issues of a deterministic character. Within a certain set of premises, one evolves through reasoning from current state to a desired state of a given situation. Creativity, however, deals with problems that are so underdetermined and ill-defined, that reasoning falters, rules should be changed, and risky opportunities are explored. Creativity explores highly probabilistic and chaotic settings through disruptive association rather than reason. In the classical sense, problem solving is a goal-oriented activity and requires a set of strategies and procedures applied in a certain order. It involves cognitive processes to reach a preset goal. The overall goal that is to be achieved should be cut down to smaller sub-goals. Different strategies can be applied such as difference reduction, means-end analysis, or backward and forward reasoning. These strategies are all analytical and rule-based and can hardly deal with so-called ‘wicked problems,’ which are greatly underdetermined complexes of interacting problems that have no right or wrong answer. Such dilemmas or challenges need to be approached differently. They require intuition, empathy, and creativity, focusing less on specific goals. Which approach is chosen depends on whether a problem is well-defined or not. Because problems may have more answers, decisions should be made about the sort of solutions one wants. To do so, various contextual variables should be taken into account, for which many decision support-systems exist. Which system applies best to a problem depends on problem type (ill vs. well-defined), decision type (structured vs. unstructured), and underlying decision model (deterministic vs. probabilistic).

1. The two ways

The current chapter shows how creativity can be regarded a special case of problem solving, which traditionally is focused on analytic and intelligent approaches. Both creativity and intelligence can lead to innovations but the first tends to be disruptive whereas the second is more evolutionary. The current chapter examines

the merits and drawbacks of both so that problem solvers have a better idea when to apply what strategy.

Problem solving is an area that studies the heuristics, strategies, means, and methods by which humans work out questions as well as the cognitive-affective processes involved in that. Problem solving and, subsequently, decision making are traditionally seen as goal-driven activities (cf. Eysenck, 2001, p. 315): People wish to achieve a desired situation that is not easily established. Choices are made from a finite set of options to arrive at the desired goal state and such decisions are regulated by someone's beliefs and desires (Peterson, 2009, p. 4). This may range from everyday questions such as where to park the car as to the artist who wonders how to express herself on the canvas.

Certain types of problems demand certain problem-solving strategies (Figure 1). Analytical problems typically ask for rule-based strategies (cf. Newell, & Simon, 1972) such as goal decomposition, distance reduction, means-end analysis, and reasoning backward from the goal. Less precise problems ask for associative strategies such as brainstorm sessions, empathic listening (e.g., Davidson & Wood, 2004), and creative problem solving (e.g., Hargadon, & Bechky, 2006). Analogical reasoning is somewhere between rule-based reasoning and association.

2. Problems are not problematic

Let me upfront address an issue of idiom and wording. Use of the word 'problem' might evoke negative connotations such as 'problematic,' 'hurdle,' and 'full of difficulty.' In the scientific literature, 'problem' is meant in a neutral way of a situation that is desired but not immediately accomplished (e.g., getting food when hungry).

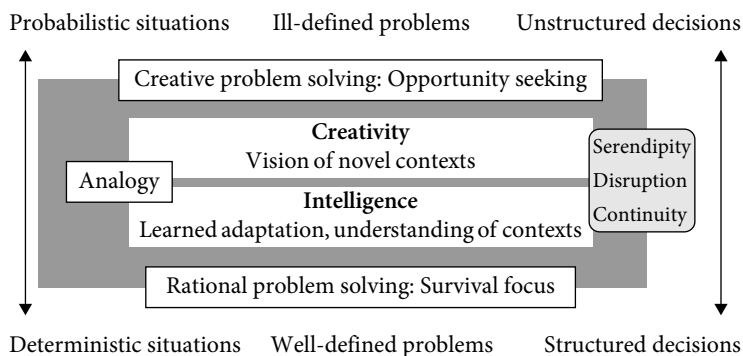


Figure 1. Two types of problem solving contextualized

In that sense, artists solve problems as well, for example, to ban subjectivity from conceptual art (cf. LeWitt, 1967). Problems become a challenge when they cannot be solved by logic and reasoning, for instance, when certain premises are missing or when many variables are unknown (e.g., how to adapt to climate change). When probability has the upper hand, creativity enters the stage (Figure 1).

For creative people, complex problems or challenges are “sources of inspiration” (Csikszentmihályi, 1996, p. 83). Challenges may arrive from personal experience so to reconcile two opposites (ibid., p. 84). It may come from requirements of the domain, for example, to rebel against the *status quo* or state-of-the-art of a discipline (ibid., p. 87). Challenges may stem from social pressure such as war (ibid., p. 94). For creative people, complex problems are the impetus to the creative process (ibid., p. 95); their dissatisfaction with the here and now leads to experimentation (Friedel, 2007, p. 4). Creative people tend to assimilate information such that they can change the cultural and knowledge domains they work in (Csikszentmihályi, 1996, p. 28).

3. Commonalities

Human existence is largely based on the skill to overcome difficulties by thinking over alternative solutions. Problems may be small (e.g., how to turn on the light), they may be theoretical (e.g., algebraic proofs), practical (e.g., work planning), or religious (e.g., abbot Suger creating a symbol of light – Chapter 2). In all these cases, being confronted with a problem supposes that a goal is set but that the way towards it is obstructed or not immediately accessible. Well-defined problems explicitly specify the goal, whereas ill-defined problems do so implicitly or not at all. In rational and creative problem solving alike, one should perceptually recognize the problem, represent it in working memory, and retrieve relevant information from long term memory. Thinking out the tactics, techniques, and methods to reach the desired object or state is the core of problem solving and applies to almost every aspect of the human condition, including arts, science, technology, governance, and business.

Figure 2 shows a functional outline of human memory in solving problems, whether rationally or creatively. All problems have a so-called problem space, composed of the short, middle, and long term goal states of the problem and the knowledge required at each of these steps. Long term memory provides working memory with knowledge of the various heuristics, strategies, practicalities, and procedures that can be applied to solving a problem. Working memory feeds back information of the problem space to select the proper operation, after which a decision should bring the current state closer to the goal state.

The aim of solving a problem is to make the current state (i.e. the undesired situation) more similar to the goal state (i.e. the desired situation). In other words,

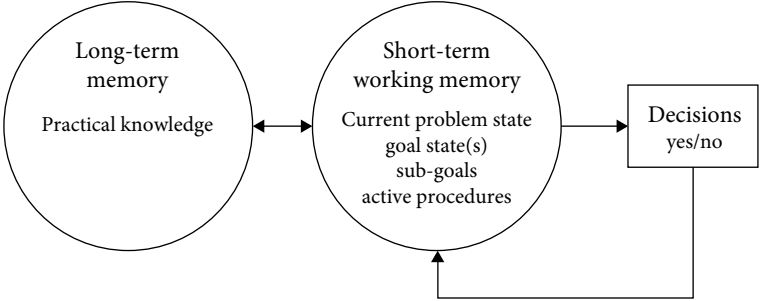


Figure 2. Memory activity in problem solving and decision making

certain aspects in the current situation should be changed or transformed (deleted, added, altered) so that it looks more like the ideal future state. A future state can be vaguely defined or very precisely (e.g., a wish list or requirements document) but in both cases, priorities come to the fore, designating what must be solved, should be, could be, won't be (because it is undoable), and *should not* be solved (because it is fine as is).

Translated into a set theoretical account (Figure 3), the current problem state (*set X*) should change features such that more features of the goal state (*set Y*)

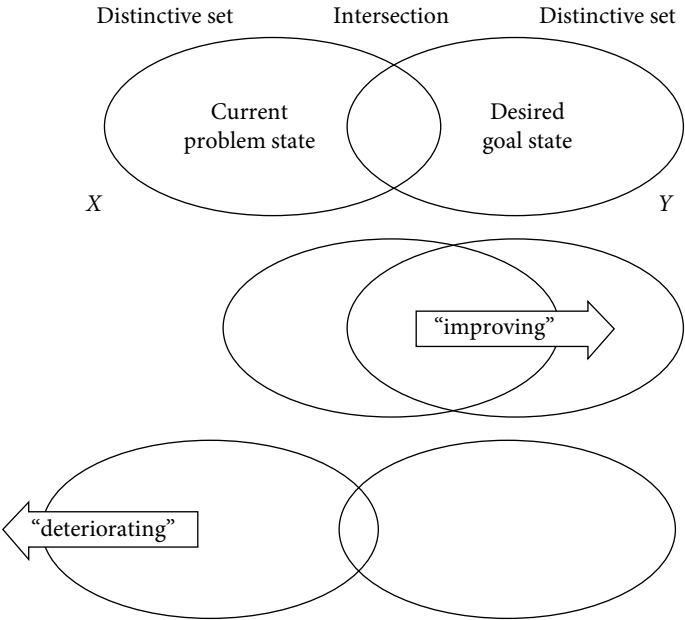


Figure 3. Solving a problem: X should change so to overlap Y

become part of the intersection, which will count as an improvement. Reversely, if features of the current situation are changed such that the intersection with the desired situation shrinks (and hence, the distinctive sets grow), this may count as a deterioration (Figure 3) (also Gruber & Wallace, 1999, p. 95). Additionally, if features of the future goal state (Y) are altered such that the intersection grows, this may be regarded as ‘being realistic,’ ‘making it feasible,’ or from a downside point of view, ‘corrupting the vision.’ If features of the future goal state are altered such that the intersection shrinks, people may judge that the ideal is unrealistic and ‘building castles in the air.’ Thus, certain features may or may not intersect between both states whereas others are distinct. The goal in problem solving is to increase the intersection at the cost of the distinctive sets by altering features of X.

4. Convergent and divergent thinking

Csikszentmihályi (1996, p. 60) explains that a problem can be approached via convergence or divergence. *Convergent* thinking is related to rationality and involves well-defined problems that have one correct answer: Conclusions follow from the premises. In Figure 4, convergent thinking is associated with intelligence and incremental solutions that add to the continuous evolution of a situation or artifact.

Divergent thinking draws in unusual perspectives, which may be conflicting or might seem irrelevant at first. Divergence leads to solutions that are not necessarily agreed upon. It involves the flexibility to change perspectives and the production of a great number of ideas (“fluency” or “ideation”). The originality of the unusual associations and combinations of ideas is what we habitually call “creative.” For an overview of the concept of divergence in relation to creativity and ideation, see Runco (2010).

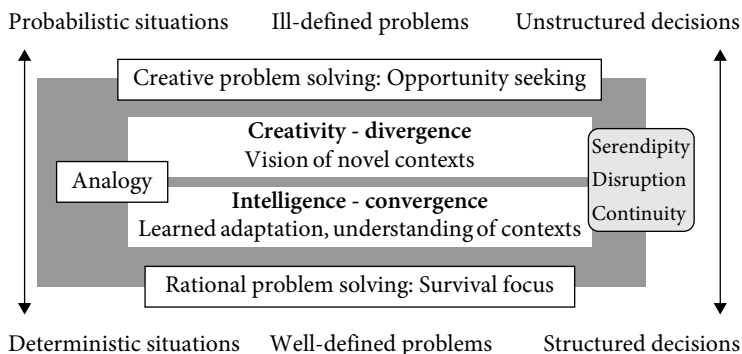


Figure 4. Convergent intelligence and divergent creativity

4.1 Conventional computing systems are “convergent”

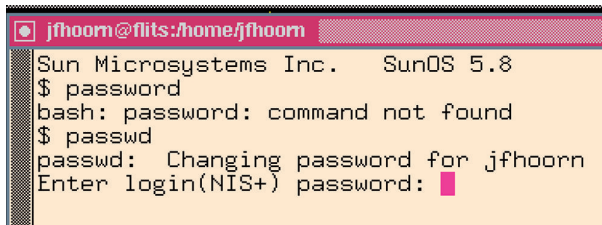
In well-defined problem spaces, what to find, the information you need, and how to do it are perfectly clear (Eysenck, 2001, p. 316). In the sentence “The boy are mad” a strict grammatical rule of subject-verb agreement is violated. My word processing software just underlined the mistake and offered two alternatives: If the subject is singular, then take a singular verb (‘boy is’); if the subject is plural take a plural verb (‘boys are’). Selection of the right option immediately resolves the trouble.

Ill-defined problems, however, are much harder to tackle. You do not know what to find, you do not know what operations are allowed, and you do not know what the end state is supposed to be (Eysenck, 2001, p. 316). Try to make sense of Carroll’s (1872) Jabberwocky talk: ‘Twas brillig, and the slithy toves did gyre and gimble in the wabe. The syntax is correct but there is no one correct answer to what this sentence conveys or how to go about the construal of its meaning.

People are better at solving ill-defined problems than conventional computer systems. This has to do with the difference between rule-orientation of computers and content-orientation of humans. A computer needs literal instruction. The screenshot in Figure 5 shows that although <password> is unambiguous language, the Unix shell can only interpret the strange abbreviation <passwd> as input whereas it replies with <password>. For conventional systems, what was taught should be repeated irrespective of its contents. The software does not interpret commands beyond the already known (Figure 5).

4.2 Humans can do both

Humans can be logical *and* make associative jumps. In daily life, purely logical problems occur less frequently than messy ones. Therefore, the associative style is employed more often. Humans get the gist of a message and assume its goal if it is not explicitly stated. They are more tolerant to deviations from the rule and repair



```

jfhoorn@flits:/home/jfhoorn
Sun Microsystems Inc. SunOS 5.8
$ password
bash: password: command not found
$ passwd
passwd: Changing password for jfhoorn
Enter login(NIS+) password:
  
```

Figure 5. Conversation with a Unix shell

what is inconsistent or what is unexpected. In Figure 6, the phonemes of the secretary with a cold are degraded but you probably have not much trouble reading her lines out loud in proper English.

Figure 6. The flu deciphering function of humans is superior to that of software systems. Parisi, M. (2000). Voice Dictation Cartoon # 2000-03-31



Unconventional computer systems that make use of artificial intelligence, fuzzy algorithms, or semantic search may do something that resembles human activity. Those systems can deal with, for example, different handwritings. However, the range of variation they cover is still small compared to us. Computers still have a hard time to translate speech to text, for example.

For computers, grammar is crucial, whereas for humans, semantics dominates grammar. Human interpretation prefers contents to rules. Additionally, human interpretation of a problem takes the context into account. Computers need a correct, prescriptive, and law-like grammar; for humans, grammar is a pragmatic guideline and subordinate to semantics. A computer is capable of context-free interpretation but a human hardly is. That makes the computer fit for the reasoning type of problem solving, which is focused on absolute differences and exactness. Humans perform context-sensitive interpretation (socially, semantically) and have a focus on fuzzy similarities. That provides more adaptability to changing situations and it makes humans fit for the more associative and creative styles of problem solving. Making computers that emulate humans in this respect may be possible but is still a heroic endeavor (also see Section 5.5).

5. Rational problem solving

Western culture prefers to solve problems rationally, even in underdetermined cases. The word ‘logical’ is often used rhetorically in this respect whereas it merely indicates that a particular option is the first thing one thought about or is conventionally the most acceptable. It is ‘logical’ that drunk driving leads to accidents, although the effect is merely highly probable and not a guaranteed consequence of the cause.

5.1 Breaking down the problem

In the West, the most common way to tackle ill-defined problems is to cut it into smaller problems that can be clearly specified (see Chapter 2, Section 5.1.1).



Computing Services

Mission Statement

To create an online community, like no other, encompassing every facet of every municipality in the United States; to aid in online economic revitalization in partnership with local businesses and local, state and national government agencies; to publish, maintain and connect a network of community websites designed to entertain, educate and enlighten the residents of our great nation, while maintaining the highest standards of personal morals, business ethics and web etiquette.



A+ BBB Rating
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Figure 7. Mission statements have ill-defined problem spaces. Targets have well-defined problem spaces. Retrieved Oct. 22, 2010 from <http://www.a2zcomputing.com/mission.html>

Businesses and organizations try to be a kind of problem-solving machines for that matter. For instance, A2Z Computing Services avow in their mission statement that they want “to create an online community that covers every aspect of every US town” (Figure 7). The business mission is the general purpose and nature of the business. It articulates the highest and most vague goals it is striving for. Obviously, the A2Z mission is not accomplished overnight. To reach it, goals are decomposed into several smaller so-called business goals, which are medium to long term results to be achieved by the business. A2Z sees as business goals, for example, to support local e-commerce, to host community websites, and to maintain high moral standards in doing so. Again, business goals also are not achieved easily. An even smaller subdivision is needed to supply the workforce with goals that are easier met and, thus, raise more manageable problems. A business objective or target, then, is a measurable formulation of a goal. For A2Z it might be an increase of the percentage of participating municipalities from 20% to 45% within 36 months.

The A2Z example illustrates the strategy of *goal decomposition* (Newell & Simon, 1972) and is the most frequently employed approach to solving complex questions. It comes down to setting many easier-to-reach sub-goals that together support the one complex goal to arrive at. Consequently, cracking the smaller sub-problems contributes to solving the big puzzle of, in the case of A2Z, creating

a community of US towns. Goal decomposition is done to change an ill-defined problem into a well-defined one. Of course, goal decomposition can go on to extremely fine-grained levels. How far you go in decomposing goals depends on the extent (resolution) to which you want to achieve the goal state: by and large or exactly?

5.2 Forward and backward reasoning

In a deterministic universe, the Classic problem solver reasons forward and backward to predict all possible states an entity was in or can be in. Forward and backward reasoning require well-defined problems with explicit formal limitations. *Forward reasoning* is a logical operation that makes use of inference rules and predicts the future of a problem state. The traditional *modus ponens* is a good example:

If a design is patented, the law protects it against copying.
The Statue of Liberty is a patented design.
Therefore, the law forbids copying it.

Forward reasoning presumes that a general rule is known that applies to many if not all cases. *Backward reasoning*, however, attempts to single out one particular cause, fact, or rule that explains a manifold of specific events. In reasoning backwards, the solver knows what the goal state should be (e.g., a bug-free program, Box 1) and tries to eliminate the symptoms of error one by one by inferring their cause.

Box 1. Bug tracing

In the 14th century, the Welsh word “bwg” for “elf” meant “an object of dread” (Concise Oxford Dictionary of English Etymology). Thomas Edison used the word “bug” to indicate a design defect. Yet, U.S. Navy Admiral Grace Murray Hopper (1906–1992) was credited with coining the term “bug” in reference to a glitch in a computer system (Figure 8a,b). Hopper was a pioneer in computer technology. During World War II, she worked at the C. W. Post Center of Long Island University on the Mark II Aiken Relay Calculator, the forerunner of modern computers. “Things were going badly; there was something wrong in one of the circuits of the long glass-enclosed computer,” she said. “Finally, someone located the trouble spot and, using ordinary tweezers, removed the problem, a two-inch moth. From then on, when anything went wrong with a computer, we said it had bugs in it.” Although Hopper is not the inventor of the term “bug” for a technical error, in the mid-1950s, she extended the meaning of the term “debug” to include removing programming errors. The moth that was removed between points at Relay # 70, Panel F, of the Mark II was pasted into a logbook, now in the collection of Smithsonian MoAH.

Figure 8. Grace Hopper (a) and the bug she made famous (b)



In the analysis of chess games, backward reasoning is often applied to point out what went wrong during a game. You can find it by looking for the well-known phrase “he should have played:”

Topalov prepares the activation of his bishop through g6, in order to give even more force to his attack. In doing so, he might have missed White’s next move (since 37.Rxg6 should be just too natural for him). Before weakening the seventh rank, he should have played 35...Rb1 when the queen would have been forced to abandon the seventh rank, in order to maintain the g2-square under observation. After that, Black could have safely played 36...f6, or, in some cases, even 36...f5 as, for instance, after 36.Qe4+ , in order to play ...g5 next. (Commentary on Levon Aronian vs. Veselin Topalov at the 2010 Linares Chess Tournament. Retrieved Oct. 21, 2010 from <http://www.chessbase.com/newsdetail.asp?newsid=2936>)

In the example above, the chess analyst has full knowledge of the current problem state (e.g., the possibility that Topalov misses White’s next move), knows the goal state (i.e. a safer attack), and knows that proper procedures exist to find the solution (i.e. “...he should have played 35...Rb1”).

The combination of forward and backward reasoning leads to solutions that are systematic, repeatable, and controllable. With forward reasoning, one can do *hypothesis testing*. Through *trial-and-error*, theoretical assumptions are put to the test. Through *formal modeling* and *abstraction*, the logical consistency of a hypothetical solution can be verified (cf. Zimmermann, 2010); through empirical research, the ecological validity or applicability of a solution is validated (e.g., Hinkelmann & Kempthorne, 2008).

Figure 9 offers an example of abstraction and backward reasoning. The question is how many blocks were used to build the construction? Probably you start counting the blocks in the rows and columns, and reason back how many blocks there are in abstraction but not visible. Most likely, your answer is 43; a precise, controllable, and repeatable solution.

Backward reasoning from a multitude of existing data may lead to *problem transformation*, where the ill-defined problem in one domain is redefined in terms of another domain for which solutions exist (also see Section 6). *Root-cause analysis* is typically found in solving technological problems (cf. Box 1). By systematically switching circuits or sub-systems on or off, the cause of the problem is detected and then eliminated.

Forward and backward reasoning are fit for standardization of problem-solving procedures, for instance, to withdraw cash from an automated teller machine. To avoid the repetition of design errors, software engineers and system designers collect their experiences in so-called pattern frameworks, which provide standardized solutions to regularly occurring design problems (e.g., Borchers, 2001).

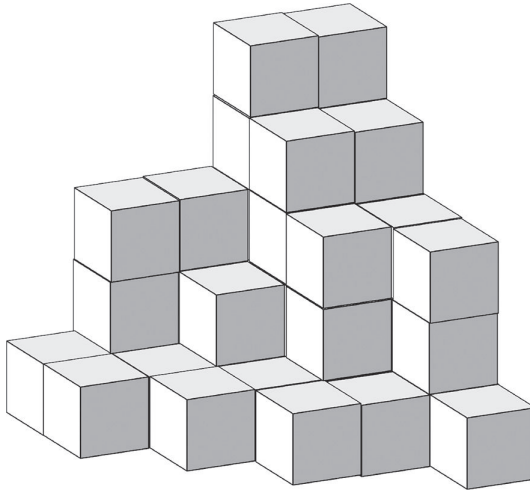


Figure 9. How many blocks in this construction?

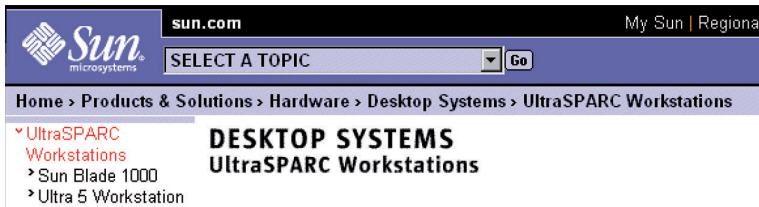


Figure 10. Breadcrumb trail on the Sun web page

In web design, the use of ‘breadcrumb trails’ is an example (see Figure 10). It is a piece of standardized code that allows users to go to next, previous, backwards, cancel, or to jump to the end.

The breadcrumb trail on the Sun web page (Figure 10) is an example of a standardized solution to the problem of quickly finding your way in a large hierarchical structure (more than three levels deep) – forward and backward. A breadcrumb trail makes the structure explicit and allows the user to jump back and forth:¹

Home > NextLevel > NextLevel > **Current page**

The sub-goal structure in programming breadcrumb functionality should look like (courtesy Martijn van Welie):

1. <http://www.welie.com/patterns/crumbs.html>

link(home) > link(parent(parent(current))) > link(parent(current)) > current

Creative problem solving is the flipside of applying design patterns. Creativity becomes useful when standard solutions fail.

5.3 Difference reduction

One of the simplest forms of a reasoning strategy is the *reduction of differences* between the undesired current state and the desired goal state. Difference reduction is a strategy in which each sub-goal that is achieved brings the current problem state closer to the goal state. If someone is thirsty, each action that is performed (get glass, get bottle, pour water, move glass to mouth) brings the current situation closer to the desired situation. Difference reduction is an easy strategy and often applied. It is, however, not necessarily the best strategy (Box 2).² Difference reduction is often instilled by a desire of immediate goal satisfaction (a childish ego-problem, the therapist would say).

5.4 Means-end analysis

A cleverer way to reduce differences between current problem and goal state is a strategy called *means-end analysis* (Newell & Simon, 1959, 1961). The current problem state is compared to the goal state to find the most important difference. Reducing that difference then becomes the main sub-goal (cf. prioritization of requirements). If something comes in the way of achieving that sub-goal, removing this barrier becomes the new sub-goal and receives the highest priority. It may be that solving such new sub-goals temporarily lead away from the desired end state. However, if you do not solve them, it may be that the obstruction will never allow you to solve the overall problem at all. Box 3 provides an example where means-end analysis is the way to go and Box 4 shows an example of where its limitations lie.

5.5 Problem complexity

The artist of Box 4 sought the most efficient path to collect his materials, deliver them at his studio, and then return to fetch the kids. One way to solve the puzzle is to walk every route possible and count the yards. Computer scientists do not want to do that; they want to calculate how difficult it is to find the solution.

2. All problems mentioned in this chapter are fictitious and do not relate to existing companies.

Box 2. The back-office-girl problem

Phil is put on a job at the Doyle Commercial Bank. They want a front-office (FO) application called Moneta that can direct currency streams to a back-office (BO) system. In the requirements document, Phil reads that files should make use of standard formats and layout, re-use of existing functionality and technology, and that he has minimal development time. After two days, Phil tests the system and sees that files arriving at the BO do not have the proper and agreed-upon format. One way or the other, the mid-office (MO) transforms the files to another layout. The project timeline forces Phil to come up with a quick fix. Because the work at the FO and MO has already been done, the critical time path is with the BO. These turn out to be nice people and one of the girls is very helpful in creating a new design that can bring the wrong format back into shape. Phil is happy, the BO is happy, but the client is not. It turns out that less functionality can be re-used and that development time is way beyond deadline. The bank's application manager of Moneta cannot understand that the BO is not ready yet. "Everything was clear from the start, wasn't it?" he says. Phil gets fired but marries the BO girl.



Many questions arise here. What was the strategy Phil applied and why was it devastating? What was wrong with Phil's analysis of the current problem state? With respect to goal prioritization, what was the role of the time pressure in this project? Phil thought that the time path of the BO was critical and this forced him to apply difference reduction by accepting the quick fix the BO girl offered him. Phil wanted to achieve the desired goal state as fast as possible and did not allow any detours. He got rid of the symptom (troubleshooting) but did not address the structure (problem solving). Who was the problem owner here? It was not the BO but they got themselves into trouble by proposing a difference reduction solution (i.e. the extra design that reformatted the corrupted files). Phil should have turned to the MO and fix the file corruption. That would have taken more time but the BO solution also passed the deadline. More importantly, however, less functionality could be re-used with the BO file-format fix (which will cost time and money in the future). The mix-up in prioritization of goals was that short-term time efficiency was more important than long-term effectiveness.

Box 3. Unique plug-ins

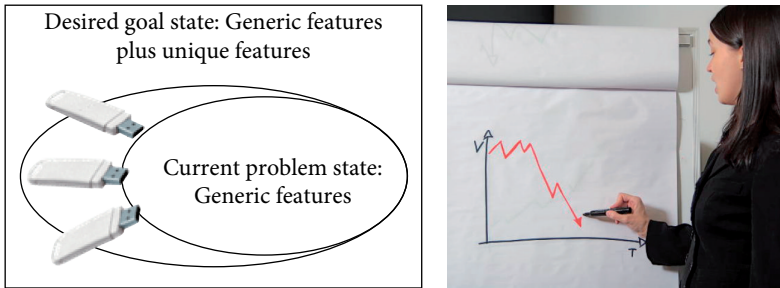


Figure 11. Current and desired goal states can be represented as Venn diagrams, the overlap of which illustrates how much ‘difference’ is yet to be reduced

Caren is a business analyst and she is put to work at StarDex, a company that takes care of the back-office systems of three clients: Sinecure Soft, DeterMining, and BetaSlam Inc. StarDex wants to offer these services in a generic way. However, Caren notices soon that due to the generic approach, all the functionality that is client-specific is lost. The clients do not like this and wave with their contracts but StarDex does not want to spend money on unique features because their business case is to offer a generic solution that can be sold repeatedly. How to satisfy the clients without raising costs for StarDex? Would Caren solve the problem through difference reduction? What about means-end analysis?

Caren’s situation is that the current goal state is included in the desired goal state. The generic features form a shared set with all the features the clients expect (Figure 11). Caren decides to advise the following. She says that the unique features in the distinctive set should be separate plug-in applications that feed into the generic system. She then advises StarDex to adapt the business case and to break down the main service into smaller parts that can be separately sold (a cover-up for higher pricing). For every next client, the whole bundle will amount to a little more than originally was planned. With that money StarDex can create the plug-ins. The generic approach is repeatable so that this measure can become cost-effective. Because the unique plug-ins are dedicated to the client, in addition she advises to charge new clients for tailor-made extras, just enough to break even and compensate the loss of making plug-ins for the current clients.

Difference reduction would have created a deadlock here. The clients have their contract and StarDex does not want to lose money. Caren had to apply means-end analysis, thinking of detours (i.e. adapt business case, decompose the bundle, raise prices, sell plug-ins, compensate losses later) that finally would lead to satisfying both StarDex and its clients.

Box 4. The logistics of painting

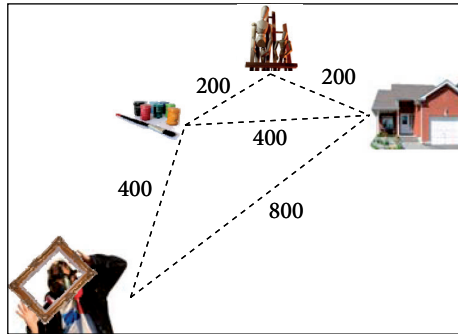


Figure 12. Difference reduction or means-end analysis?

Figure 12 shows an artist with a logistics problem (and a gasmask on). He is to move to his studio (the house) with a picture frame he just bought. Moreover, he needs groceries such as a few boxes of oil paint, brushes, and an easel, after which he should rush back to pick up the kids from school. The dashed lines indicate the distances he has to walk. What does he do? Difference reduction would suggest that he first brings the frame to the studio (800 yards). Then he buys new paints (400 yards) and brings them back (400 yards), after which he goes to get a new easel (200 yards) and brings it to the studio (200 yards) and then turns back (800 yards). In total, he walked 2800 yards which is almost 1.6 miles to get this job done.

Means-end analysis would suggest temporary goal evasion. Go to buy paint (400 yards), pick up the easel (200 yards), deliver everything at the studio (200 yards), and return to base (800 yards). Now he walked 1600 yards, which is not even a mile. However, the solution to a problem often brings about another problem. The painter is not strong enough to carry such heavy load. Given the circumstances, then, the labor-intensive difference reduction was perhaps sub-optimal but the best he could do. The choice for means-end analysis would force the painter to drive a car, which in his case meant that he should get a driver's license first.

In other words, the very problem-solving strategy you choose may predicate new investment: following courses, purchasing new machinery, or developing new technology. A preferred line of problem solving may even change complete business models. If the suppliers understood this customer well, they would start an Internet ordering service and made sure this artist could purchase his supplies online and have them delivered to his studio.

Vinay Deolalikar of Hewlett Packard reiterated one of the hardest issues in theoretical computer science (Deolalikar, 2010). In mathematics, there are difficult and less difficult problems with complex and less complex solutions to them. The artist doing groceries can choose between solving or verifying the problem. In such situations, computer scientists wonder: If a solution can be verified quickly for correctness, can the solution be calculated quickly as well then? Problem complexity

is estimated by computer calculation time. Now if the number of places the artist wishes to visit increases, the number of possible routes would increase exponentially, making it a problem of great complexity (an EXP problem). Problems solved by addition, subtraction, or multiplication, are considered simple and solved in “polynomial” time (P problems). In between are problems called NP, of which the shopping artist is an example. It takes a lot of time to try all routes in Figure 12 but all routes can be verified for correctness pretty easily (e.g., when not coming back to base for the children).

If a computer non-deterministically can select whatever route, the problem is solved quickly by checking the guesses. NP, then, stands for a non-deterministic polynomial problem (i.e. addition, subtraction, etc. with making guesses). Certain people believe there is no difference between P and NP problems but Vinay claims to have proven that the difference does exist ($P \neq NP$). That means that there are problems that are easier to verify than to solve and that at certain problems computers start guessing in a universe of probabilities rather than determining the exact solution.

6. Intelligence and creativity

Intelligence and creativity are not the same thing but both may engender innovation. The main difference is that intelligence does not cross over to intersect with an associatively faraway domain. Intellectual insight is ingenious, applies different logics, and asks: How can I do it smarter? Intelligence offers another *method* to achieve what was asked for and tends to innovation of the *process*. A creative solution demonstrates similarity between problem and goal state where no one saw it before or between problem domains that everybody thought were unrelated (e.g., Csíkszentmihályi, 1996, p. 9). Creative insight is associative, crosses boundaries, and asks: What does it look like? Creativeness is *content* oriented and offers different *goals* than were asked for.

The remainder of this chapter is devoted to the differences between intelligent problem solving and solving problems creatively. For creativity it is important to consider a diversity of information sources and to switch perspectives frequently: Whereas reasoning may benefit from a narrower focus, in creativity it must be wide. This relates to two types of thinking: convergent and divergent (cf. survival focus vs. opportunity seeking). Convergence builds upon known practice, whereas divergence draws in the unexpected. Analogical reasoning is a fine example of convergence combined with divergence; a vehicle of intelligence as well as creativity. We then embark on the differences between expert problem solving and that of novices. Experts will look for known structures and apply reasoning strategies

(see previous sections); novices jump to conclusions and apply knowledge that to experts seems irrelevant. Hence, novices are bound to solve problems not in an intelligent but rather in a creative manner. As a case in point, I discuss the alternate uses of standard functionality that is often found in children. Different problem representations may shed new light on an issue: For analytical problems, usually one single representation is best (e.g., algebra) but multiple representations (in text, sound, image, etc.) commonly lead to more creative solutions. Finally, whether problems are solved with intelligence or creativity; they always have a moment of decision making in them. Dependent on the type of problem, decisions are more structured and based on determinism or unstructured and probabilistically based. This also has its consequences for how to run an organization.

7. Switching perspectives: narrow vs. wide

Creativity in problem-solving is to develop a new perspective, breaking new ground, and forging a new point of view (Gruber & Wallace, 1999, p. 109). Creative solutions typically involve seeing a known problem in a new way (e.g., Sternberg & Lubart, 1993). To see things anew, one must have access to novel information sources. Whereas rule-based problem solving focuses on the problem elements, creative problem solving requires more diffuse attention that includes peripheral cues, which seem unimportant at first but may eventually lead to insight (Ansburg & Hill, 2003). A creative problem solver focuses on aspects that are pertinent to the current problem and simultaneously monitors what analytically would count as irrelevant information. This way, creative solutions combine ideas that seemed unrelated at first (ibid.). Thus, creativity is not breaking down but looking beyond the givens.

8. The balance between convergence and divergence

James Carse (cited in K. Kelly, 2010, p. 353) writes that games such as chess and Tetris are finite: Players play within the boundaries set by the game. In infinite games, however, players play *with* the boundaries and this is exactly what creativity does. The hallmark of creative solutions is to think out of the box. De Bono (1971) calls this “lateral thinking,” other literature speaks of “divergent thinking” (e.g., Bethune, 1837; Jevons, 1877, both cited in Becker, 1995, p. 220, p. 225). All these thinking styles lead to multiple views on the problem as well as its solutions. Divergent thinking is the ability to complex ideation as described by William James (1880):

Instead of thoughts of concrete things patiently following one another in a beaten track of habitual suggestion, we have the most abrupt cross-cuts and transitions from one idea to another ... the most unheard-of combinations of elements, the subtlest associations of analogy; in a word, we seem suddenly introduced into a seething caldron of ideas ... where partnerships can be joined or loosened in an instant, treadmill routine is unknown, and the unexpected seems the only law. (William James, 1880, cited in Becker, 1995, p. 222)

Isaak and Just (1995) introduced the following problem: Suppose there is a \$100 bill on the ground kept in place by a gigantic pyramid of steel standing perfectly balanced on its point. How will you get the \$100 without touching the pyramid? A convergent perspective would think up all kinds of engineering solutions: Magnetize the steel and lift it with magnets, nitric acid to dissolve the steel, dig a narrow tunnel to reach the bill.

The divergent answer would be to draw in a business perspective. A business person would look at the exchange rate for steel and sell the pyramid to the highest bidder while giving a discount of \$100 (the buyer can keep the bill). The divergence is in drawing in more information than the problem representation offered. Nobody stated that an engineering perspective should be taken. Nobody said that you cannot switch focus and approach the problem (heavy pyramid) as the solution (steel has value as well). Nobody forbade that you donate the problem to someone who is not restricted to not touching the pyramid or who just tears the bill away. In addition, the proposed goal may not be solved (you getting that particular bill) but the solution is multiple times better (solid steel sells for more than \$3000 a tonne).

Divergence opens up. Divergence is important to increase the empirical validity of a solution. Therefore, becoming acquainted with multiple perspectives is by no means trivial (e.g., Cech, 2001, p. 15). Runco and Sakamoto (1999, p. 65) report on evidence that original thinking arises from drawing multiple views into the equation, applying multiple strategies, using multiple information sources. Rigidity and fixity are counterproductive in this respect (*ibid.*, p. 66). For creativity to occur, then, it is useful to work in a multicultural environment (Csíkszentmihályi, 1996, p. 9).

Free association has a similar function. Divergent thinking is closely related to free association (or ideation), which gives access to 'peripheral cues' (cf. Ansburg & Hill, 2003). In the arts this approach was most ardently promoted by Breton and Eluard (1938) as a technique to create surrealistic poetry, sculpture, and paintings. Free association helps to arrive at unusual ideas and is currently employed in so-called *brainstorming* sessions (e.g., Osborn, 1953). During a brainstorm, fast generation of multiple ideas and a free interplay of thoughts are concentrated on a particular topic or issue. Quite often, brainstorming is a group effort and

evaluation of ideas is usually postponed until all suggestions are recorded, for instance, in a so-called ‘mind map.’

Showing empathy is a characteristic of emotional intelligence and attempts to accurately understand emotions and needs of those involved in a problem (Wolff, Pescosolido, & Druskat, 2002). As an aspect of divergence, empathetic inquiry precedes and enables the more cognitive processes and skills (convergence) such as analysis of the task situation and reasoning strategies (ibid.). Therefore, *empathetic inquiry* to understand the other perspective is usually employed in the early stages of designing a solution, when the context is still complex and ill-defined. At this stage, affective and conative aspects are more important than cognition (Jonassen, 2000).

8.1 Intelligence: first convergence, then divergence

Divergence typically is a quality that bridges intelligence and creativity. Intelligence is not the same as creativity but both may produce innovation by thinking divergently. Figure 15, for instance, shows a triangle made of 18 matches. Your job is to move 6 of them so that two identical hexagons arise. Just take a few minutes to solve this puzzle before reading on.

Probably you recognized the six sides of the hexagon in the middle of the big triangle and you tried to replicate it using the six matches of the three angles, falling short of one match (Figure 16). This is convergent thinking.

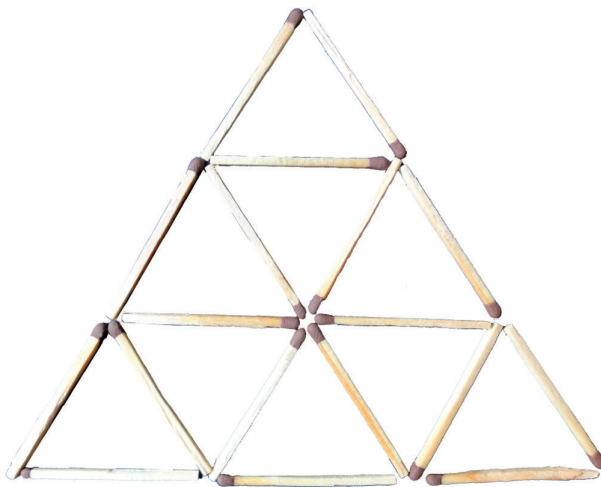


Figure 15. Triangle of 18 matches

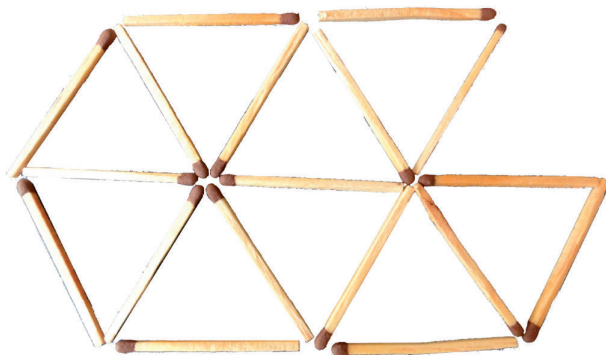


Figure 16. Two hexagons, one incomplete

Here is the first step to illustrate intelligence that is not convergent. If you formed the triangle with real matches, the first thing you should *not* do is touch it. Do not move matches around to find a solution through trial-and-error. It will lock you up in two dimensions. Abstract from the representation (see Section 11) and think of the triangle as composed of geometrical lines instead of matches. Now expand your solution space by thinking in *three* dimensions. If you pull up the midpoint of the hexagon in Figure 15 and fold down the three small triangles at the top and the base (= 6 matches) such that the points meet, you get two hexagons lying on top of each other, sharing the same matches on the six-sided outline (Figure 17). Obviously, you can also fold the three small triangles up and over the first hexagon to get the same result.

Abstracting from the representation and bringing in a third dimension are manifestations of intelligent reasoning of a divergent kind. The abstraction makes it

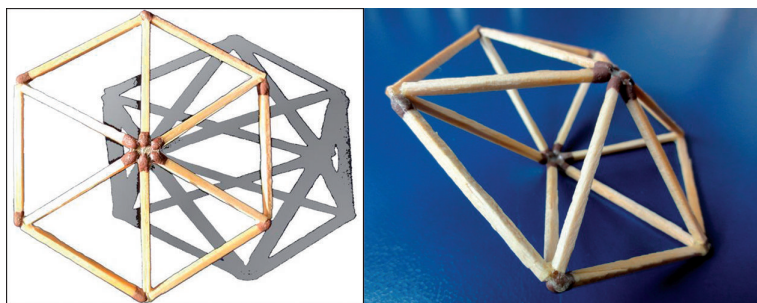


Figure 17. Hexagons collapsed (left). The shadow shows they are two (right)

possible not to be restricted by empirical constraints (which in Figure 17 were solved by using glue). The divergence in this solution lies in the transformation of rules (going beyond 2D) so to make more options available for moving the matches around. However close this is to and preparatory for creativity – the result is innovative – it is still not a creative solution yet.

A small step into that direction is to think in terms of paper folding. That was not necessary in principle because pure spatial reasoning would have been sufficient. But envisioning a triangle of matches as folding a piece of paper, matches being folds, was a transgression of categorical boundaries, seeing commonality between disparate entities. In this case, connecting matches to paper folds made it easier to work with the abstraction. Creativity asks ‘what does something look like?’ Interpreting the two hexagons in Figure 17 as a “diamond,” for example, would count as a larger creative step than matches and paper, stating that a triangle of 18 matches is like a diamond of 12 facets – when you fold it.

The result becomes creative in a symbolic sense once the double hexagon is lifted to the roof of a synagogue as a skylight (Figure 18). If you look at it from under the right angle, from six sides you will see a David’s star. A simple puzzle that demands intelligence can be promoted to religious architecture when approached creatively.

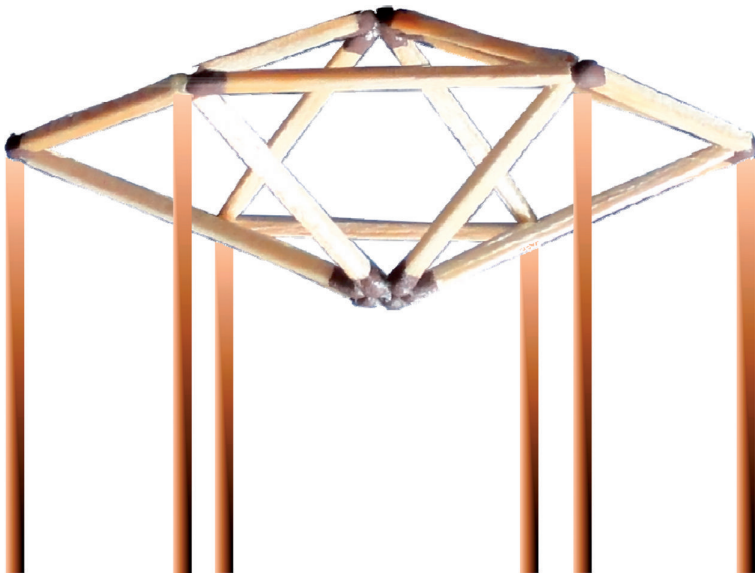


Figure 18. Synagogue skylight with six David’s stars

8.2 Creativity: first divergence, then convergence

The previous section showed that in creative problem solving, cognition and reasoning are not absent but less leading (Hélie & Sun, 2010). Divergent thinking opens new perspectives and generates novelty after which the evaluation of the novelty runs via convergent thinking (Cropley, 2006). Creative people can alternate between those two styles relatively easily (Kris, 1952). Divergent thinking helps to redefine the problem or turn it into a new question (see this Chapter's motto). This is as much a part of creativity as formulating a solution is (e.g., Runco, 1994; Nickerson, 1999, p. 395). Within that new perspective, convergent thinking is more analytic, reasons from the new situation to the single best solution or the proper answer (Guilford, 1959).

Please turn back to Figure 9, Section 5.2, where the question was how many blocks there were in the depicted construction. The convergent thinker in you probably answered that the construction consists of 43 blocks. Although nothing indicates that one should, the convergent thinker assumes the Gestalt of “good continuation” and infers that blocks are present where you do not see any. It is the Classicist conception of the harmonious non-disruptive universe that can be inferred and predicted. A divergent thinker would say: “I don’t know. Can’t tell. The problem is underspecified.” The divergent thinker imagines deviation and complexity: Blocks you do not see may be missing (cavities). Certain blocks may be placed under ground. Perhaps some are split in two. Perhaps that the invisible elements are not blocks but triangles. And indeed, I rotated the construction in Figure 19 to show that the construction is hollow, that one block is missing, that a ball replaces a block, and that the construction actually carries a complete statue inside. By thinking convergently, you missed an archeological discovery!

Convergence is fine to verify the internal logics of a hypothesis (Section 5.2), divergence leads to empirical validation. On the other hand, when divergence is employed in isolation and not followed by convergent thinking, divergence may entice the most fantastic and pseudo-creative solutions (Cropley, 2006). Therefore, divergence in unison with convergence may lead to exacter solutions than mere reasoning alone. After imagining all kinds of alternatives (divergence), I turned the construction around to evaluate my hypotheses (convergence). It shows that apparently well-defined problem spaces probably are ill-defined as the rule of rules suggests that in any given system, perfect order is the exception (Chapter 1, Section 13). Assuming good order may be convenient and internally satisfying but is not strictly valid. It ignores all kinds of options and alternatives right from the start. In solving a problem, start divergently so to end with convergence.

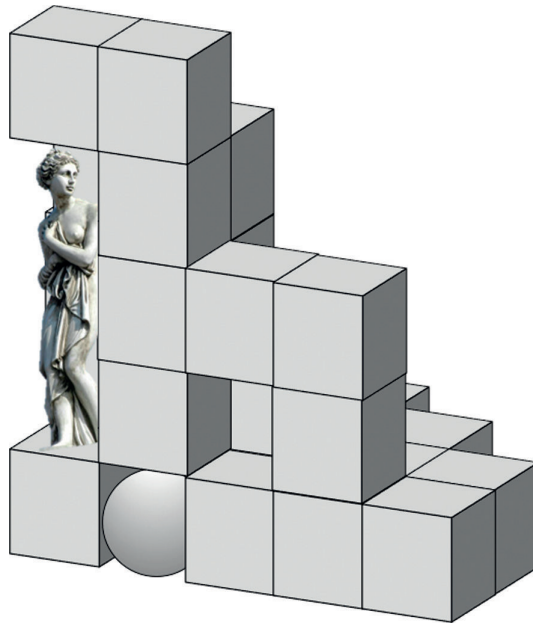


Figure 19. Divergence leads to better accuracy

9. Analogy: An associative reasoning strategy

We saw that strategies such as difference reduction, means-end analysis, and backward reasoning are the more rational types of problem solving. Creative problem solving works through association and similarity. Seeing similarity between problem domains is most prominent in solving analogy type of problems (e.g., Gordon, 1961). Solving problems through analogy is to see an associative connection and then to reason how the solution in one domain applies to another.

For example, barbed wire was inspired by thorn-hedge fences, electric motor technologists looked for examples in steam engineering, and Edison's electrical lighting system was modeled after the gas illumination system (Basalla, 1988/1999, p. 62; Kroeber, 1948, p. 260). Making analogies is important for technological invention and for the derivation of functional requirements of a system (Basalla, 1988/1999, p. 46; pp. 62–63). Analogies follow the form of $A : B :: C : D$. For instance, NASA's computer engineers realized that blood flow (A) through the heart (B) is like fuel flow (C) through a rocket (D). Therefore, they used the simulation models of the Space Shuttle fuel system to design a miniature heart pump for patients awaiting a transplant (Bluck, Apr. 2, 2002).

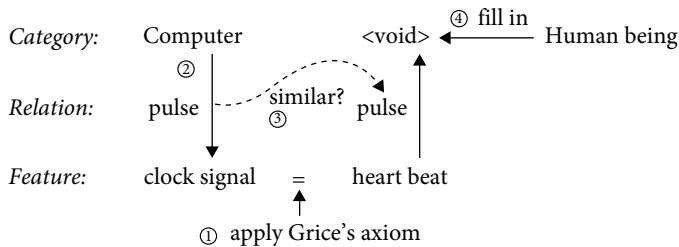


Figure 13. Solving an analogy

9.1 Solving an analogy

Analogies may give rise to creative solutions, but they also pose a problem to those who should understand them. On the one hand, they seem to be logically clear; on the other, they may be associatively weird. If in a manual, someone writes “The clock signal is the heartbeat of a computer,”³ quite a few (semantic) operations and rules of thumb apply to make sense of that statement (Figure 13):

1. The first thing one has to settle is that the statement ‘a clock signal is similar to a heartbeat’ is not nonsensical. To do so, the context, a manual, is important in which someone usually tries to explain something and not fool people with weird puns. With this, the receiver should apply the rule of thumb that someone who explains you something probably has serious intentions. Then, one starts searching for meaning and should not reject the expression as an abnormality. This is one of Grice’s conversation axioms (Grice, 1975). Grice states that people give a speaker momentary credit so to understand an utterance later on, after they have done more processing or when more information is provided.
2. The current problem state in solving the analogy is that there is a ‘void address,’ that is, the comparison is incomplete. The goal state is that you can fill in a meaningful solution by finding a word that (semantically) fits. That is why people look for what is already known. In long term memory, the associative knowledge base assures that ‘clock signal’ is a feature of the category of ‘computers.’ Their relation is that the pulse of the clock dictates each process of the system.
3. Next, one should copy this relationship to the other knowledge base (the reasoning), those of which ‘heartbeats’ are a feature. Someone can do this only by assuming – another rule of thumb – that features are compared with features and that categories are compared with categories. The question in mind is whether the pulse relation can be made similar in both domains by finding a meaningfully fitting category word.

3. http://www.computertutorials.thetazzone.com/system_clock.html

4. In the last step, the problem is reduced to a two-sided question: Find a word that indicates the category to the feature 'heartbeat' and that has a pulse relation with it. After searching the associations in the knowledge bases that have heartbeats and pulse relations in them, the receiver will probably end up with 'human being' or 'animal.'
5. Postprocessing. Based on finding a fitting solution to the hypothesis about similar relation(s) in different domains of a pulsating, existence-sustaining mechanism, the receiver solved the analogy that clock signal (A) is to computer (B) as heartbeat (C) is to human being (D). From this analogy, one can conclude that the writer thinks computers can be compared with humans. As an extra confirmation of Grice's axiom, this interpretation fits a culturally very old (e.g., Descartes) and widely held metaphor of 'a human is a machine.'

In computerized problem solving, analogical reasoning is often referred to as case-based reasoning (Figure 14). Case-based reasoning can be used in, for instance, medical diagnosis and jurisprudence.

9.2 Limitations of analogy use

Problem solving by similarity (and analogy as an instance of this) is to see that the features of two problems are the same whereas domains may be different (cf. problem transformation). In the case of an analogy, these features may be similar relations or problem structures. In using analogy, you can derive the solution for the current problem state from the goal state of the similar problem.

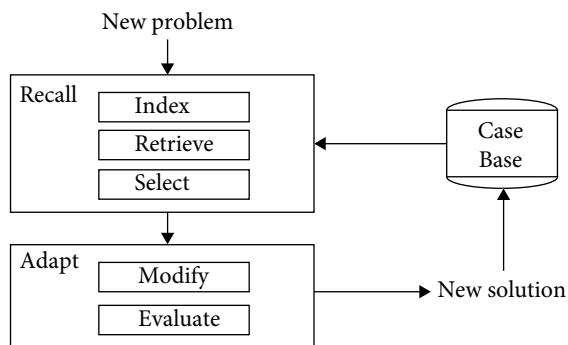


Figure 14. Case-based reasoning (Maher, Balachandran, & Zhang, 1995, p. 5)

However, there are also certain drawbacks in using similarity and analogy in problem solving. First, that problems seem similar does not mean that they are identical. In other words, one should be pretty sure that the desired goals and the means to achieve them (i.e. the functional requirements) are applicable to both problem domains. Second, the analogy may be overgeneralized: Not all aspects of the one solution apply to the other and when they do the analogy is not a one-size-fits-all for all related problems.

Third, a source of confusion also may be that people sometimes maintain the old nomenclature in the new domain although this may be incorrect. Such remnants in wording often follow the functional analogy. Basalla reports, for instance, that transistor engineers treated semi-conductors as if they were small-size solid-state vacuum tubes, the terminology of which was adopted in transistor engineering. Such remnants in wording of the sample system may deceive people and lead to misunderstanding: Although nothing is emitted, nowadays the transistor contact points are called *emitters* and although nothing is collected, the electrical connections are called *collectors* (Basalla, 1999, p. 46).

10. Experts and novices

When problems can be solved with rational, convergent strategies, there is no doubt that experts solve them better than novices. Experts are strong at solving formal and rule-driven problems, recognizing a principle or mechanism that can be applied to many cases. In creative problem solving, novices actually may have the upper hand because they do not suffer from tunnel vision and copy outcomes from one domain to another.

10.1 Experts converge

Novices and experts solve problems differently. According to Adams et al. (2009), these differences have been widely studied with formal problems in physics, maths, chemistry, computing, and chess. Groundbreaking work on analytical problems in physics has been carried out by Simon and Simon (1978). They found that expert problem solvers reason forward from the givens and carefully plan the solution before writing up equations (*ibid.*). Novices jump at a solution and try to work their way back to the givens.

In rule-based problem solving, expert solvers recognize patterns and constellations and, for each configuration, the expert knows what action to take. Experts store more, more different, and more precise strategies and *representations* in memory than novices (cf. Eysenck, 2001, p. 348). Because experts go through

many cycles of repetition, the methods they develop come to mind almost automatically (ibid.). A good example of habitual problem solving is driving a car or playing the piano.

In an analytical setting, experts look whether the general rule applies to the new situation whereas novices try to solve a rule-based problem from scratch. An expert thinks ahead of the possible answers whereas the novice tries to copy the surface structure of the old to the new problem (cf. De Jong & Ferguson-Hessler, 1986). In analytical settings, novices get confused when the same type of problems is represented differently (e.g., once in text, once as a picture) (Yarlas & Sloutsky, 2000). Novices rely on representations more than experts do; experts rather look into the structure of the problematic. To make programming languages less abstract, for instance, visual programming has gained some popularity (e.g., LEGO's Mindstorms robots).⁴ However, as Petre (1995) stated about visual programming:

Experience in digital electronics warns that a typical novice error is too 'literal' a transcription of the domain, a failure to abstract; novices often reflect the eventual physical layout rather than the logical layout. In effect, they draw a picture of the artifact, rather than depict the structure of the solution. (Petre, 1995).

Thus, a novice represents a formal problem in terms of phenomena ("I get those weird messages again and my system is slowing down. I was working on a spreadsheet but I could not save it to the C-drive"). An expert mentally represents a rule-based problem in terms of a *cause or mechanism or principle* ("It's another virus"). Experts look ahead and calculate the various outcomes of different options, whereas novices tend to work backward (Larkin, Heller, & Greeno, 1980). Moreover, because experts have ready access to more formal procedures, within their domains they have a larger repertoire to solve new analytic problems (e.g., using virus signature files to detect new mutations). Novices tend to focus more on the obvious means and resources (e.g., running commercial virus scan software).

10.2 Novices diverge

The problem solving strategies of experts also have their limitations: Their skills are domain dependent. Those of novices can be applied to almost any domain (they are unspecific to the problem at hand). This may be a drawback for rule-based strategies but may be advantageous in creative problem solving, where multiple domains are crossed over. After all, the novice will copy the surface structure of the problem in one domain to that in a different one (cf. De Jong & Ferguson-Hessler, 1986). That may not be appropriate from a convergent point of view ("It won't work") but at least it brings in a new perspective ("But you never considered the option") (Box 6).

4. <http://zone.ni.com/devzone/cda/pub/p/id/8>

Box 6. Rows in the field, lines on a screen

From Schatzkin (2002, p. 17): "... the summer of 1921 found Philo T. Farnsworth, age fourteen, strapped to a horse-drawn disc-harrow, cultivating a potato field row by row, turning the soil and dreaming about television to relieve the monotony. As the open summer sun blazed down on him, he stopped for a moment and turned around to survey the afternoon's work. In one vivid moment, everything he had been thinking about and studying synthesized in a novel way, and a daring idea crystallized in this boy's mind. As he surveyed the field he had plowed one row at a time, he suddenly imagined trapping light in an empty jar and transmitting it one line at a time on a magnetically deflected beam of electrons. This principle still constitutes the heart of modern television. Though the essence of the idea is extraordinary simple, it had eluded the most prominent scientists of the day. Yet here it had taken root in the mind of a fourteen-year-old farm boy."

Expertise is valuable if the division in specialization domains is appropriate, domains do not change, links between them are unimportant, and the problem space can be represented as the sum of constituent problems (Savransky, 2000, p. 16). The replication of such specialized behaviors holds the danger of developing a monoculture, which is vulnerable to external events. Experts may be fixated by the habits of their trade and approach problems more restrictively (i.e. tunnel vision) (Sternberg & O'Hara, 1999, p. 256). Novices have fewer constraints on producing 'realistic' or 'valid' solutions. Expert problem solving, therefore, is less successful in probabilistic settings. Tetlock (2006, p. 67), for instance, analyzed 20 years of forecasting in newspapers and on TV. He found out that in ill-defined problem spaces such as politics and economics, non-experts with broad and eclectic knowledge predicted events better than experts did.

However, specialism breeds diversity and diversity of views also helps to adapt to change (Lumsden, 1999, p. 156). The crux is to avoid tunnel vision and acknowledge that other specialists have valuable knowledge as well. Associative styles can be used to bridge the specialisms and eliminate the stereotypical solutions that expert solutions tend to (Hélie & Sun, 2010).

10.2.1 Alternate uses

When you are capable of looking at something in a different light, *alternate uses* of common utilities transpire. For instance, e-mail was meant to support bilateral digital communication but today, people tend to use the 'new message' mode also as a template to write a memo or letter (with all the text satellites automatically generated). They print out the electronic letter and send it offline as a hardcopy (!). Sometimes the drafts folder is used as a calendar or as a personal list of things to do, created at work and consulted at home.

It is unpredictable what the use of an innovation will be (K. Kelly, 2010, pp. 243–244). I have been in shabby cafés where old CDs were used as coasters. But you can also use a CD for a drop spindle to spin wool yarn (Figure 20).

Figure 20. CD used for a drop spindle



Children typically re-function whatever they get into their hands and turn it into something else. Beds become airplanes, tubs become boats. In Figure 21, twenty months old Nina saw the similarity between the toy work bench and her baby chair and creatively solved the problem of not having a chair by making alternate use of her workbench.

We learn from these examples that looking for form similarity helps to find similarity in function or contents, sometimes after adaptation of features (Hoorn, 2002). Form similarity can be a searchlight for finding functional similarity between entities but convergent thinking tells us that this should not be done uncritically.



Figure 21. Creativity in its simplest form. Retrieved Oct. 22, 2010 from <http://www.babyinkids.nl/img/3/1275.jpg>

Figure 22. Alternate uses incorporated: Turning a display screen into a mirror



People do not always grant a product the function that its designers envisioned. I have seen girls check their lipstick using the self-portrait function on their smart phones. The challenge is to adapt the original plan to the creative use people make of it. The designers at *Elle Publications* and *Alcatel* probably noticed the same. They developed a glitzy phone: The screen converts into a mirror when not in use (Figure 22).

10.3 Being knowledgeable

Solutions to complex problems, dilemmas, or challenges are not solved by either experts *or* novices. Solving complex problems requires many different skills – some of which are divergent (a novel insight) and some of which are convergent (the reality check).

Runco and Sakamoto (1999, p. 66) review experimental studies in which creativity was not served by expertise but rather by being ‘knowledgeable,’ having an optimal instead of maximal level of domain expertise. Simonton (1984) corroborates the view that after an optimum, formal education stifles creativity. Weisberg (1999, p. 232, p. 234, p. 242) reviews evidence that practice and knowledge gained outside the formal educational system does not impede but rather foster creativity. In a vast historical overview of technological leadership, Davids (2008, p. 527) concludes that innovation is best served by mixing learning-by-doing with formal education. In other words, for the well-defined and more rational problems, formal expertise is germane; for solving ill-defined problems formal training may stand in the way of a creative answer, which is rooted in knowledge gained from experience.

Who the expert is then is not at all certain in ill-defined problems. A mathematician may be an expert on algebra but a novice of number theory (Csikszentmihályi, 1996, p. 9). Someone may be an expert on graphic design but a novice on animation. A car that does not start may be a huge problem for a rocket scientist but not for the car mechanic around the corner (Savransky, 2000, p. 5): Expert on one task, novice on another. One person’s insoluble trouble is another person’s routine job (*ibid.*). Present day emphasis on crowdsourcing, co-creation, and user-generated content helps to shape products, services, economies, and societies more creatively. It is assumed that the collective intelligence of large groups shows more aptitude than a small group of experts (Surowiecki, 2004/2005) because small product niches become more important than the ‘hits’ of big companies (*cf.* Anderson, 2006).

11. Problem representations: Single or multiple?

It is not merely the well or ill-definition of a problem that urges the rule-based or creative solution. The way a problem is represented also directs the way it is

solved and sometimes whether it is solved at all. For example, do you frame copyright issues as a legal problem (“Not allowed, enforce the law”) or a business problem (“This free copy is financed through crowdfunding”). Representing a problem differently may change the perspective on it, and so may open opportunities for its solution (inspiring divergent thinking) or close them off (prompting convergence).

Different representations of a problem can show or hide possible solutions (Box 5). If you ask a six-year old to divide eight cookies over four kids he or she does not hesitate to give each child two cookies. If thereafter you ask the same child to calculate $8 : 4$, he or she will lack the answer. If you want to explain someone the way to the city center, the best you can do is to draw a map. Spatial information can be easily accessed by a drawing. If you want to explain the tenets of democracy, the best you do is to consult the written Constitution. Abstract concepts such as “freedom” and “rights” are better understood textually.

In pre-Cartesian times, geometrical problems were spelled out in words and problems were often approached through spatial ‘intuition.’ However, that resulted in such long, complicated, and sometimes imprecise sentences that mathematicians such as Descartes and Fermat started to develop a symbolic language for the representation of the abstraction in spatial problems. This form of representation had tremendous consequences. Geometrical problems were translated into arithmetic and algebra, which side-winded the need to draw on geometrical ‘intuition’ (Beaney, 2009). This opened the way, for example, to computational approaches to space navigation.

Box 5. Three layers of problem representation

VisChem helped students of chemistry connect three levels of thinking in chemical analysis, which they otherwise found extremely hard to reconcile (Figure 23). The visualization of ice melting shows the visible laboratory level, emphasizing color changes, formation of solids, and boiling. The molecular level is represented by a Quicktime animation, illuminating the changes in structure and processes of atoms and ions. The symbolic level makes the form transition from solid to liquid matter accessible to logical reasoning. Each representation has its unique qualities in dealing with ice melting but none can do all three. The multimedia interface takes care of the fourth layer of information: The interrelations among the other representation forms.

Figure 23. Different representation forms explain the process of ice melting. When you interfere with one level of analysis, the interface shows the consequences for the other two





Figure 24. Tiltable and turnable helicopter made of scrap materials

In design, complex problems are commonly represented in various ways. Handicrafts, card-boarding, or models made of scrap materials are used to create mock-ups of possible solutions (see the tiltable-turnable helicopter, Figure 24). Acting out different scenarios may help to understand the conditions under which a solution has to work. Mood boards are a composition of texts, photos, drawings, and artifacts to express the look and feel of a solution. Writing up different personas gives an impression of the possible stakeholders in a problem. Working with the hands, learning-by-doing, offers a perspective that complements the cerebral approach of formal training and analysis.

Representing the world about us is a complex operation that results from our sense perceptions and cognitive processing (Hoorn, 2012; also Miller, 2000, p. 15). The world is a mental construct which may contain “incorrect” assumptions that are maintained for the time being until counter-evidence suggests something different. There may be consensus among people on what reality is, having a shared understanding of the warranted as well as the unwarranted assumptions. However, what is unwarranted or not is dependent on the flexibility of the world view or belief system that someone adheres to *a priori* (Hoorn, 2012, Chapter 1).

The way we conceptualize the world and visualize that conception may seem intuitively clear but can be highly misleading. Reversely, it may be imperfect but yet render an acceptable approximation of ‘the world.’ As Miller (2000, p. 15) puts it, “Nature gives us data. Both Aristotle and Galileo saw a stone falling down. But how we interpret this phenomenon, that is, how we read nature, depends on one’s conceptual framework.” Aristotle visualized the trajectory of a cannon ball as a

circular arc; Galileo visualized a parabolic curve (ibid., p. 16). Accepting one or the other framing of the problem leads to different solutions: When a cannon ball is fired in accordance with the angle of Aristotle's problem representation, it will not land where expected. Galileo's calculus obtains better results. Yet, Galileo's representation was not exact either because he did not reckon with the centrifugal force of the earth's rotation – the Coriolis force (Miller, 2000, p. 82). Had Galileo's measuring devices been better, the resolution of his data would have been too high to see the general regularity that in most everyday cases, objects approximately fall according to a parabola (ibid.).

At times, approximations are better than exact theories. Figure 25 shows the chart editor of the Microsoft Word program. Both representations show the same data. However, the table provides exact local detail whereas the bar chart offers a global overview, emphasizing proportional relatedness. Basically, the mode of presentation confronts the observer with a particular *framing* of the problem. *What* gets represented, which parts of the problem are *relevant* to represent (e.g., exact details or global relations), and the *mode* you choose (text, sound, graphics, etc.) depend on how well-defined the problem is, the desired detail of resolution that the goal state should be in, but also on a person's capabilities. A novice may be helped with the bar chart whereas the expert might prefer the tabulated numbers.

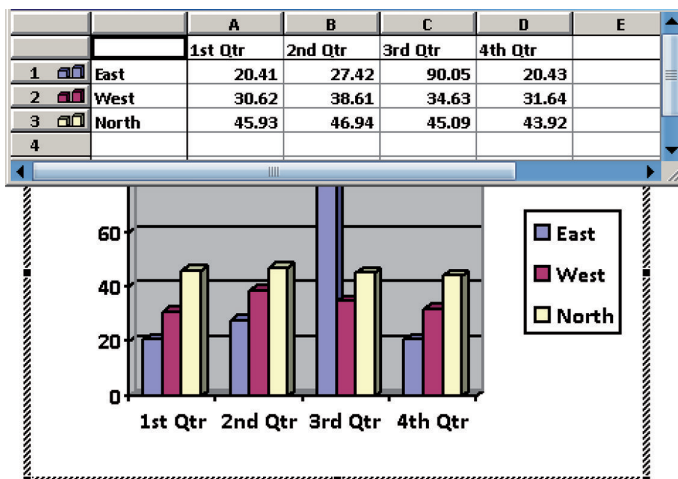


Figure 25. Microsoft Word chart editor

12. Decision making: deterministic – probabilistic

Whether solutions are generated through creativity or rationally, during the process of reasoning or association, various decisions have to be made. Particularly in ill-defined situations, multiple routes may be taken and more solutions may occur. Decision making is about choosing the best possible option from a number of solutions (Eysenck, 2001, p. 331). What the best option is cannot always be determined rationally (ibid.). Damasio (2001, p. 66) indicates that rational decision making is strongly intertwined with emotional responses.

Simon (1960) distinguishes three phases in making a so-called ‘structured decision.’ *Intelligence* (in the sense of information) pertains to identifying the problem. *Design* means to generate alternative answers by doing qualitative and quantitative analysis. *Choice* encompasses selecting the solution with optimal fit to the goal state, that is, making the decision (Figure 26).

Structured decisions usually relate to better or well-defined problems and a more precise problem state. More standardized strategies may support the three phases in decision making. In cases of complete specification, it is possible to reason backward from the goal to support a decision. *Unstructured decisions* often coincide with ill-defined problems and imprecise descriptions of the problem state. They do not follow or they skip one or more phases of a structured decision. Typically, the *Design* phase in Figure 26 becomes a mix of analysis and creativity. To make a proper decision for ill-defined problems requires employing divergent strategies (e.g., empathic inquiry plus prototyping) for one or more phases in the decision making.

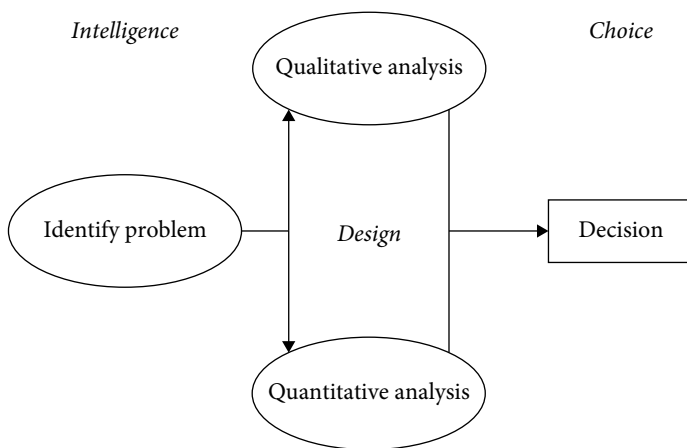


Figure 26. Simon's three phases of structured decision making

13. Decision models

Decision models can be deterministic or probabilistic. *Deterministic* approaches are mathematically-oriented and suppose full specification of single valued inputs under strict parameter conditions. Provided that the input is identical, the output choice will always be the same. These models often deal with the simpler type of problems and sometimes render acceptable results even in probabilistic cases.

Probabilistic models are statistical or stochastic approaches (Chater & Oaksford, 2008, p. 5), acknowledging that a problem space hardly ever is completely specified, that there is random variation in the data, and that variables are described by probability distributions. Probabilistic models come in three forms: normative, descriptive, and prescriptive.

Normative decision models originate from logics and their truth is relative to presumptions, whereas descriptive ones are empirical or psychological (Peterson, 2009, p. 3). Normative decision models suppose that people make rational decisions, that they can prove which solution is best, that they rank-order the possible outcomes, and estimate the probabilities to outcomes (Peterson, 2009, p. 3). Normative models address how decisions are to be made to satisfy the assumptions believed to be desirable. Normative models demand expert domain knowledge and much human input to make accurate predictions. From the givens (e.g., goals and parameters), a normative model tells what is the logical choice under conditions of uncertainty. Normative models do not allow much room for creative ideas.

Unlike normative models, *descriptive* decision models assume that humans do not always make the most rational choices and do not state how people ought to choose if they were well informed and were perfect analysts. Descriptive models state how people actually behave. Descriptive models are a means of investigation, not of optimization (Peterson, 2009, p. 3). The technology used here often is the simulation of possible problem spaces. Factors are manipulated to predict possible outcomes, which do not need to be rational or optimal. Due to their exploratory nature and little focus on improvement of known practice, descriptive decision models do allow for creativity.

Prescriptive decision models describe how decisions ought to be made under the circumstances outlined by descriptive models. Prescriptive models, therefore, could advise how to write a creative novel, although prescription supposedly is at odds with being creative of course.

14. Individual and group decisions

The early studies into decision making mainly focused on individuals making choices. More recent approaches also look into the group decision process, represented in sub-branches such as social choice theory and game theory. These approaches take into account the choice behavior of other decision makers such as collective decisions (cf. consensus making) or decisions that concern others. Group decision models can be useful in co-creation sessions.

Whereas the assumption of individual decision-making is that people will try to maximize the expected utility of an option, game theory is more concerned with scenario building (cf. the famous prisoner's dilemma), balancing strategies, and foreseeing what others will do. In co-creation, mutual trust is more important than employing control mechanisms. Game theory investigates how people cooperate and help each other as related to their trust or mistrust of fellow participants (Peterson, 2009, p. 10). Social-choice models are normative in that they seek to establish principles for how decisions involving multiple decision makers ought to be made (Peterson, 2009, p. 8).

15. Decision-support systems

For each phase in the decision-making process, decision-support technology is available (Figure 27). In helping to identify problems, artificial intelligence applications may spot patterns and trends. In business, for example, detected patterns in suppliers' reliability and customers' preferences are fed to Executive Information Systems to help senior managers make strategic decisions.

In the qualitative analysis of a problem, Expert Systems help improve or substitute professional judgment. Expert Systems try to replicate the skills and knowledge of experts in a particular field. In a way, they form the knowledge store of earlier problems and solutions – an artificial long term memory as depicted in Figure 2. Currently, crowdsourcing techniques are used to complement expert systems in finding new niches in the market (e.g., Lego Digital Designer).⁵

In the quantitative analysis of a problem, Data-Based DSSs extract information from large databases to summarize, explain, and predict the patterns, trends, and behaviors as observed during the problem identification. With Model-Based

5. <http://ldd.lego.com/nl-nl/>

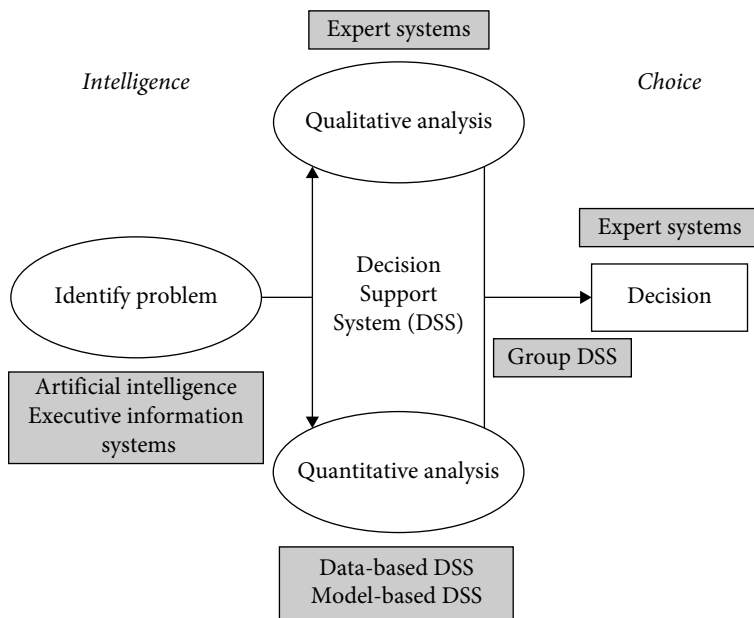


Figure 27. Decision technology as related to Simon's phases of decision making. After Forgionne (2003, p. 13)

DSSs, mathematical models can be built and analyzed to characterize the underlying processes of the observed patterns, etc. In the final phase of decision making, Group Decision Support Systems (GDSSs) can be used to arrive at a common decision among several decision makers. GDSSs support the cooperation and communication among people, distinguishing the parts in which the opinions differ the most and in which a consensus has been found among decision makers. This allows concentrating on vital aspects in teamwork-based organizations. Applications can be found in digital customer panels and inquiries as well as multicultural and multilingual electronic meeting systems. In GDSSs, decisions are made in distributed groups and they highly depend on human input.

Earlier we saw that representation and framing of a problem bias its solution. The same is true for decision technology. If the choice for a DSS does not follow problem diagnosis, the problem is (re)framed *a posteriori* and decisions are made for the wrong reasons (Box 7).

Box 7. Problem diagnosis predicates decision technology

Whether you advise a client to diagnose (and represent) a business problem as a form of case-based reasoning or as a decision tree has quite an impact on the solution you offer and may even affect the choices your client makes. Daily gas consumption by households and industry, for instance, is a type of problem referred to as numerical sequence prediction (<http://cyber.felk.cvut.cz/gerstner/machine-learning/gas/>). Because not all factors that affect daily gas consumption are known, the problem state partially is unspecified (Figure 28a, left panel). Past use does not clearly predict future use so that case-based reasoning may be an option (cf. analogical reasoning). In such systems, computer memory organization and indexing may remain simple because you only need a large library of cases and examples. Drawbacks are that maintaining your library is an effort in itself. You need a case similarity metric of which many exist. Which one fits your case best? You need to find the optimum attribute weights but you never know if tomorrow brings another optimum. Moreover, adaptation of old solutions (consumption values) to a new day requires insight and creativity again. In cases of quick interactivity (e.g., telecom servicing machines), case-based reasoning software may not keep up with the speed of human performance. In handling air traffic, for instance, slowly responding systems may increase the risk for collisions. In such cases, decision trees are faster.



Figure 28. Case-based reasoning (a) or decision trees (b)?

Certain gas and oil companies use PrecisionTree (<http://www.hallogram.com/precision-tree/index.html>) to make decisions when developing an oil field (to drill or not to drill?) (Figure 28b, right panel). Probabilities of events occurring and payoffs for events and decisions are added to each node in the tree. Decision trees represent a time series of choices and possible events and show the general structure of a decision. However, this presumes that there is a structured path to a solution and that probabilities of events and their consequences can be estimated quite reasonably as based on empirical data. In other words, application of decision trees presupposes a better-specified problem space than case-based reasoning. Note that the gas consumption example relates to human behavior, the patterns of which are harder to predict than geological events and related costs in the oil-drilling example. In all, it depends on your analysis of the problem space what you will advise to a client. For more ill-defined problems, you may think of case-based reasoning first whereas for better-defined problems, decision trees may be more in place.

16. Decision support and its place in an organization

There are different types of information systems but not each system can be used at any place in the organization. Each organizational layer handles different types of problems. Laudon and Laudon (2006, Chapter 2) point out which decision

support relates to what kind of organizational interest. Top management uses Executive Information Systems (EISs) to help define the strategy of the organization (Figure 29). Given the mission statements, these systems help decide on the procedures to reach high-level goal states such as the selection of plant location or environmental impact planning.

Middle management uses Decision Support Systems (DSS) to help arrive at the business goals of an organization. Examples may be to overcome economical recession and to launch a promotion campaign. Decision support applications include financial planning and sales promotion planning.

Figure 29. Types of information systems as related to organizational level (Laudon & Laudon, 2006, Figure 2.1)



Operations management decides on the short term targets aided by Market Information Systems (MISs). How to produce and sell twice as many products in two years? Applications may help to schedule the production line, rearranging the workflow, and inventory control.

At the work floor, finally, operations can be routinely executed by Transaction Processing Systems (TPS). For example, the computer directly replies to user requests and authenticates buyer and seller before the transaction occurs. An Automated Teller Machine is a good example of a TPS.

17. The distribution of innovation power through organizations

Consequently, the problem space that senior managers work in is vaguer than that of the production employee. Section 5.1 indicated that the mission statement, the domain of top management, is far less precise than the business targets, the domain of the operational people. In other words, senior managers live in a probabilistic universe in which ill-defined problems lead to unstructured decisions. The most applicable problem-solving strategy is creativity; to be open like a novice and let serendipity do her work in recognizing opportunities. They have to be *generalists*, supported by Group Decision Support Systems.

The operational work floor lives in a different domain. They specialize in solving well-defined problems in a deterministic system (e.g., car assembly) that helps them make structured decisions (drill a hole before attaching the bolt). Their work is paced by time, place, and effort. They are the experts of detail, *specialists*, supported by Transaction Processing Systems. Innovation by the workforce will be incremental,

aimed at the optimization of a process, or the refinement of a technique. Basalla (1999, p. 108) states that routine innovations and random variations in an otherwise standardized production process highlight the conservative aspect of handicrafts.

Middle management is supposed to balance both worlds, rationalizing for the workforce the vague ideas of the leadership. On the one hand, they have to inspire the workers to the vision of the executives; on the other hand, they should tidy the work processes such that employees know their tasks and targets. Middle managers are 'knowledgeable' in that they know more about operations than top management does but not as much as the specialized worker. Figure 30 shows an integration of these ideas, with Laudon and Laudon (2006, Figure 2.1) loosely at its basis.

The leadership of an organization will propose different kinds of innovations than the professionals (the 'craftspeople') do. The leadership may want to turn a hospital that is organized after a factory into a "care village" integrated in the neighborhood and with public functions other than healthcare (e.g., a market or a cinema). The innovation by the professional will concern how to save time in making the beds or improve the quality of the food.

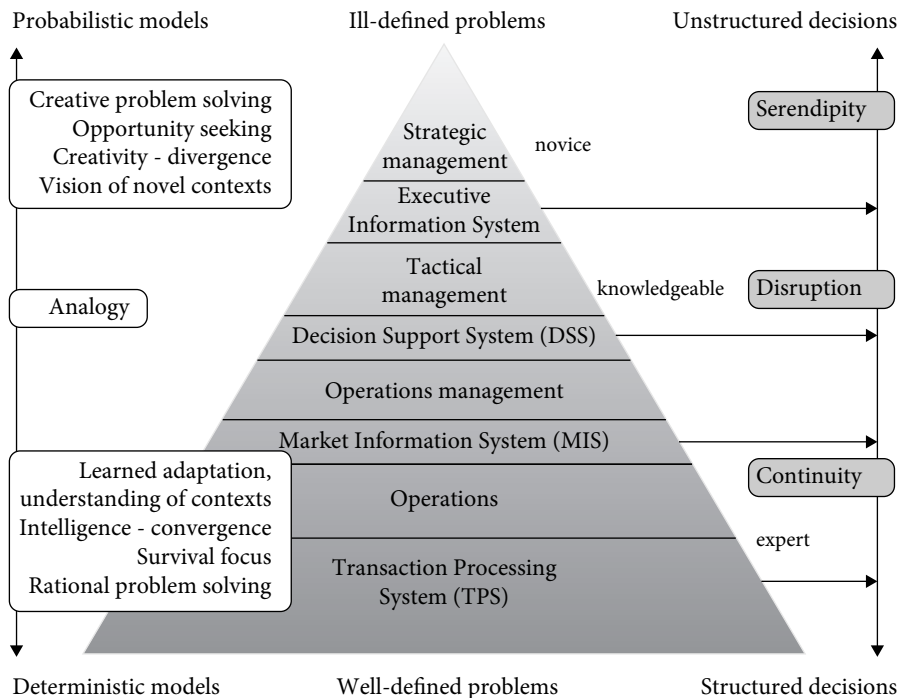


Figure 30. World view per organizational plane, type of problem solving and decision support

Due to the problem space they live in, not all innovations will be appreciated throughout an organization. Professionals will not like it when the leadership changes their production house into a service organization because it will change or perhaps even cancel their jobs completely. Reversely, management may not feel like spending much time and money on quality improvement if it does not fit the business model, although the professional just found a way to make a surface smoother, a dye more colorful, or a bolt stronger.

The workforce often complains that top management does not know what they are talking about. This is because the problem space of the work floor is rather precise whereas the leadership consists of generalists. Reversely, top management often thinks that the workforce is too narrow-minded to accept (non-incremental, radical) change. However, that is because the work floor lives in a more deterministic world where such change disrupts the routine work flow and entails a lot of adaptation work or even new routines. If all goes well, the work floor feels no need to do things differently.

17.1 Middle management: Pockets of resistance or agents of change?

There is a tension between the problem space in which someone works, the willingness to innovate, and the kind of innovation that can be expected. Homans (1974) points out that craftspeople at the bottom of the hierarchy innovate the things they work with (i.e. products or processes) so to move upward. They have little to lose and can only hope to draw attention to themselves (*ibid.*). By contrast, people at the top of the hierarchy should maintain their leadership position by continuously proving their abilities. For this they have the freedom to do some experimentation, sometimes leading to major innovations. The middle group has most difficulties in changing their behaviors because they do not have the freedom to innovate at will, whereas they do fear that change may threaten their position.

With respect to middle management, Homans sketches a situation where managers concentrate on survival issues (e.g., rank, order, competition, wages). In that case, middle management may play a conservative role in the innovation exchange between top and bottom. If managers are opportunity seekers, however, they could serve as agents of change, translating and modifying the big vision into feasible terms. Homans probably is right that middle management endures pressure from two sides. When in a deadlock, disruption may be their only way out.

As said, middle management does two things: The translation of ill-defined problems (the realm of serendipity) into orderly procedures (the realm of

continuity) and feeding back the precise requirements of the work floor to senior management. Middle management cannot rely on chance alone – they are responsible for orderly work procedures and producing expected outputs. They cannot solely rely on work floor traditions either because in a changing world lack of innovation is losing market share. Without turning things into chaos, middle management may rejuvenate tradition by disruptively changing certain maladaptive aspects of deep-rooted practices.

The creative process

“... the concept of similarity is ubiquitous...” (Tversky, 1977, p. 327)

Creativity is important in problem spaces of a probabilistic kind but not absent in deterministic settings either. The current chapter proposes a process model that describes how creativity happens in the minds of individuals while happily transgressing deterministic rules and classifications. ACASIA is short for Association, Combination, Abstraction, Selection, Integration, and Adaptation and can be envisioned as a flow diagram describing the relations among a number of itself repeating stages. When ACASIA keeps within the bandwidth of accepted behaviors ('the rules'), it contributes to the continuation of the evolutionary line of creativity. When ACASIA bridges extremely large associative distances between domains or categories, it disrupts the initial evolutionary line and can start a new one. The focus of ACASIA is on establishing similarity – the flash of insight – between associatively remote entities.

Seeing and reinforcing similarity at the flash of insight contributes to the continuity aspect of creativity and innovation. The remaining dissimilarity contributes to the discontinuity aspect, a clash of meanings. Perceived similarity and dissimilarity between two remote entities are reflections of the (fuzzy) intersection and distinctive sets, respectively. The smaller the (fuzzy) intersection or the larger the distinctive sets, the stronger a connection must be made, which demands higher levels of inventiveness. Similarity can be established deliberately but can also happen at random, for example, when two or more entities that are disparate according to a certain belief system simultaneously come to mind (co-occurrence) and coincidental matches happen between the features present in the associated semantic networks or feature sets. These may be partial matches (cf. fuzziness) or correlations and, therefore, form a basis for elaboration in order to strengthen the discovered connections (from correlation to co-relation to creation). As a result, the brain establishes new neural association paths between areas where concepts are stored that were earlier unrelated. It thus follows that exposure to large quantities of diverse information and allowing many loose-fitting associations to the core concepts (cf. divergent thinking, free association, brainstorming) raise the likelihood that lucky combinations will strike. When they do, they stimulate the growth of a tighter network of neuronal connections, which together constitute the new belief system. The present chapter ends with a simulation of the ACASIA model and the designs it suggested.

1. Cross-fertilization

The current and subsequent chapter form the heart of *Creative Confluence*. This chapter zooms in on creativity per se, exemplifying how it works its way through probabilistic problem spaces. The next chapter shows how this mechanism produces output that we recognize as a growth curve of creative development, evolving from probability to determinism. Both chapters are perhaps most difficult for many readers, but others may find them most enjoyable. Whereas the previous chapters mainly reviewed and synthesized existing work, the upcoming two chapters are more ‘active,’ presenting models, simulations, and research results.

The current section discusses cross-breeding and cross-fertilization between species to relate this occurrence to human conceptual blending. This is to argue that what we do in our minds is replicating mentally what nature inherently does already, demonstrating to us that categorical contradictions can be turned into concrete manifestations of reality.

Some would say that this is farfetched. That it is impossible to compare organic species, which develop naturally, with cultural artifacts, which come from human fantasy. One obvious difference would be that artifacts can be combined across different domains (e.g., typewriter plus television plus tape recorder become personal computer) but that biological organisms cannot be combined across species (Basalla, 1988/1999, p. 138). Well, that remains to be seen.

According to Kozo-Polyansky (1924/2010), evolution shows many examples of separate species merging into one single organism (*symbiogenesis*). This way, certain bacteria became the mitochondria of plant cells. Or, fungus plus algae became lichen. What once was an intruder became part of the genetic inheritance. *Mesodinium chamaeleon* is a single-celled organism that has distinct features of a plant (i.e. photosynthesis) as well as an animal (i.e. it chases after other organisms) (Moestrup et al., 2012). The advantage is that these new species can occupy evolutionary niches that their ancestors cannot. As Christian put it, “Migration into new regions, or minor innovations in lifeways or genetic endowment, may enable a species to widen that niche, or even to exploit new niches or new regions” (Christian, 2011, p. 133).

Incompatible species can exchange genomes when they come into close contact with each other, for instance, when an oak tree intertwines with a birch. This non-sexually transferred genetic information can be inherited by the next generations, producing an organism with new capabilities. The DNA even may become a mixture of the donor and the recipient (Stegemann et al., 2012). This is not vertical inheritance but a ‘horizontal gene transfer,’ not limited to bacteria or other micro-organisms without nuclei but also found between disparate animal tissues after transplantation.

Kozo-Polyansky regards biological cells as cooperative systems that allow cross-breeding. Dawkins alludes to the same possibility (Dawkins, 1999, p. 3). To date, there is quite some evidence for the migration of genes and genomes across species (e.g., Gogarten & Townsend, 2005). This produces novelties that can be passed on to later generations.

But hybrids also may be bred sexually, for instance, through interspecies mating of animals. Here, the inheritance of genetic information is vertical: When a polar bear mates with a grizzly, their offspring becomes a “grolar bear” or “pizzly” (Mallet, 2008). A tiger with a lion breed a “liger” or “tigon;” horse and zebra produce a “zorse” or “zebroid;” camel and llama make up a “cama;” dolphin and killer whale make a “wolphin.”¹ In a review paper, Mallet (2007) estimates that 10% of animal species and 25% of plant species probably hybridize; many of them being fertile and reproductive.

After all, *symbiogenesis*, horizontal gene transfer, or interspecies breeding may not even be that awkward when you come to realize that through organic synthesis, chemists are capable of designing and creating new bioinspired molecules from natural ones (Wender & Miller, 2009). These natural compounds constitute complex biochemical systems responsible for many if not all aspects of life, procreation, and death. Yet, the functions of these non-natural, designed molecules are sometimes completely unique and superior to the compound molecules they were created from (ibid.).

2. The symbiogenesis of ideas

When humans naively look upon nature, many miraculous events take place. Fire from a mountain becomes fertile land, an acorn becomes a tree, moist air against a cold window turns into ice flowers, little fish become frogs, and caterpillars transition into butterflies. Without deep knowledge of physics or biology, what makes this happen is a true enigma and to an uninformed belief system, these occurrences are a transgression of conceptually fixed categories (i.e. fire is not land, an acorn is not a tree, moist air is not ice, a fish is not a frog, a caterpillar is not a butterfly). As people began to see associatively remote entities transform into one another, they started to imagine other metamorphoses as well (Hoorn, 2012, p. 76): Strands of hair became snakes (Medusa), a river nymph became a laurel tree (Daphne), a hunter became a horned stag (Actaeon).

In shifting from one entity into another while staying within the same natural class, natural metamorphosis is a manifestation of continuous, evolutionary

1. <http://www.hemmy.net/2006/06/19/top-10-hybrid-animals/>

creativity – it is a drastic upgrade or redesign of the same entity, going from a current to a desired situation. Humans, however, perceive the great adaptations and reorganizations of materials as a disruptive shift from one conceptual category to another, which they are forced to combine mentally into one blend (Hoorn, 2012, pp. 77–78).

Another natural occurrence that may have served as an inspiration to human creativity is the crossbreeding of flowers and animals (previous section). Cross-breeds within category, of course, lie within a continuous line of innovation: A red tulip with a white tulip breeds a pink tulip. In horticulture, however, gardeners intentionally put the branch of one plant (the ‘scion’) into the stem of another (the ‘rootstock’).² Such hybrids (or *graft chimaera*) are artificial fusions of unlike tissues of two species and they grow and flourish together sometimes better than their parents do. Organ transplants and genetic engineering, obviously, follow the same pattern of thinking, hoping for vital improvements and better fitness by combining distinct qualities.

From the occurrence of (misunderstood) metamorphosis, *symbiogenesis*, interspecies mating, and *graft chimaera* that sometimes grow naturally, people may have inferred that creative evolution does not have to be incremental but also may proceed by unexpected mergers between unlike categories. Unique combinations between entities from different categories that can adapt to new circumstances may have inspired human imagination to make the category violation a bit wider, combining stems instead of branches of the evolutionary tree: A fish combined with a woman makes a mermaid, a horse with a man produces a centaur, lion and eagle make up a griffin, and recently, a rooster with a rhinoceros make a rhinooster (Figure 1).



Figure 1. A rooster-rhino or rhinooster

Basalla (1988/1999, p. 138) contended that unlike cultural (i.e. technological) artifacts, organisms cannot be combined across species. Yet, we just saw plenty of examples of the reverse. His argument can be saved, however, if we allow the nuance that for human creativity it is by far easier to combine any two species or artifacts than it is for nature.³ In nature, more constraints determine what can be crossbred

2. See for example, the cactus polyp *Myrtillocalycium* at <http://northants.bcss.org.uk/nl172/nl172odds.htm>

3. For example, try the *Spore Creature Creator* at <http://www.spore.com/>. For an introductory clip, see <http://www.youtube.com/watch?v=Ox3gvP7osPo>; <http://www.youtube.com/watch?v=mDUIDO-Njho>

than what is possible in fantasy. From near-determinism to probability: Cross-breed between categories in the natural world is hard but not impossible, in technology feasible, in the arts, no problem (Figure 1).

Human creativity is nature's accelerator to fill up niches in evolution more quickly than ever before (Lowcre, 2013, pp. 20–21). As through crossbreeding, nature makes it pretty hard for humans to strictly discriminate between stimuli (e.g., Mallet, 2010), fuzzy perception and categorization opened the way to making creative blends. In deliberately making cross-category combinations, human creativity may be envisioned as a hyperbolic form of hybrid speciation: The artificial symbiogenesis of ideas.

That very same faculty gives way to magical thinking and illusory experiences as well (Hoorn, 2012, Chapter 4):

Like the caterpillar's metamorphosis into the butterfly, death doesn't end our existence but frees us to pursue an even greater development.⁴

And indeed, Hindu incarnation into another species is not unacceptable once you allow that natural categories are permeable and that life springs from dead matter (see Schrödinger, 1944/2010). It is all a matter of deviation tolerance within a certain belief system that is or is not accepted in advance (Hoorn, 2012, pp. 151–153).

The remainder of this chapter, then, focuses on the combination of familiar objects or concepts ('entities') in an unusual way. It will proclaim that the association, combination, abstraction, selection, integration, and adaptation of features are human means to establish an optimal fit between two or more associatively remote entities. An entity can be anything, an object, concept, or a complete context (cf. Pfenniger & Shubik, 2001, p. 235). The sub-goal is to find (a quantity of) similarity where no one saw it before. The end goal is to expand the possibilities of a given situation, (showing how) to find new directions for solutions, new ways to achieve an objective, a new niche, to pose a new question or to give a new answer.

Depending on signal strength, personal sensitivity, and tolerance levels (Hoorn, 2012, p. 137), the balance between similarity and dissimilarity may decide whether the combination can be regarded as a 'creation.' The effect of a creation may be surprise as a function of the tension between similarity and dissimilarity of the combined entities. Depending on their goals and concerns, people may qualify such a creation as satisfying, aesthetically pleasing, useful, valuable, apt, relevant, culturally significant, etc.

4. <http://www.himalayanacademy.com/resources/pamphlets/KarmaReincarnation.html>

3. Five steps

Next, I will try to find out how precisely the process of creativity works. The study of creativity counts an incredible number of models that one way or the other allow for (aspects of) the creative process. Greene (2001; 2004) offers an exhaustive overview and comparison, where models range from explaining surprise, to non-linear systems, paradox generation, social movements, and beyond.

In spite of all these differences, most commonly, five steps are discerned in the process of creating (cf. Wallas, 1926; Csíkszentmihályi, 1996, p. 79–80). *Preparation* is to become immersed into a question, societal issue, or problem that raised curiosity. Here, understanding the problem takes place, formulating the goal of the challenge, asking the right questions (cf. problem finding), collecting information, reading up on the literature, and gathering artifacts that may be relevant associatively.

During *incubation*, people start mulling over the problem unconsciously, making unusual associations. Here it is important to take multiple perspectives on the problem (divergence), freely raise ideas, thoughts, and associations in an appreciative empathic way without further qualification (“Yes! And...” instead of “No, but...”). Savransky (2000, p. 167) lists a number of phrases that can be regarded as true innovation killers (e.g., “That’s not in your job description,” “Put it in writing,” “We’ve done alright so far,” “Be practical!”). Fisher, Ury, and Patton (1992, pp. 59–60) advise to “separate the act of inventing options from the act of judging them.” Judgment hinders imagination (ibid., p. 58, p. 60) and critical thinking should be separated from creative thinking (ibid., p. 60).

Then the great insight should follow but sometimes this moment is postponed because evaluation may take place anyways during the creative loop. Before the moment of insight, then, certain evaluative steps may occur (cf. convergence). For example, ordering, connecting, and selecting ideas is done on personal impact and intuition (“Does it touch me? I feel there is something in it”).

Evaluation or verification entails uncertainty and insecurity while confronting ideas with the criteria of others. These evaluative steps may sometimes result into strong feelings of deception and disappointment (e.g., door slamming, emotional outbursts) because all that came up so far seems to be completely trivial to the case (cf. convergence). This is a stage that takes great perseverance, self-confidence, and leadership to yet push through.

Then the *flash of insight* or *illumination* takes place (cf. the ‘jump’); also known as *epiphany*, the Eureka moment, Aha-experience (see the Prague School linguist Bühler, 1907), or Gestalt switch. The idea behind the Aha experience in Gestalt psychology is that it goes against functional fixedness. Someone (in a group) ‘sees’ the connection between a number of remote ideas and now the new creative

concept can be formulated, supplemented with supporting ideas and a storyline. This new concept predicates all the creative decisions that follow from it and each choice can be tested against that very concept.

During the *elaboration* of the new concept, ideas are written down, visualized, communicated, and brought back to the original problem (“Is the proposed solution still in line with the question at hand?”). This stage requires craftsmanship and the materialization of ideas in concrete forms (e.g., text, image, music, stone, performance, story, etc.). At this instant, the implications and specifications are formulated for the further implementation of the concept in real life as a perpetual beta version of a solution that will be constantly redesigned (incremental change).

The linearity of this process only counts by and large. For example, elaboration can take place only after an idea was born but if that happens right away, elaboration may occur early in the process. However, loops between the several phases are quite frequent, phases are skipped, or the order of phases is changed. Although not recommendable, evaluation often interferes with incubation and then inhibits free associative flow and ideation. In other words, evaluation should commence after incubation has finished. Yet, the creative process can be restarted at any given point and is less linear than recursive (Csíkszentmihályi, 1996, p. 80).

4. ACASIA

ACASIA describes how creativity happens in the minds of individuals (Hoorn, 2002) and can be envisioned as a process model, describing the relations among a number of recursive stages. ACASIA could count as a specification of Bransford and Stein’s (1984) IDEAL model of solving ill-defined problems: Identifying problem, Defining it, Exploring problem strategies, Acting on the problem strategy chosen, and Looking back to evaluate the effectiveness of the chosen strategy.

Figure 2 offers a rough overview of ACASIA, which later on in Figure 14 will be improved. *Association* is the capacity to generate images, words, meanings, and other semantically related features in response to a stimulus (an entity) (cf. Smith, Shoben, & Rips, 1974). *Combination* is the process in which connections between associations of disparate entities are established, rooted in a matching mechanism of (fuzzy) feature sets and reflected in a measure of perceived similarity (and hence, dissimilarity). *Abstraction* is a means to bring certain phenomena on such a conceptual level that the connection actually can take place (i.e. similarity increases at higher abstraction levels). *Selection* is to dismiss those features that cannot be

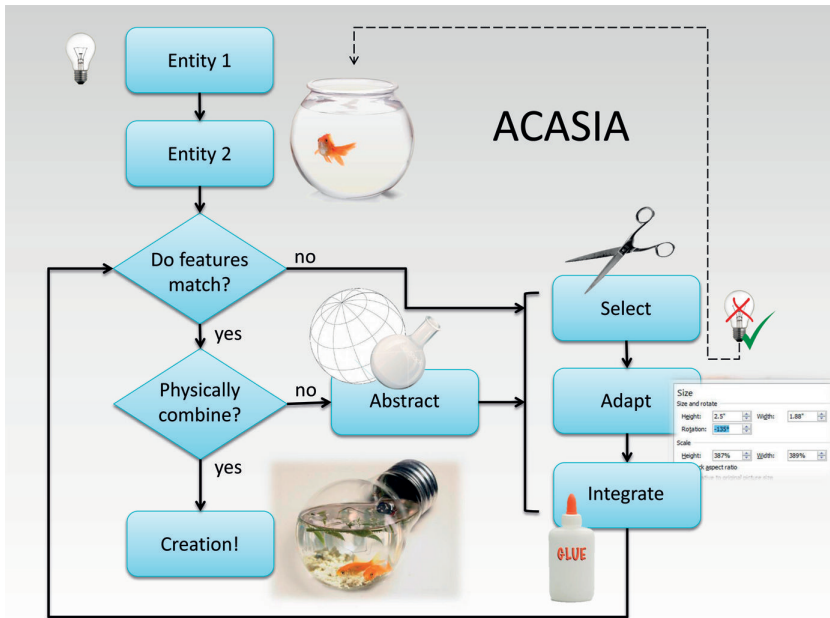


Figure 2. ACASIA simplified version

used to make the combination acceptable in the eyes of the creator or her audience, hence affecting the measure of dissimilarity between disparate entities. *Integration* is an activity to literally attach the features of one entity to the other. *Adaptation* is to change individual features such that the transition from the one entity to the other would become acceptable (i.e. optimizing the blend). In the next sections, I attempt to put the ACASIA stages into place with the five steps of the creative process, while explaining them more thoroughly.

5. ACASIA in five steps

5.1 Preparation: Familiar but unusual

To become acquainted with a question or problem in the *Preparation* phase and to comprehend the ins and outs of an issue, some form of study is required. This could be desktop research, going to art school, stakeholder consultation, participatory observation, traveling, or experimentation in a laboratory. Yet, all these forms of collecting information are meant to increase the knowledge about a problem space, upgrading the belief system, which might provide an angle to a

solution. Familiarity is the reflection of the number of features (including relations with other features) that a person mentally activates in response to an entity (cf. Tversky, 1977). The more someone knows about something, the more he or she can tell about it. Thus, familiarity of an entity pertains to the level of knowledge someone has about it, which is materialized in the size of the elicited feature set (for a refinement of this view, see Shiffrin, Huber, & Marinelli, 1995). High levels of familiarity contribute to the experience of continuity in a line of innovations, affect the level of perceived (dis)similarity, and are conducive for innovation acceptance. This is also the stage in which problems are reformulated or newly found (e.g., Runco, 1994; Mumford et al., 1996). Although Chapter 3, Section 10.3, indicated that creativity may be suffocated by an overdose of knowledge and expertise, becoming familiar with a problem domain is nevertheless of interest (e.g., Csíkszentmihályi, 1996, p. 47). Finding the right question may evolve from challenging the original question, which can be done by preparatory studies.

In Hoorn (2002), I stated that making something new, unique, and dissimilar from everything that was ever seen before is hard because something cannot be made if there is nothing to make it from (cf. the continuity view). Ingres (1822) already stated that “You don’t get anything from nothing” (cited in Boyer d’Agen, 1909, pp. 419–420). Hoorn (2002) contends that people need something old to understand the new (e.g., Rosch & Mervis, 1975; also Ward, Smith, & Finke, 1999, pp. 193–194) and creators are no exception to that. Making something new, Hoorn (2002) continues, usually brings together familiar things but in an unusual connection (e.g., Csíkszentmihályi, 1996, p. 9). Runco and Sakamoto (1999, p. 67) report on empirical studies suggesting that creativity stems from combining exemplars from remote categories while “restructuring” their features.⁵ In jest we may state that, in creativity, we are looking for ‘familiarity.’

Hoorn (2002) introduces a bike frame standing on its back suspension fork (Figure 3) and claims that the features that make the bike look familiar are its cog-wheel, cranks, steel tubes, and shape. There is also a picture of a prancing horse with four legs, manes, and hooves. The separate pictures are quite common but in unison they create a new image, a prancing horse of iron (Figure 3, at the right). Hoorn (2002) asks what the ingredients are that let most people judge that the third picture is more creative than the other two?

5. Watch “Everything is a remix” at <http://www.youtube.com/watch?v=nxrjsHSbHkY>

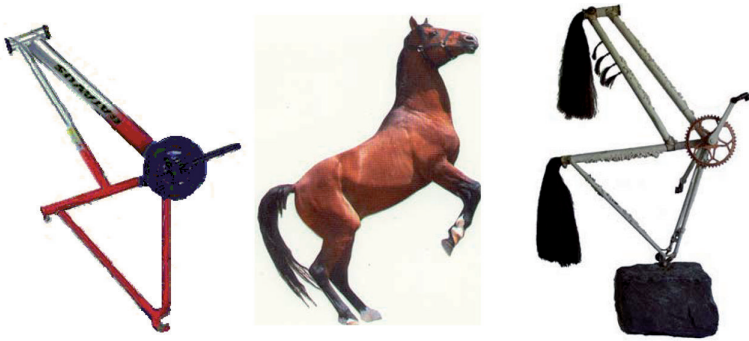


Figure 3. Prancing horse of iron (Hoorn, 1989) combines bike frame with horse content (Hoorn, 2002, p. 187)

5.2 Incubation: Association and types of features

Cognitive accounts of what happens during incubation assume that information processing goes on even when we are unaware of it, following the rules of association (Wallas, 1926, p. 86; Csíkszentmihályi, 1996, p. 101). Subconscious thinking does not follow rational lines, yet it follows patterns that were established during conscious learning (Csíkszentmihályi, 1996, p. 102).

The entities combined into a creation always have a certain degree of familiarity. This has to do with the elicitation or the association of features for those entities. The term ‘feature’ is used quite loosely here. Features may be properties and attributes but also meanings, words, sounds, images, relationships or anything else that comes to mind. Humans continuously activate features for the things they encounter to compare them with the features of other entities. When a feature set is empty (read: when someone knows nothing about it), there is nothing to compare or connect, and thus, the creative expression remains meaningless, incomprehensible, or anomalous. The associations that are elicited do not need to be obvious or close by; they may be of diverse and apparently unrelated nature (Pfenniger, 2001, p. 92). People in an uncreative mode merely have close associations; people in a creative mode also have remote associations (Martindale, 1999).

The more and the more *diverse* features someone has available, the higher the probability that a person will find a match with or can make a connection to features of another (distant) entity. Note, however, that there is a ceiling effect. If people have too many ‘factual’ details available and do not allow for farfetched associations, each and every feature of the one entity will seem to differ from each and every feature of the other entity (cf. the way computer compilers interpret code). Signal strength calculated as the number of features that indicate the stimulus will be high

and hence will allow for strong stimulus discrimination. How much someone knows may differ from entity to entity (cf. Chapter 3, expert on one thing, novice on another). As said, one should be knowledgeable but not an expert in order to be creative and the association range should be indifferent to common category boundaries. When a creator starts *associating*, it is a way to assess familiarity of the entities and to estimate the probability of finding matches or connections between them.

5.2.1 *Feature sets, semantic networks, associative models, and statistics*

How exactly semantic memory works and whether associations should be represented by a feature list, a network, or a stochastic process remains a scientific debate. The feature set approach represents associations to a stimulus as a list of relatively unstructured meanings, words, etc. Relations between concept classes are not readily available but rather are computed in an indirect way (cf. Tversky, 1977). Features may have a weight, which may indicate frequency of occurrence, salience, or ease of retrieval. Weights are influenced also by the perspective of the observer, goals, concerns, biases, priorities (cf. Hoorn, Breuker, & Kok, 2006) but also typicality. Certain features may be more central to an exemplar and certain exemplars more central to their categories, which makes them prototypical (Rosch, 1973). A cat is more prototypical to the category of mammals than the platypus. Fur is a more prototypical feature of a cat than its *tapetum lucidum*. In recent set theories, category boundaries are not crisp but rather ‘fuzzy’ (Zimmermann, 2010), allowing that with a certain probability features are a member of multiple sets as based on global or partial similarity (i.e. features do not have to be identical to establish a match).

Semantic networks consist of interrelated nodes, which are words, attributes, features, concepts, etc. The links go one way only and point from a base node to a target while links can represent any kind of relationship (e.g., proposition, possession, analogy). Semantic networks usually spread activation over nodes where the links may differ in length or have different weights to account for differences in accessibility of features (cf. Kintsch, 2008).

Alternatively, instance theory envisions associative learning as cued recall. People would remember individual examples in separate traces. When confronted with a cue to the example, all traces are activated simultaneously and selected via a weighted sum of the traces (the “echo”). The model proposed by Jamieson, Crump, and Hannah (2012) explains a host of associative learning phenomena such as acquisition, generalization, overshadowing, and many more.

Association models work much the same way as semantic networks except that the association is defined as a pair. Each node represents one unique concept in memory but to speak of an association it is always connected to another. An association, then, always entails the co-occurrence of two distinguished entities in the mind. The associative strength between two concepts can be estimated from

the established links. A concept can be evoked by another concept or by the context in which it is encountered. The frequency of co-occurrence indicates 'semantic relatedness' (cf. Raaijmakers & Shiffrin, 1981).

Stochastic approaches are indebted to the previous ones in that concepts are connected to contexts in a matrix form, cells containing the frequency of occurrence of a concept in a particular context (e.g., words typical for a text genre). Semantics are derived by employing statistical procedures, for example, by relating the found structure to target ontologies or through the correlation of concepts with contexts that occur together in a corpus (cf. vector spaces in Turney & Pantel, 2010).

The semantic networks, association frameworks, and stochastic models constitute the 'traditional' approaches to association with Newell and Simon (1961) or Fodor (2008) as their key proponents. Those approaches are most successful in reasoning types of problem solving, which demand abstract representations. The latest development is the idea that concepts are not stored as abstractions per se but are connected to sensori-motor associations. Theories of 'embodied cognition' (e.g., Johnson, 1987) claim that the amodal symbolic logics of association attempted by 'rational' approaches should be replaced (or at least supplemented) by empirical and perceptual experience: The modality by which associations are formed (e.g., touch, smell, pain), weigh in as they may establish arbitrary connections to the world. Strange associations are possible this way (cf. Barsalou, 2009), which are conducive to metaphor and creativity. For instance, learning what a table is by bumping into it, the word 'table' may not only stand for the desk-like object but also for 'pain.'

This overview is inevitably sketchy and incomplete. Irrespective of the veracity of the proposed theoretical positions, most important in understanding the role of association is that entities trigger meanings, colors, smells, memories, relations, abstractions, bodily experiences (I call them 'features'), which in the creative process should be plenty. Features should be of a diverse kind (not only factual) and insensitive to conventional categorizations so to increase the probability that unique links are established. Putting a title to a painting, for example, is priming the interpretation of it. The word 'grass' below the image of a green square shrinks the possible range of associations (e.g., 'meadow') that the image might evoke and hence reduces the possible meanings and interpretations the green square might have had (e.g., "It's a power button") (cf. Ward, Smith, & Finke, 1999). For conventional communications such disambiguation is advantageous; for creativity, it is not.

5.2.2 *Feature types*

It is indifferent which kind of features are evoked, whether they address the relationship of possession (e.g., squares have four edges), whether they are inferences (e.g., Mondrian painted squares, therefore, he painted multiples of four edges),

contexts (e.g., in Bauhaus style), or simple attributes (e.g., square, edge, table of four, Mondrian, painting, Bauhaus). Features may be factual ('literal') or representational ('figurative'). With regard to the latter, Stevens (2001, p. 180) argues that a line in a picture may symbolically be associated with "cool" and "rational," whereas color may stand for "passionate" and "irrational" (also Steenberg, 2007). Apart from being symbols, features can also be principles of order (Pfenninger & Shubik, 2001, p. 235). One could think of compositions typical for Mondrian or the fractal patterning of Pollock's drip paintings (Taylor, Micolich, & Jonas, 1999). Certain features may pertain to form and outer appearance (e.g., edge, line, color) whereas others carry more functional and content aspects (e.g., 'tool for cutting' or 'provides relaxation') (cf. Stent, 2001, p. 33–34).

5.3 Flash of insight: Novel combinations

Conceptual combination is to make complex concepts from simpler ones, for instance, by combining an adjective with a noun (e.g., 'white' and 'horse' become 'white horse'). From a limited number of regular constituents, this way large numbers of new combinations can be created. This combination may not only be done in an abstract and amodal sense (e.g., Fodor, 2008), which is functional in reasoning tasks, but may also have an embodied side (e.g., Machery, 2007) where, for example, visual imagery is connected to 'white' (e.g., Snow-white) and to 'horse' (e.g., a knight in shining armor).

Insight is the conceptual formation of a novel combination across category boundaries, which causes a flash effect. It is the Aha experience or "happy idea" (Wallas, 1926, p. 80). Such a connection may be deliberately sought after or is the result of blind chance ("serendipity").

Most of the literature from a wide range of disciplines agrees that making new combinations lies at the heart of creativity (e.g., Poincaré, 1913, p. 286; Mendelsohn, 1976, p. 366; Csíkszentmihályi, 1996, p. 9; Albert & Runco, 1999, p. 25; Miller, 2000, p. 324; Damasio, 2001, pp. 65–66; Pfenninger, 2001, p. 96; Heilman, Nadeau, & Beversdorf, 2003; Ansburg & Hill, 2003; Santanen, Briggs, & De Vreede, 2004; Mashal et al., 2007; Fleming & Mingo, 2007; Davids, 2008, p. 437; Arthur, 2009, p. 20; K. Kelly, 2010, p. 45; Ward & Kolomyts, 2010, p. 101). In Lowcre (2013), we argued that combination is fundamental to creativity in physical nature and is sustained and optimized in the creativity of organisms.

The only challenge I saw to combinatory creativity is Boden (1999, pp. 352–353; Boden, 2009), who argues that there is something she calls exploratory and transformational creativity. Exploratory creativity stays within the boundaries of a given style, genre, or theory. I would say it is the incremental kind of creativity within an evolutionary line. Transformational creativity is an aspect of exploratory

creativity in that it changes the rules under which something is made, for example, if in a drawing people are allowed to have three arms instead of two. I believe that rule transformation surely can help to broaden the bandwidth of possible behaviors. In the section *Organic creativity*, however, I will argue that actions such as rule following or rule transformation may be of influence but are not central to creativity. I guess I join the majority of authors here when I state that creativity is to make the unique combination, fresh blend, the original crossover, or the “sudden juxtaposition of seemingly incongruous ideas” (Medawar cited in Cech, 2001, p. 17).

A range of authors combines the notion of making novel combinations with qualifications such as “useful,” “valuable,” and “impactful” (e.g., Sternberg & Kaufman, 2010, p. 481; Simonton, 2009, p. 23; Hoorn, 2002; Pfenninger & Shubik, 2001, p. xi; Sternberg and Lubart, 1999, p. 3; also Mayer, 1999, p. 450). Here I depart from the position of most authors in that I strongly believe that aspects such as evaluation and selection are creative moderators rather than a part of the creative act itself (see *Organic creativity*, Section 6).

It is possible to make a novel combination without it being useful, impactful, satisfying, or aesthetic at all. Selection on aesthetics, for instance, may even be a conservative act rather than an innovation strategy. Organisms systematically show a biological preference to group averageness, to what is known (so-called *koinophilia*), because this would indicate fitness for survival (i.e. healthy genes) (Koeslag, 1999). On that view, mutant features and fringe individuals are suspect (ibid.). Yet, pure creativity advances beyond the known, making novel crossovers, mutating features and originating *unica*, not *replica*. They provide the features that help adapt to change (cf. Lumsden, 1999, p. 158).

In physical creativity (Lowcre, 2013), substances combine into new matter without any purpose – it just so happens. Although perhaps aesthetically pleasing, machine creativity generates fractal images independent of sentiment or any particular idea of beauty (Mandelbrot, 2001, p. 210). Something creative does not have to be purposeful, emotional, or beautiful; it is merely there. Organic or even human creativity also may happen without being useful. There are thousands of patents on the shelf that will never be put into practice. There are dozens of artists who were mocked at first and discovered or rediscovered decades and sometimes ages later. They are the suspect mutations and fringe individuals, the sleeping beauties, lying in wait to come to expression (be useful) when the time is ripe, that is, when things have changed (cf. Albert & Dennett, 1995, p. 248).

5.3.1 Feature matching or correlations

Runco and Sakamoto (1999, p. 69) review Rothenberg and Hausman who found that if two images were visually superimposed on one another more creative new identities and metaphors would be produced than through analogical, association,

or Gestalt processes. These authors also discuss (ibid., p. 68) experimental results of Baughman and Mumford, who found that original categories arose only when at least two feature sets of remote entities occurred *in tandem*, where intersecting *unusual* features were used to construct a new category (“inclusion”) (cf. Ranjan & Srinivasan, 2010) or distinctive mundane features were eliminated to construct a new category (“exclusion”). Ivancevic and Ivancevic (2007, p. 86) report on the technique of “focal objects,” in which the distinctive features of two or more entities are synthesized into something new.

If making novel combinations is at the center of creativity (cf. Joycean language), then its main mechanism is to connect two (or more) previously unconnected feature sets, semantic networks, or associations. When this is done within a known category, the creativity is incremental. For example, one could mix the horizontal movement of Arab belly dancing with the vertical motion of Greek line dancing to create a new style of dance. All three are dances but, in the third, these particular features were never combined before. When the connection is established outside common category boundaries, creativity is disruptive: For example, a ballet dancer with a robotic exoskeleton could lift the prima ballerina or multiples of her in ways that are humanly impossible, making moves that may not even be called dancing any longer.

Through adaptation and selection of features, mixing and matching feature variants among parental entities may lead to series of recombinations. It could well be that in the beginning of a new innovation line the category boundaries of parental entities are fuzzy while during development (feature selection, increasing rule pressure) they gradually become more closed (see Chapter 5).

If we want to capture these considerations within a theoretical framework, a practical difficulty is whether we should envision the connectivity between remote entities in terms of, for example, the comparison of feature sets so to calculate matches and mismatches or, for example, in terms of the correlation between nodes, matrix cells, etc. Keeping in mind, however, that on a global theoretical level it is of minor importance what the detailed representation should look like, most of the characteristics of the one approach can be accounted for by or combined with the other approach. In Chapter 3, I represented the comparison between current and desired problem state as the matching of feature sets and I will stick to that convention for now.

5.3.2 Fuzziness

For creativity to happen, category boundaries and the membership of an exemplar to a category should not be too clear. If categories were dichotomous (feature is in or out), signal strength and stimulus discrimination would be too strong to make the unexpected crossovers. Therefore, features of an entity should be regarded as

belonging to a fuzzy set: With a certain percentage they can be more-or-less a member of a number of categories (cf. have stronger or weaker connections to other nodes).

In combinatory creativity, precision and definitive parameters should be traded for ambiguity and uncertainty. Fuzzy set theory offers a mathematical approach to vague concepts and notions as well as a modeling language for indistinct criteria, relationships, and phenomena (Zimmermann, 2010). Fuzzy sets can handle various grades of determinism and probability in a problem space, which as a theory makes it suited to handle creative serendipity in an innovation line that may become more deterministic over time (cf. Chapter 5). In other words, to become a member of another category, features do not need to match completely with the features of that second category. Features may partially match; they need not be identical.

5.3.3 *Similarity, dissimilarity, complementarity, and perceptual biases*

As soon as someone perceives that two or more features (partially) match, a certain measure of similarity transpires (Tversky, 1977). Under soft constraints, for example, robins and blue jays may count as similar (Hélie & Sun, 2010). If creativity is about the combination of features from associatively more remote categories, then creativity is about perceiving similarity where it previously was not seen. The resemblance between a light bulb and a fishbowl may count as a case in point (Figure 2, Figure 4).



Figure 4. A light bulb shares certain features with a fish bowl

Yet, not all features between two entities match. And the features that do match do not do this to the same degree. In addition to a measure of similarity, then, simultaneously a measure of dissimilarity emerges (Ranjan & Srinivasan, 2010) as a reflection of the sizes of the distinctive feature sets (Tversky, 1977). For example, a fishbowl usually does not have an Edison screw (Figure 4) but the Edison screw adds to the impression of a light bulb. Further, certain perceptual factors bias the estimates of similarity and dissimilarity, depending on the focus of attention, direction of comparison, or the proportional relationship between the size of the intersection and the sizes of the distinctive sets (Tversky, 1977). Hence, these and other perceptual biases (Heit, 1997; Weber & Osherson, 2010) also concern claims to creativity.

However, similarity is not based on near-identical features alone but also on complementary features. Dawkins (1999) claims that genetic information coding

for a particular characteristic or behavior (perhaps through intermediate steps) are building blocks that contain parts of a design plan that needs additional information to create a complex organism. Thus, information combines with different but complementary information (e.g., hair color with bone structure) but competes with information that codes for the same function in a different way (e.g., brown or blond hair). In other words, dissimilarity is preferred when it adds to the concept (e.g., a pony tail attached to a bike frame). By contrast, not all similarity is preferred when two features occupy the same function (e.g., a bike saddle or a horse saddle).

5.3.4 *The flash of insight and the clash in hindsight*

As a result of finding a new combination, creators would experience the ‘flash of insight,’ which often is hailed as the hallmark of creativity. Cech (2001, p. 15) states that both artists and scientists have flashes of inspiration or “rapid insight.” “As if by a flash of lightning I awoke” August Kekulé writes when he realized that the molecular structure of benzene looks like a ring (Roberts, 1989, pp. 75–81).⁶ According to Greek legend, Archimedes shouted “Eureka” when he found a way to measure a body’s volume. The Aha experience would come from “luminous detail” as Ezra Pound put it: “... certain facts give one a sudden insight into circumjacent conditions, into their causes, their effects, into sequence, and law” (Kern, 1996, p. 146).

The flash of insight is considered to be related to breakthrough thinking (Perkins, 2000; Csíkszentmihályi, 1996, p. 80) and behavioral and brain studies have investigated its experiential and neuronal correlates. Creative insight has hedonic value. It is sudden, fluent (easy), is accompanied by positive affect, and makes the creator feel highly confident that the insight is right (Topolinski & Reber, 2010). In line with Martindale (1999), behavioral, brain-imaging, and EEG studies point out that the more diffuse attentional states needed for creativity are mainly supported by the right hemisphere (Anaki et al., 1998; Bowden & Jung-Beeman, 2003; Schmidt et al., 2007; Jung-Beeman et al., 2004; Sotillo et al., 2005; Grabner, Fink, & Neubauer, 2007). So far, however, brain studies were not capable of identifying specific neuronal markers related to the insight experience (cf. Kounios & Beeman, 2009).

Because creative insight concerns the mental reconciliation of entities that seemed to be unrelated at first, it is worthwhile to look into the process of metaphor comprehension, which is based on similar assumptions (cf. Ward, Smith, & Finke, 1999, p. 192). In following Koestler’s (1964) idea of “bisociation of matrices,” Turner and Fauconnier (2002, p. 37) advance the notion of “conceptual blending.”

6. The concept of insight, although genuine, also suffers from severe mystifications as Miller (2000, pp. 340–341) pointed out for Kekulé.

This supposedly is a subconscious process in which aspects of different conceptual domains are integrated and line up with each other. In “His *sunny* smile *lit up* the room” (ibid.), aspects of seeing have been put into correspondence with feeling.

Steen (2008, p. 222) qualifies “deliberate metaphor” as explicitly meant to change a person’s perspective on a topic by looking at it from a different conceptual domain. The apparent falsehood of the assertion is compensated by drawing new information into the equation (ibid.). However, instead of a ‘flash of insight,’ this type of metaphor theory assumes a ‘clash of meanings.’ For example, Beardsley (1982, p. 264) states that in novel metaphor, “the concept loses its ordinary extension because it acquires a new intention and this twist in meaning forces inherent tensions and oppositions.”

I prefer to state the theory as a theory not about the effect of metaphor, but about the linguistic structure that causes the effect – about the ‘clash of meanings’ itself. (Beardsley, 1982, p. 267)

In Hoorn and Woestenburg (1996, 1997) and Pynte et al. (1996), brain studies showed a systematic negative shift in the EEG amplitude 400 milliseconds after metaphor presentation that was related to semantic unexpectedness. This so-called N400 potential is usually interpreted as a reflection of the mismatch between semantic expectations based on previous or surrounding context (cf. the priming or disambiguation of meaning) (Kutas & Federmeier, 2009). In metaphor, this signal could be seen as a marker of the ‘clash of meanings.’

However, the clash of meanings is an effect in hindsight, whereas the creator experiences a ‘flash’ due to foresight. We could go about this in two ways. Each creator is the first perceiver of his or her own creation so that N400 reflects the clash that the creator experiences after having made an unexpected combination (‘I surprised myself!’). In that case, N400 is the substrate of the (semantic) disparity between entities or, put differently, N400 would be a function of the remaining dissimilarity between entities; a violation of the rule-based categorizations (cf. Hélie & Sun, 2010).

Yet, a flash is not a clash and the behavioral literature does not talk about disagreement and restoring associative conflict. On the contrary, the scientific and anecdotal literature has it that it is a most satisfying, smooth, and unifying experience: “Here the goal is to restore harmony in the system by reconciling the apparent disparities” (Csikszentmihályi, 1996, p. 114). The absence of N400 or any other marker of unexpectedness during the creation of a novel combination (cf. Kounios & Beeman, 2009) could be the indication of just that: The focus is on similarity, not on dissimilarity. Thus, creativity is signaled by an out-of-category connection, yet without the occurrence of the N400 component. It perhaps may be that the focus on similarity explains the absence of N400. It does not explain the experience of a

flash, which seems to describe enhanced electric activity where it was not before, comparable to a stroke of lightning.

Damasio (2001, pp. 60–61) indicates that subtle modifications in the function of brain circuitry probably explain variation of talents and characteristics among people. The human brain is densely wired with recursive and bidirectional pathways that link lower cortical areas, in which concrete images are stored, with higher association areas that hold abstract representations. In connection, ‘mental images’ occur that can be elicited by sensory input and by higher association areas. This function of the brain makes it possible to have internal mental representations, which we call ‘mind.’ The wiring of the pathways, then, explains what kind of mind we have. Pfenniger (2001, p. 92) adds that creativity involves the association of diverse and apparently unrelated entities and that the brain’s plasticity allows that neurons adapt their connectivity to function (*ibid.*, p. 95). In other words, new semantic connections will not only be associated or correlated but over time become hard-wired in the network of associations:

... complete sets of data stored in many different circuits in the cerebral cortex may become integrated, perhaps in a novel way ... and this may result in a new vision of, or the discovery of a new causal relationship between these data sets. Such a process would constitute creativity.” (Pfenniger, 2001, p. 96)

Thus, the flash of insight could be the effect experienced by the creator of the first time that an electric current runs through a newly established neuronal connection. Synapses clasp together and voltage oscillations in the pre-synaptic cell for the first time hit the post-synaptic cell. Perhaps the time it takes to reach that insight is the time it takes to grow synapses between neurons of remote regions of the brain and ‘foresight’ would be the first synapse making the connection while insight would occur when a bundle of neurons supersedes some minimum number of synaptic connections required.

The sudden quantum leap that Schrödinger (1944/2010, p. 106) described for mutations in the DNA may also happen between synapses, for example, when one synapse is positively charged and the other negatively. Before synapses connect for the first time, a quantum jump between the energy levels of the atoms may take place: The flash of insight thus depends on abruptly exceeding an energy threshold.

This would account for the miraculous transition to a new thought, called the “mystery of the stages” (Feldman, 1999, p. 183).⁷ Goswami (1997, p. 88) explains this as follows: “Essentially, this is a creativity model for evolution:⁸ ... I have

7. After Piaget.

8. Goswami follows Piaget here.

recently argued that human development follows a pattern of alternating periods of rapid creative bursts of quantum origin and homeostasis, when classical continuous changes prevail..." He continues (p. 90): "Creative insight ... is found to be sudden and discontinuous. It is the analog of the quantum leap – a discontinuous leap of thought without going through the intermediate stages. Unconscious processing [incubation/association] produces a multitude of possibilities; insight is collapsing one of these possibilities into actuality." [Insertion mine]

In other words, if energy is drawn away by repetitive or focused tasks, insufficient energy flows to remote association domains and the threshold is not surpassed. The jump does not take place. Unfocussed attention frees energy to spontaneously help connect synapses through quantum activity (ionization) (cf. Schrödinger, 1944/2010, p. 33–35, p. 63).

Quantum jumps excite electromagnetic radiation, including that of light. Thus, photons are emitted every time a synaptic connection or a burst of synaptic connections is established between associatively remote areas. Light is not a metaphor for insight: When a creative combination is made, the brain without the mediation of the eyes literally 'sees the light' of the photon-emitting quantum jumps of discontinuous thought.

Would this excitation or heat motion during moments of insight be visible in a spatiotemporal temperature increase? Hélie and Sun (2010) review studies that report increases in heart rate prior to moments of insight. Would disruptive combinatory creativity be the ionization inside a certain volume of about 10 atomic distances between synapses cubed? Would the energy for exceeding threshold resemble the 30 electronvolts observable for X-ray forced mutations? (Schrödinger, 1944/2010, p. 65).

Photon emission is gamma radiation and Jung-Beeman et al. (2004) observed a sudden burst of high-frequency gamma-band neural activity in the right anterior temporal area, starting 300 milliseconds prior to establishing a solution by insight. These authors state that during comprehension, this brain region makes connections across distantly related units of information. The "sudden flash of insight occurs when solvers engage distinct neural and cognitive processes that allow them to see connections that previously eluded them" (Jung-Beeman et al., 2004). Not being too focused and in doing so not maintaining the habitual associative pathways may be just the right mode to have new neuronal connections established. In sleep or reverie (Darsaud et al., 2011), attention is defocused and thus the likelihood increases that the brain will grow connections between remote association areas.

In conclusion, suddenly seeing the similarity between previously unconnected entities is what I would call the "flash of insight," which is the experience of high-frequency gamma activity (i.e. photon emission) in the right anterior temporal area

as conducted by newly established neural pathways between previously unconnected brain regions. It is the quantum jump of creativity. The remaining dissimilarity is what would cause the “clash of meanings,” reflected by N400, for someone who has not established the (neural) connection yet or who in an analytical mode focuses his or her attention on the discrimination of stimuli on the basis of the distinctive features. The level of perceived similarity as marked by the flash of insight would stimulate the idea of continuity, whereas the level of perceived dissimilarity as marked by the N400 amplitude would arouse a feeling of disruption.

5.3.5 *Novel, unique, and original*

The core of creativity is combination making. One of the distinctive aspects is that this combination did not exist before. This may be in physical nature or in the mind. Point is that to be recognized as such the novel combination has to be observed one way or the other. It follows, then, that the combination of more-or-less familiar entities has to be perceived as *unusual*.

In the wake of Kant, Simonton (2009, p. 14, p. 22) affirms that creativity is largely defined by originality (cf. Box 1). Writing the word ‘horse’ under a picture of a horse may be apt but is not creative because that word and that picture are used for representing horses all the time (Hoorn, 2002, p. 187). Such literal uses may be quite usable, valuable, understandable, perhaps boring, but they merely illustrate that *infrequency of occurrence* plays a role in designing something creative (Hoorn, 2002, p. 188). Sternberg and Lubart (1999, p. 7) state that originality is the statistical rarity of a response. Plucker and Renzulli (1999, p. 93) refer to the Test of Creative Thinking, which regards originality as statistical infrequency of ideas.

Box 1. Wayward creativity

Galina Ustvolskaya (1919–2006) by many is seen as a composer who came from nowhere and has no followers. She herself denies to have undergone any influence by her tutor Dmitri Shostakovich, who admittedly cited from her work. Her unearthly music is extremely intense and is not composed to please the ear, sometimes resembling the early Romantic work of Schönberg (i.e. *Verklärte Nacht*) or Stravinsky’s *Firebird and Rite of Spring*. Her work feels like a religious experience and works with the most unusual settings of instruments. For example, *Composition #2 “Dies Irae”* (1972–1973) combines the beating on a wooden box with eight double basses. In her *Second Symphony* (1979) for orchestra and solo voice, a single cry to the Lord is an extreme and tough repetitive element. Living in complete isolation in Petersburg, Ustvolskaya may perhaps be seen as one of those exceptions that can be considered truly original, radically choosing for creativity and spiritual content, indifferent to public opinion. For a performance of the *Second Symphony* by Reinbert de Leeuw and the Radio Philharmonic Orchestra, listen to <http://www.youtube.com/watch?v=ynhdxHOrPm4&feature=related>

However, infrequency of an event is relative to the observer who experiences it. Davids (2008, p. 456) observes that new knowledge to some extent always builds on knowledge accumulated in the past. Knowledge creation is never an entirely innovative, purely individual act, but also draws on a set of “communal” resources. Shiff (2003, p. 145) muses that originality implies coming first, doing first, and therefore cannot be separated from chronology. If artists cannot create from nothing, then how can their work attain originality? Shiff claims that uniqueness boils down to what people *believe* is original (*ibid.*, p. 146) (cf. Box 2). Somewhat differently, Basalla (1999, p. 78) states that “What is traditional practice for one culture may be an important innovation in a different setting.” In other words, what is new is the perceived dissimilarity with the predecessors and continuity is the remaining similarity that is perceived.

Thus, frequency of occurrence is related to a particular (historic) community (cf. Nickerson, 1999, p. 394, p. 400). Words, images, objects and concepts have a frequency of occurrence or a frequency of use relative to a particular group of people, which may be small or very large. Horse riders mention the word ‘rein’ more often than bike riders (cf. Hoorn, 2002, p. 188). Maasai encounter lions more often than the Inuit do. In other words, creativity and particularly the uniqueness or rarity of a creation depends on the type and size of the community in which the creation occurs. It is more likely that an individual idea is regarded as infrequent in a small and isolated mountain village during the Middle Ages than on the current WWW. This also tells us that what may be common practice in one community is a revolutionary novelty in another (cf. Basalla). The degree of originality, then, is a judgment based on the frequency of occurrence of a combination relative to the sample size. The larger the community, the harder it is to be celebrated as a genius or be condemned as a fool. Individual variability counts less in larger samples.

Box 2. Creative Industries

Creative Industries is a contradiction in terms. On the one hand, for something to be creative it should be highly original, which happens in an open environment without constraints. On the other, something becomes producible and profitable when you can repeat it; make multiple copies, under strict conditions of time, money, and labor. In other words, when we shift from probability to determinism, creations become more industrial or in reverse mode, become more original again. Hollywood makes huge profits out of franchise and sequel movies. Ebert (2011) complained that the summer of 2011 held the record of 27 sequels with the highest number of fourth sequels ever, fifth, seventh, and even eighth sequels (i.e. Harry Potter 8, having a Part I and a Part II). Yet, originality is not similar to popularity (cf. the disinterest in art house movies or the compositions of Ustvolskaya). Popular usually is what sounds and feels familiar, with a very little twist: Something that is industrial, with a tiny bit of creativity (cf. Serrà et al., 2012).

The trick is that entities in a creative expression may be familiar and even may have a high frequency of occurrence in a given community but using them together, suggesting that they belong together, should have a frequency of occurrence that approaches 1 (Hoorn, 2002, p. 188). That the entities are familiar (but not too familiar) increases the possibilities to establish meaning connections through intersecting or related features. That their combination is unusual provides the experience of newness, providing new meaning to old ideas. The most original creation is the combination of associatively unrelated entities that has a frequency of occurrence of 1 ($Freq. = 1$) within the largest possible sample. This account is not limited to creativity alone – extrapolating the utter consequences of certain premises may be done for the first time as well, specifying that intellectual thought can be just as original as creative ideas.

5.3.6 *Metaphor*

Unusual combinations that make connections between non-adjacent domains typically are the realm of metaphor production and reception. Metaphors are regarded as models of works of art across all media (Hausman, 1989, p. 118) as well as models of scientific thought (Miller, 2000, p. 219, p. 252). Certain authors even claim that metaphors are the way we think throughout (e.g., Lakoff & Johnson, 1980).

Indeed, metaphors affect our reasoning. If crime is framed as “a virus, infecting the city,” people reason in terms of causes why it spreads; if framed as “a beast,” people will reason in terms of “caging it” (Thibodeau & Boroditsky, 2011). Ensembles of metaphors lead to advances in (scientific) thought (Gruber & Wallace, 1999, p. 104). Christiaan Huygens, for example, tried to understand the propulsion of light in terms of water waves. Modern physics also uses plenty of metaphors such as ‘quarks are building blocks’ (Huang, 1992, p. 25) or ‘quantum’ (Johnson-Sheenan, 1997) and according to Miller (2000, p. 235) theoretical advance in physics works through nothing but metaphor: An atom is a billiard ball (classical physics), an atom is a solar system (Bohr), the electron is a wave (De Broglie), the electron is a string (e.g., Witten). The playwright Tom Stoppard (1994, p. 7) stated that “Every atom is a cathedral.” In resisting the standard representation of atoms as solar systems, he imagined the nucleus to be the altar of St. Paul’s cathedral; the electrons like tiny moths flitting about in that empty space, one instant by the dome, and the next by the altar.

Certainly, the importance of fantasy in arts and science can hardly be underestimated. It is appropriate, however, to bring some nuance to the claim that metaphor would be omnipresent. First, certain works of minimalist art are not intended nor interpreted as metaphoric: They are what they are without referring to anything, not even themselves (e.g., LeWitt’s work, Chapter 2).

Second, metaphor is not the only way to have a new idea. Drawing the utter consequences of an assumption through strict logical reasoning may lead to different, perhaps not creative, but at least unusual vistas on an issue (cf. the invention of graphene, Chapter 2; also Chapter 3, Section 8.1). Although the contents of the premises may be metaphoric (cf. Thibodeau & Boroditsky, 2011), the reasoning itself is not.

Third, metaphors wear out. By high-frequency usage, they become part of the standard, literal repertoire of utterances in a certain community. In the same way as literal expressions, metaphors that have become clichés address the inter-subjective knowledge base people use to communicate with each other and empathize (Lakoff, 1987, p.263, p. 302; Johnson, 1987, p. 196, p. 212). Such conventional metaphors serve as literal utterances. And although their metaphoric origin can easily be revived, the innovations that are derived from them through inference are pragmatically non-metaphoric.

Fourth, analogical reasoning, which is adjacent to metaphor but not identical, may do the trick as well. For example, Maxwell drew an analogy between gear-boxes and electromagnetic fields to exert a mechanism that could explain how rotations in the flow of an electric current come to a halt (Nersessian, 2002). Engineer Brunel looked at a woodworm to dig tunnels through a river bed (Box 3).

Box 3. Brunel's digging system was a non-metaphoric analogy after nature

After fleeing the French Revolution to Britain, naval engineer Marc Brunel built the Thames Tunnel at Rotherhithe. Drilling through the extremely muddy and instable river bed was a dangerous endeavor because the drill hole could easily collapse while building. Brunel then laid eye on the woodworms at the piers and bollards of Chatham Dockyard. These animals drilled their holes and pushed their soft bodies through the wet wood without being squashed. Brunel discovered that the reinforced jaws of the worm ate the wood, while excretions created a calcium tube behind the worm (Figure 5). In analogy to the woodworm, Brunel designed a tunnel digging system featuring a tunneling shield. At the front, workers would hack away the rock from a compartmentalized frame (cf. reinforced jaws) while jackscrews pushed the frame forward. Behind it, bricklayers would cover the tunnel's inside with a protective brick shield supported by numerous arches. The analogy is that if the woodworm has a shielding system to protect it from being squeezed when it drills holes in an unstable environment, and if the civil engineer also drills holes in a similar environment, the engineer should also have a shielding system to protect him from being squeezed. Novel, clever, creative, but no deeper meaning intended.

Retrieved Feb. 24, 2011 from http://www.infobritain.co.uk/Brunel_Museum.htm

Figure 5. Drill hole (right), drilling head (middle), and calcium tube of the woodworm to protect it from being squashed by the wood



Fifth, to be creative a combination of two unrelated entities does not have to be metaphoric. It may just be a comparison of physical form or of identical functionality without any figurative intentions (cf. billiard ball, solar system, wave, string) (Box 3). Osage Orange twigs have a thin long form and were used as cattle fences. Metal wires also have a thin long form and were used as cattle fences. Hence, the conceptual merger of these out-of-category entities on the basis of plain similarity made barbed wire (Figure 6).

Figure 6. Non metaphoric innovation: Osage Orange twig with thorns inspired Michael Kelly (1868) to the combination with metal wire fences to create barbed wire



Sixth, it may not be metaphor as such but being able to imagine or visualize fictional worlds (the “as if”) or ‘possible worlds’ to expand a theory or a device and try to capture phenomena thus far left unexplained or possibilities left untried (Hoorn, 2012, Chapter 3). For excellent examples of assimilation and accommodation of theoretical physics through imagining partially fictional or ‘possible’ worlds, see Miller (2000, pp. 256–257). Basalla (1988/1999, p. 97) claims more-or-less the same for technological innovation, stating that visualization and non-verbal thinking are important for technical creativity. Savransky (2000, p. 177) also posits that fantasy is required to make an amalgamation of known homogeneous systems (cf. continuity) as well as to create new non-existent objects (cf. disruption). He points out that in the first case, fantasy may be little (e.g., a watch with a mobile phone) but, in the second, it may be wild and uncontrolled, rendering enigmatic properties and unclear functions (e.g., a pencil with a mini saw) (ibid.). Regarding biology, K. Kelly (2010, p. 113) explains that not all niches in evolution are filled because not all possible combinations of atomic structures and life functions have come to expression yet. In other words, there are still animals that “could be” (cf. the crossbreeds) and sci-fi stories show us such creatures, which are usually constrained by the typical natural forces of gravity or design principles such as symmetry.⁹ Sometimes, sci-fi and cartoons are visionary for later developments. For creative advance, then, the use of metaphor can be functional but does not have to be: Merely fantasizing about certain possibilities may suffice (Box 4).

9. See for example, the National Geographic Channel documentary *Extraterrestrial* (2005): <http://channel.nationalgeographic.com/channel/extraterrestrial/index.html>.

Box 4. Communicators and videophones; BCI, VR, and the Wish Fulfiller

The original science fiction television series *Star Trek* (1966–1969) featured one of the first mock-ups of a mobile telephone, the 23rd Century communicator (Figure 7a). On Apple's real 21st Century iPhone (Figure 7b), an app called Star Radio Communicator can be installed that blinks and bleeps just like the original *Star Trek* Communicator.

Figure 7. Replica of the fictitious *Star Trek* Communicator (a) and a real iPhone imitating the fiction (b)

Basalla (1988/1999, p. 66) states that play and fantasy in creativity “go beyond what is feasible” (also Savransky, 2000, p. 178). More pre-inventive examples of current technology can be found in the cartoon albums of *The Rise and Fall of the Trigan Empire* (Butterworth & Lawrence). In the tale *The Wish Fulfiller* (*Look and Learn*, May, 27, 1972 to July, 22 1972), a magic box with electrodes at the scalp (Figure 8) induced wishful dreams to the user such that it made them psychologically dependent. This comes close to a merger between contemporary attempts of using brain-computer interfaces (BCIs) for virtual reality (VR) applications (Lecuyer et al., 2008) and effects of videogame addiction (Brian & Wiemer-Hastings, 2005).

Figure 8. The Wish Fulfiller is a BCI, inducing Virtual Reality that makes the user addicted to a desirable fiction. Image scanned from the Dutch translation of the album *Mysterieuze Krachten op Elekton* (p. 17). Oberon, 1980

5.3.7 ‘As if’ but not figurative

During creation, novel comparisons can be used in an artistic and in a scientific way (Hoorn, 2012, pp. 198–199). The constituent entities of a comparison are out of each other's category – that is why there is a smaller or larger ‘leap’ into another knowledge domain. Each entity in the comparison evokes a number of features (as said, meanings, images, etc.). These features may be factual denotations according to a world view, theory, or belief system and people use them as literal descriptors. Literal features describe an entity according to an accepted ontology. Figurative features are representational, indicating that they stand for something else in a way that does not match the accepted ontology of how things are (hence, the fictional aspect). For example, the Osage Orange thorn may stand for heartache (but is not heartache) and barbed wire may be a symbol of the divisive nature surrounding modern immigration (but may be only an exponent of it). This is the point where a novel combination brought up by technical or scientific imagination enters the

artistic domain. Due to the figurative extras, the concepts in their new constellation stand for more than what they denote, and, because of this, a novel metaphor transpires instead of a new literal statement on the world about us. *Science does fantasy (the 'as if') but science does not do metaphor.*

The assumption of figurative features is not circular; they are part of the association list or semantic network that is elicited for any single item or entity. Novel metaphors make use of those older symbols and common metaphors that have become conventional or even fossilized in a culture, a community, or even for a single person. What novel metaphor distinguishes from literal comparisons (e.g., he is like his father) and sheer anomalies (e.g., the moon is a yore) is that the literal comparisons only match literal features, and anomalies have no matches whatsoever, whereas metaphors connect literal features of the one entity to figurative features of the other and vice versa (extensive evidence for this position can be found in Hoorn, 1997).

For the sake of argument, I will illustrate the point with a conventional metaphor. In 'love is a rose,' 'red' as a literal feature of rose is figurative for love and may have the connotation of warmth and passion. 'Blushing' may be elicited as a literal feature of being in love but may count as a figurative feature of rose. 'Blooming' may be literal for rose but is figurative for love, etc. In novel metaphors, the novelty is that what was conventionally considered to be a literal description of reality is now framed as symbolic (and thus, fictional); reversely, what conventionally and according to belief was always regarded as a symbol (and thus, fictional) now is presented as the literal truth ('This bread *is* my body').

Novel comparisons challenge belief systems and therefore are suited to 'venture into the unknown.' In the case of new literal comparisons they advance theories and do inventions, or in the case of novel metaphors, they make new (referential) works of art and religion (Hoorn, 2012, pp. 198–199).

To take it one step further, scientists could make use of metaphors if they only focus on the literal features. Metaphors not only establish mixed intersections of literal and figurative features, they also establish a large intersection of purely literal features (Hoorn, 1997). In other words, metaphors may encompass new literal feature matches as well. The different uses that arts and science make of metaphors is that arts are focused on pulling the literal into the figurative, opening opportunities to provide the world with new meanings, whereas science may use metaphor to explore the imaginative and see in how far its literal overlap can serve as a model for the world (see Box 5). As Miller (2000, p. 219) puts it, metaphor in science is used to seek out new literal descriptions of the world (i.e. new theories). But science should refrain from providing meaning beyond denotation. When it does not, it becomes art or religion.

Box 5. High flyer, deep diver

The best scientists think the impossible and bring probability down into the realm of determinism. The greatest artists bring determinism back to the realm of probability again by thinking up the next impossibility. The artist is the high flyer, the scientist a deep diver. Head in the clouds, feet on the ground: The genius flies up, condenses around a speck of dust, a union of remote ideas, and falls down deeply onto the bottom of the sea as heavy water. Then evaporates into the sky again, all water running. Going up and down from possibility to difficulty and back again, the genius embraces the wonders of opportunity as well as the rigidity of limitation, unifying air and rock, feeling at home in probabilistic and deterministic problem spaces alike.

Anything distinctive adds to the perception of dissimilarity and disruption. Anything intersecting adds to the perception of similarity and, hence, continuity. Connecting literal features of one entity to figurative features of another from a different category increases the likelihood that the perceived continuity is considered fiction with no claims to truth. Connecting the literal features of entities from distinct categories will be considered fiction that has more pretenses to truth.

5.4 Evaluation 1

As soon as a novel combination, unique mixture, inventive link, or original blend is conceptually established and feelings of truth, joy, confidence, or perhaps even pride have ebbed away, the creator becomes his or her worst judge. It is a phase of verification (Wallas, 1926, pp. 85–86). Uncertainty and insecurity become prevalent because cognitive and analytic operations are executed on the newly established creation and evaluated in the light of earlier examples and the imagined judgments of peers. The creator of a breakthrough is also the first to optimize it. Incremental improvements are done through the selection of features so to optimize fit. This conceptual tweaking concerns the ratio between similarity and dissimilarity and, in the case of a novel metaphor, as based on the numbers of literal and figurative features.

Not every feature that is perceived or associated by the creator is or can be used in a creative comparison. If we return to Figure 3, the wheels and the saddle may be salient features of a bike but they are removed to make the bike look like a horse. Deleting the saddle is peculiar because a saddle can be a feature that bike and horse share. However, putting the bike frame upright makes the saddle occupy the ‘void address’ of the horsetail, and, therefore, conflicts with the concept of a

horse (Hoorn, 2002, p. 188).¹⁰ In the case of Michael Kelly's barbed wire, the metal wire fence without barbs had 'void addresses' that were filled out by the thorns of the bush. Thus, features are selected according to their weights or their importance for establishing optimal fit (ibid.). Not maximal fit, because that would have meant that Kelly deleted the distinctive feature of thorns from the wire fence, which was the very reason for combining them in the first place.

On what grounds the features are deemed important is an open issue. Variation in artifacts comes from adaptation and selection of features, which often are directed at functional requirements "to conform to changing circumstances and patterns of usage" (Basalla, 1988/1999, p. 91). Selection of features and artifacts then is based on the altered functionality as related to the goals and concerns of the individual, group, or both. Such objectives could be biological, technological, psychological, social, economic, cultural (Basalla, 1999, p. 136), which shows how versatile a creative solution can be.

In the case of art and design, the weight that is attached to certain features may be aesthetics, salience, prototypicality, or emotional relevance; in the case of technology it may be usability, functionality, etc. Yet, the important part here is that creativity involves the *selection* of features that are used or discarded in the comparison and that selection depends on the goals of the selector (Hoorn, 2002, p. 188).

5.5 Elaboration

In the next sections, we will see that selection is not only a mental operation. Through elaboration and materialization of the idea, evaluation continues to play a role, taking features off of the design, putting them back on, or adding new ones. Elaboration of an idea starts with abstraction and ends with concrete manifestations such as writing, welding, and assembling, putting the molecules in a for the moment fixed constellation. An important aspect in the elaboration of an idea is to close actual physical distance.

5.5.1 *Closing physical distance*

Creativity is to put two or more familiar entities (whether objects or concepts) in an unusual combination. Putting together means that real physical distance needs to be bridged between (features of) entities (Hoorn, 2002, p. 187). This means that before creation, physical distance between entities is larger than thereafter (ibid.).

10. If you regard a horse as a data structure, then each feature that our minds detect or imagine points to data that supposedly are physically present in that horse data-structure. The position where those data are expected to be is an 'address,' which may be 'void' if there are no data available at that particular point in the structure. It is an empty reference. The Higgs boson may be considered a void address in physical theory – as a horse without a tail.



Figure 9. Hooves are represented by plumbing materials (Hoorn, 2002, p. 187)

For the fusion of two ideas, the same thing is true because as soon as they materialize, for example, in writing or drawing, the words or images describing each become spatially closer than before. At first the word ‘atom’ was put close to the word ‘ball’ then later the word ‘ball’ was removed and ‘solar system’ was put next to the word ‘atom.’

Entities in a combination can be pictures and words but also bikes and horses. Well, not really horses. If two concrete objects cannot be glued together in reality, at least one of them needs to be transformed into a concept or a representation of that object (the fictional or ‘as if’ aspect) (Hoorn, 2002, p. 187). In the bike-horse example, the concept of a horse is combined with the physical bike but at least the concrete feature of the ponytail is fixed to the bike, literally decreasing physical distance between a bike and (an aspect of) a horse. This can go on within the work at increasingly smaller scales. In Figure 9, plumbing materials represent the horse’s hooves but first abstraction had to take place before the ‘hooves’ could be attached to the crank (ibid.).

5.5.2 *Abstraction*

Abstraction is important in creativity because at high abstraction levels things become more similar and hence connect more easily (cf. Ward, Smith, & Finke, 1999, p. 198). Dawkins (1999, p. 3) explores the thought experiment that if you go up the evolutionary tree high enough, any two species can evolve into each other. Through a number of hypothetical animals, this way a beetle could evolve into a red deer (ibid.). Complex forms are created from simpler forms. By the end of the day, everything is connected through, for example, geometry.

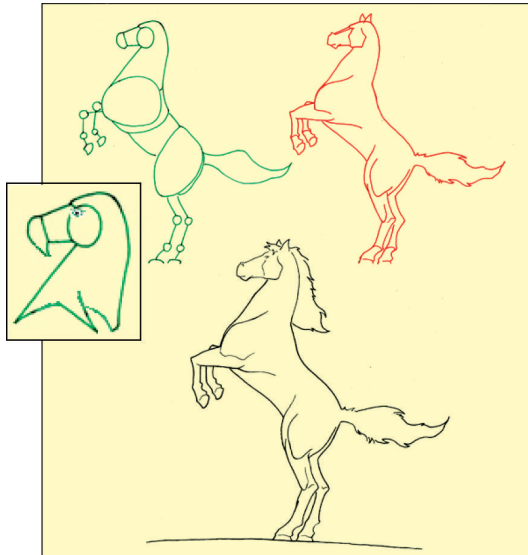


Figure 10. Sketching a horse. The more abstract (top left), the more freedom for making unexpected connections (see the insert of an eagle's head). Retrieved Sept. 25, 2013 from http://3.bp.blogspot.com/_FbaCSodvS_0/TEKkSDs6FUI/AAAAAAAAABCI/e8CPRkYw2HM/s1600/how-to-draw-a-horse-2.jpg

Figure 10 shows how to sketch a horse. The most abstract form (top row, left) is constructed of single lines, circles, and cylinders. Such basic forms can be recognized everywhere in nature. The abstract forms make it easier to associate the cylindrical body with a soda can, the line-legs with a straw, and the circular joints with marshmallows, creating a pony that little girls would call 'Candy.' Adding more details and specifications of a horse (bottom sketch) drives creativity to a more deterministic resolution, which would not bring 'candy' to mind. By ignoring designating details, abstraction reduces the signal strength of the stimulus and offers opportunities to link to other stimuli. High resolutions inhibit fantasy.

The head of the most unfinished horse sketch is so abstract that it could easily be turned into the head of a bird of prey, making it a hybrid fable animal. In the insert of Figure 10, the horse's nose is turned into a bird's beak, ears are left out, and feathers are added. Thus, one of the ingredients of creativity is to turn objects into concepts through abstraction to overcome physical problems (Hoorn, 2002, p. 187) and to improve the possibilities to make connections with unexpected domains (i.e. to widen the interpretation possibilities, cf. Ward, Smith, & Finke, 1999).

5.5.3 *Integration*

Combining entities is to reduce physical distance and to make sure their molecules become connected or at least close by (Hoorn, 2002, p. 188). For a longer period of time, there is a fixed structure forced upon the free floating information. However, there is more to it. By putting entities together, people are forced almost to compare them. In other words, there is a gliding scale of becoming similarity-focused the closer entities get together (Dollard & Miller, 1950).

Similarity reflects the set size of the intersecting features relative to the number of distinctive features. More features are compared the closer two entities are. Attribution of a feature from one set to the other (feature transfer) increases similarity and if there are 'void addresses' in the receiving set (Hoorn, 2002, p. 188), the probability that feature transfer occurs increases the closer two entities are put together (cf. Ward, Smith, & Finke, 1999, pp. 198). If there are (approximately) matching features in two sets, then the intersection size seems larger the closer the entities are put together. Also, in this way, two entities get integrated, synthesized, or assimilated.

Integration is another way to optimize an innovation, bringing the entities that form the novel combination closer together. In the bike-horse example of Figure 3, the ponytail was borrowed from a real horse and then glued to the bike (cut-paste) (Hoorn, 2002, p. 188). Glue literally fills up the voids in the molecular structure of two surfaces, thus bridging physical distance (ibid.). Integration should be such that components are kept in place by (intermolecular) forces strong enough to resist decay (or entropy) (cf. Schrödinger, 1944/2010, p. 85). Other ways to integrate entities is to use bolts and nuts, sticky tape, or a medium to hold the materialized representations in close proximity (e.g., paper, canvas, film).

5.5.4 *Adaptation*

Features need not be identical; they only need to be approximately the same to let them intersect (Hoorn, 2002, p. 188): Feature sets are 'fuzzy.' The creator bends and bows the features to gain optimal (not necessarily maximal) similarity (ibid.): The bike is standing upright, holes are drilled to add the eyes (Figure 11), and the frame is painted. These are examples of adaptation, modification, or transformation of features to let entities fit or misfit in just the right way; that is, raising similarity up to an optimum as defined by a certain group or community (of which sometimes the creator is the only member).

Adaptation can take many forms, often in combination with selection. The creator may make variants of the same feature (cf. edits), variants of features may arrive with the influx of new information (cf. migration or transference of features), or by making inexact replications (whether deliberately or not). Thus, *adaptation* of features is part of the optimization side of creativity.



Figure 11. Adapted bike: Eyes are added to increase horse resemblance (Hoorn, 2002, p. 188)

5.5.5 Priming and framing reduce connection possibilities

Adaptation has to do with bringing a creation in line with current norms. This could also be achieved through the transformation of rules by which creation and interpretation are allowed (cf. Boden, 1999). For example, the change of poetics from Classicism to Modernism allowed art works to remain unfinished or to literally show rough edges, which was forbidden in the polished and rule-oriented earlier style. Rule transformation, then, is an aspect of priming and framing a creation (“This is allowed, that is not allowed”). The bulk of genre issues is related to aspects of rule transformation and concept-driven interpretation of a work (Hoorn, 2012, Chapter 2).

Apart from changing poetics or genre labels, titles can be helpful when disparate things are put on a par. They provide a concept-driven framework to interpret the unusual connection (Hoorn, 2002, p. 189). If someone does not see a horse in the bike, the title *Prancing Horse of Iron* will evoke the right feature set to compare the bike-features with (ibid.). The title semantically primes the artifact.

Putting the horse-bike on a basalt pedestal is another cue to concept-driven interpretation (Figure 12). It states: “This is art, an invitation to suppose or imagine that a bike could be a horse, not really, but in fiction” (Hoorn, 2002, p. 189). In other words, the pedestal tries to keep the statement ‘a bike is a horse’ away from the claim of truth (ibid.). Instead, the intersection of features will stimulate the similarity between the associatively distant entities. In contrast to the distinctive sets (stimulating dissimilarity), people may judge that the image is striking or not. Thus, words help to



Figure 12. The pedestal frames the object as fiction (Hoorn, 2002, p. 189)

understand the image by pre-selecting the appropriate feature sets. Framing the creation as fiction avoids rejections on the basis of truth-value (Hoorn, 2002, p. 189).

5.6 Evaluation 2

As to the effect of the creation on the perceiver (which may be the creator), a tension may exist between similarity and dissimilarity of the entities. In its outer appearance, the shapes of the bike and the horse are roughly the same. When focusing on contents or functionality, they are both to ride on. By contrast, the shapes are not exactly identical, horses have no wheels, and bikes have no legs. Both may be to ride on, but horses can travel by themselves whereas bikes do not.

Signal detection (e.g., Schonhoff & Giordano, 2006) teaches that decisions for 'same' or 'different' depend on the features that are designed into the stimulus, in particular how obvious, salient, or strong they are (signal strength). Decisions also depend on personal sensitivity to perceive the signal as well as on individual levels of tolerating deviations from the frame of reference (e.g., another example or some conceptual knowledge). The balance between similarity and dissimilarity of the combined out-of-category entities may decide whether the combination can be regarded as a 'creation' (that is, acceptable dissimilarity between associatively remote entities) but this balance may be evaluated differently by different individuals.

If things brought together are perceived as too distinct, their combination may be judged as incomprehensible or anomalous; for example, Cubist portraits that hardly resemble the person. Modern art is often rejected because it is not naturalistic (“My kid can do that too”) (Hoorn, 2002, p. 189). If things become too similar, they may be rejected as journalism or ‘without fantasy.’ Family snap shots may resemble life too much (“That’s not creative!”) (ibid.). Put differently, people build expectations upon the activated features of an entity (what they know about it, its ‘familiarity’). If combined, many mismatches can occur with the features of another entity. The increase in dissimilarity violates expectations, evoking surprise (e.g., N400), which in extreme cases can lead to rejection of the creation (ibid.).

6. Organic creativity

In Lowcre (2013), we developed the idea that combinatory creativity in humans has a physical origin (i.e. particle physics), supplemented by organic creativity serving as optimization machinery to fill up evolutionary niches such that the creation survives. The nucleus of creation, then, is the conceptual formation of a novel combination across out-of-category boundaries. This connection may be deliberately sought after, may be artificially constructed, may happen due to sheer coincidence, or is the result of a combination of these. On this view, the insight phase is at the heart of the creative process and incubation is its associative forerunner. Preparation is more analytic (cf. Hélie & Sun, 2010). The results of insight may be fantastic and not fine-tuned to reality.

Obedying the laws of nature, culture, or society may be done in anticipation during preparation but becomes pertinent during implementation. Preparation and incubation are phases that each in their own way prepare for insight while evaluation and elaboration are phases for post-processing the creation, editing it, optimizing it, and making ideas concrete. Where association and insight are less focused and more intuitive (the uncontrolled particle-physics side of the process), familiarization, abstraction, selection, adaptation, and integration are more focused and more rational (the more-controlled biological side). As an illustration, try out the *Blind Watchmaker Applet*.¹¹ It is built after the genetic algorithms of Dawkins (1987) and can evolve basic geometrical forms into virtual creatures (i.e. biomorphs). The only thing the user does is to make consequent selections (e.g., on fitness). The mutation of the code creates the next generations of the preferred biomorph in an interactive evolution where the machine invents the creatures and the user does the selection work.

11. <http://www.phy.syr.edu/courses/mirror/biomorph/>

Becoming familiar with an issue is preparatory in the sense that entities that may possibly become part of the creation become richer in features, not just the obvious ones but also the more infrequent and individual features in the semantic network. The more diverse the information, the more likely it is that unexpected crossovers may happen. Divergent thinking is important in that respect, because it sheds different light on the same issue. Brainstorming, random links, and the wild association of features provide explicit access to the breadth of knowledge-bases acquired during preparation. When multiple individuals do so, the larger and more diverse the available materials are to work with. Bringing together a variety of cultures is most valuable in this respect.

Abstraction, selection, integration, and adaptation are post-processing activities. They come into operation for the optimization of performance or the impact of a creation and handle detailed implementation issues. Abstraction is necessary when too many details (probably acquired during preparation) stand in the way of a seamless integration of the disparate entities: Creators “... abstract to situations beyond sense perceptions” (Miller, 2000, p. 36). That is why a helicopter view may be advantageous to creativity rather than insisting on the tunnel vision of a specialist.

Integration is meant to obscure the differences between the combined entities up to a preferred degree of perfection, thus manipulating signal detection mechanisms. In a simple collage, the ragged edges are acceptable or even desired whereas in the unification of Einsteinian gravitation with quantum-field rules any divergence is one too many.

Selection is not only filtering out those features that obstruct making the optimal fit and adaptation is not only modifying and fine-tuning features to establish that optimal fit; they are also the link to the outside world, telling the creator what is of what is not acceptable, useful, appropriate, valuable, significant, satisfying, or may lead to survival according to group norms, peer criteria, external goals, or societal concerns. For example, couturier Aziz Bekkaoui combined fashion with arts and politics and created the Lonsdale Burka (Figure 13). The bare-bone creativity is in combining two pieces of garment from different cultures. From a point of view of social norms, however, these clothes are each other's political counterpoint, a mix of ultra-right-wing and religious orthodox dress codes, which may aggravate both movements.



Figure 13. Lonsdale Burka at live performance of “Extremities.” *Profile: The Engagement of Aziz*, IKON, Dec. 10, 2008

Selection and adaptation may be so strong that all the features are markedly changed or even dismissed from the new combination altogether. In a drastic adaptation, the difference with common practice may not be recognizable any more (e.g., a burka with a plain black sweater, without lettering or flags). When in a radical selection all the features get dismissed from the creation, it is practically ignored or even destroyed (i.e. no burka variations whatsoever).

In other words, we have creativity-endogenous *selection and adaptation for fit* and we have creativity-exogenous *selection and adaptation for acceptability*. With different goals in mind (e.g., personal expression versus social standing), a creator may prefer to adapt or select on the basis of different sets of criteria.

7. Outline of a creativity process model

The previous sections articulated the relations between the modules of the creative process that establish an optimal fit between (associatively) remote entities. Next is an attempt to draft a process model for novel combination making (Hoorn, 2002, p. 189). The basic idea is to design a combinatory system that joins familiar entities in an unusual way and to find an optimal fit between semantically remote entities. Previously unobserved similarity can now be detected and more possibilities in a problem space can be found than by reasoning alone. The effect may be surprise as a function of the tension between similarity and dissimilarity between the merged entities. Individual tolerance levels predicate whether the balance between similarity and dissimilarity is satisfying or pleasing (ibid.).

7.1 ACASIA process

Figure 14 depicts how the modules of association, combination, abstraction, selection, integration, and adaptation operate together to establish an optimal balance of similarity and dissimilarity between disparate entities (the “ACASIA model”). The process is explained for two entities but this number can be larger. During information processing, ACASIA flexibly switches between divergent associative and convergent reasoning styles, which seems to be the guarantee for the highest degrees of creativity as compared to the application of just one style: Merely associative is no good either (Meneely & Portillo, 2005).

Figure 14 illustrates that the five steps of creativity (Preparation, Incubation, Insight, Evaluation, and Elaboration) may show certain regularity in their order of appearance but that this order is not fixed and may include several loops and omissions. All the routes from familiarization and association to physical combination and integration as well as all the cycles in-between can be executed separately at

different levels of detail: For categories, exemplars, for individual features or subsets of features, such as the horse's hooves that were replaced by plumbing materials (Figure 9).

As an outline of a process model, ACASIA does not make claims on the duration of the phases or the model as a whole. Smaller arrows may take very long time, larger arrows may go rapidly. For boxes and diamonds that represent process phases or sub-processes the same interpretation applies.

All imagination starts with observation and perception (Berns, 2010). In Chapter 2, I argued that the knowledge and beliefs someone holds strongly determine if and if so what will be created. *Epistemics of the Virtual* (Hoorn, 2012) provides the materials that can be worked with and frames an incident as a threat or as an opportunity for invention. With an open mind and tolerant to deviation, the creator starts searching for entities to associate with.

During *Preparation*, the creator familiarizes with the entities s/he is interested in, increasing the number of features that will be available for Incubation. For an incremental change, such as making a bike look like a moped, the multiple entities do not need to be out of each other's category associatively. For a larger creative step, such as making a bike look like a horse, the entities should be out-of-category according to the ontological classifications of the perceiver (which may be the creator self).

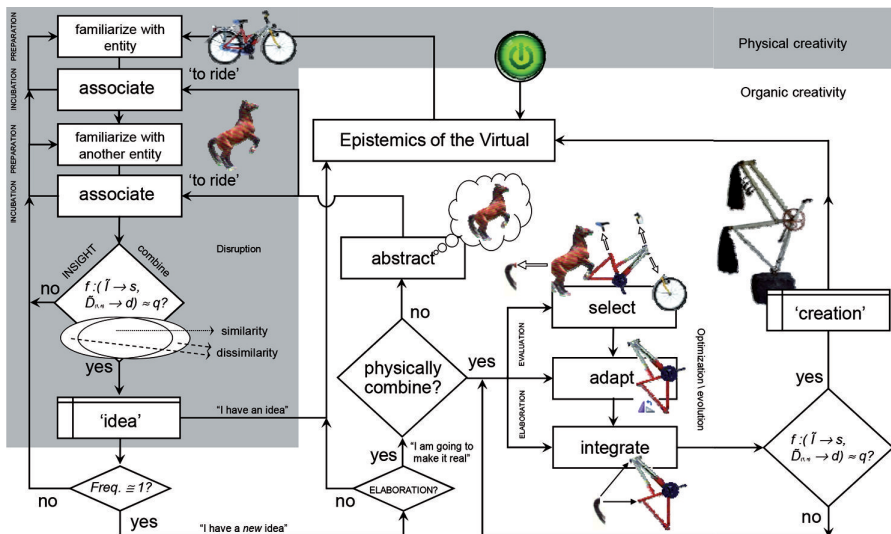


Figure 14. The ACASIA process of creativity

During *Incubation*, features are associated for the entities under consideration. Features may be attributes, literal descriptions, cultural symbols, form features, semantic relations, patterns, bodily sensations, and so on. Dependent on the theory that one adheres to, features come in the form of (fuzzy) sets, vectors, semantic networks, stochastic matrices, association pairs, cued recall of instances, or combinations thereof. Features receive weights, indicating that they may be more important, come to mind more easily, are useful, profitable, salient, emotionally relevant, culturally valuable, aesthetic (cf. unity in diversity, golden ratio, fractal pattern), and so forth. What the weight stands for depends on the goals and concerns of the creator and possibly the community the creator lives in or designs for.

The example in Figure 14 shows a bike that triggers the feature ‘to ride on’ which brings to mind a horse which is also to ride on. This is just one possible example of how multiple entities may provoke the association of features. It could also be that two entities are perceived simultaneously (e.g., riding a bike past a horse, cf. the Rothenberg and Hausman experiment, Section 5.3.1) and both evoke the feature ‘to ride on.’ It may also be that two entities do not evoke the same kind of features at all and then the connection may be artificially constructed.

Insight is designated by the first time perception of sufficient similarity between entities. Insight is greater the more the entities associatively remain outside each other’s category boundaries. Similarity between two entities reflects the size and weight of the (fuzzy) intersection ($\bar{I}$) between feature sets as established by the number of (partially) matching features (Hoorn, 2002, p. 190). Similarity estimates are affected by the remaining dissimilarity between entities as based on the size and weight of the distinctive feature sets ($\bar{D}_1$ to $\bar{D}_n$) (ibid.). In addition, estimates of (dis)similarity are sensitive for perceptual biases such as attentional focus, direction of comparison, context effects, or physical closeness of entities. After selection, similarity may be affected by the inclusion of unusual features into the intersection or excluding ordinary features from the distinctive sets (cf. Baughman and Mumford in Section 5.3.1).

ACASIA envisions Insight as a decision that assumes a signal detection account of perceiving similarity. Signal strength is an aspect of the stimulus. The features designed into or represented by an entity provide details that together indicate that what you see is a bike or a horse. In the signal detection account proposed by Hoorn (2012, pp. 134–139), the fictional aspect of a creation, here the horse, is the ‘signal’ whereas the reality-aspect, the bike, is regarded as background noise (the way things normally are). The more features the bike provides cueing that it should be interpreted as a horse or the heavier the weights of those details, the stronger the signal. Yet, signal strength also depends on individual sensitivity. People under stress or in an entrenched analytical mode of thinking may not be

able to perceive the signal at all. Rigid connections between concrete objects and their mental representations rear psychological inertia (Savransky, 2000, p. 186). It may be that creators detect cues that for others remain unnoticed, perhaps as a result of unfocussed attention, a specific interest, or physiological differences (cf. Berns, 2010). For creators it may be easier to make synaptic connections across brain areas than for others so that they are better equipped for detecting serendipitous feature matches.

In Figure 15, individual sensitivity to perceiving a horse in a bike is indicated by distance d' between the probability that a person merely responds with 'bike' (left curve) and the probability that someone responds with 'horse' (right curve). Once signal strength in combination with sensitivity allows signals to come in, individual criteria (ACASIA calls them q in Figure 14) decide what this signal actually means. This is related to the kind of uncertainty about reality one tolerates: In deciding whether the resemblance to a horse is sufficient or that we are dealing with nothing but a bike, the observer has four possible solutions (Figure 15). In a strong creative mode (association, insight), the observer is similarity prone and

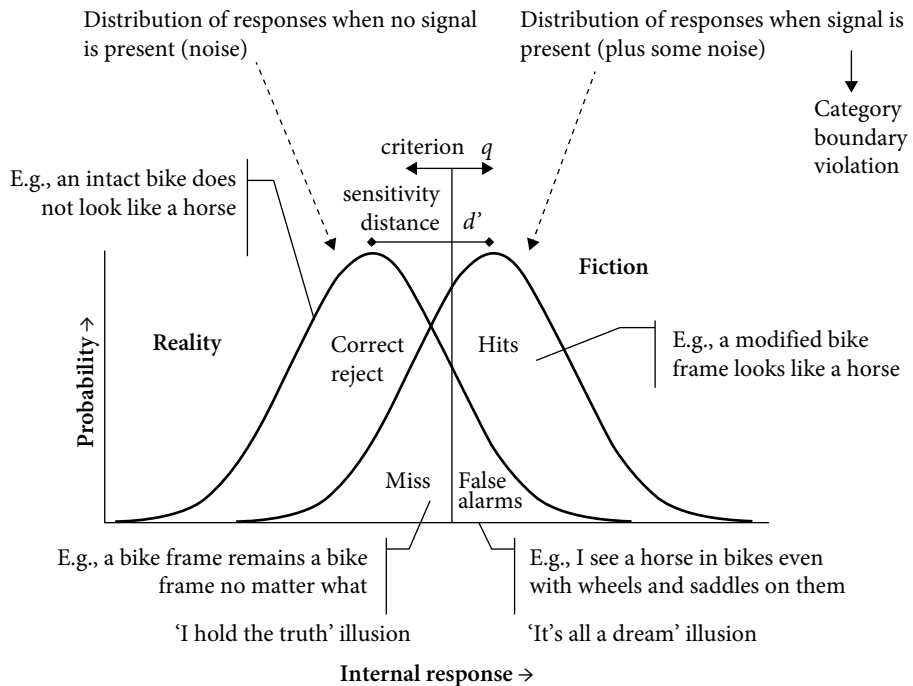


Figure 15. Signal detection analysis of the creative act of making cross-category combinations or rejecting them

produces many false alarms, seeing horses even in bikes that ride through heavy traffic with wheels, saddles, and handle bars on them. In a more evaluative mode, the creator tries to achieve many hits by selecting and adapting the bike frame such that it starts looking like a horse. When dealing with situations in daily life, the observer will correctly reject bikes with wheels and handle bars as horses because the dissimilarity is too large. In a strong analytical and cerebral mode, the observer still regards the bike frame with all selections, adaptations, integrations, a bike rather than a horse: A strictly analytical person (deliberately) will miss out on a number of features that indicate the animal (e.g., pony tail, hooves, eyes, prancing, etc.), maybe due to a temporary lack of fantasy.

When we relate signal detection to creative development (Chapter 5), the infancy of a creation is characterized by placing the criterion to the left: People allow themselves to err on the side of discovery (cf. Bem, 2003) and all reality seems to be fiction. During maturation, the criterion gradually shifts right until in an analytical mode of optimization and concrete realization, people feel they are better safe than sorry and make clear distinctions between fiction and reality: Things have to work properly in the here and now. The creative process has shifted from inspiration to optimization; from physical to organic creativity.

Given sufficient sensitivity (d'), Figure 14 informally refers to the decision for similarity (s) as a function $f: (\bar{I} \rightarrow s, \bar{D}_{(1, n)} \rightarrow d)$ (Hoorn, 2002, p. 189). This function may be handled by a partial correlation or by a fuzzy trade-off operator (for an overview, see Chen & Chang, 2010, Table 1). The output of this function should meet a certain criterion q , tolerating more or less dissimilarity (d) in a combination. If the balance between similarity as a reflection of the fuzzy intersection and dissimilarity as a reflection of the fuzzy distinctive sets is sufficient and at best optimal according to subjective criterion q , the organic phase of the creativity process comes into operation.

Now that an 'idea' has formed, it is added to the store of known things. This happens through ontological classification and epistemic appraisal (see box Epistemics of the Virtual, Figure 14). After all, the creator is the first observer of his or her own ideas. S/he may judge the novel combination as a literal finding, a metaphor, or an anomaly. From there, the novel combination can be used as input to a combination with yet another entity.

In parallel, the first confrontation with the external world is about the newness of the idea, its uniqueness or statistical infrequency. Novelty is the statistical rarity of an event relative to sample size. The smaller the number of examples one considers, the closer to 1 the frequency of occurrence should be ($Freq. \cong 1$). When frequency of occurrence of an idea remains 1 although more information is sampled, the higher its degree of novelty. If one or more similar examples exist, originality drops and the creator has to do more association work to find different

aspects to connect to or even start anew with one or more different entities s/he has to familiarize with ('back to the drawing board').

However, this is still in the mind, perhaps a unique but a rough idea. Nothing has been established concretely yet. The novel combination was thought up but not made. If the frequency of occurrence does approach 1, then, the creator decides whether to work out the idea or not (i.e. *Elaboration*). If not, the idea remains an idea, perhaps usable in combination with new entities.

If right away, a reality check tells the creator that entities cannot be combined physically (e.g., a horse and a bike), entities are abstracted and loop back. Due to the abstraction, new associations are possible and the whole is tested for similarity again. Sometimes entities such as concrete objects go through several cycles of abstraction before they can be combined with other entities – in the form of a concept. That concept may be materialized again in the form of a representation, be that a picture, symbol, or another object (e.g., a toy version), which now can be combined with the first object. Consequently, the model retains the holistic claim that, as long as you make the abstraction level high enough, any two things can be combined together.

In the case of a readymade or *naturfact* (see Chapter 2), the object (e.g., stone) fits right into the concept (e.g., hammer), deciding that two entities can actually be combined physically. For a *naturfact* it means that now use is made of what never had a use intended (e.g., a natural stone used as a hammer). For a readymade it means that a different use is made of the entity than intended (cf. Chapter 3, Figure 32). *Naturfacts* skip the optimization phase entirely when the stone is not moderated but used straight away to its new purpose.

Elaboration and/or *Evaluation* take place to establish a better fit between combined entities. This happens when the fuzzy intersection of combined entities is not sufficient or optimal according to criterion q (see Insight, Figure 14). In the post-processing for optimization, the least radical measure is to fill up the breaches between the different entities by means of glue, welds, or words. One could, for instance, talk two concepts together and try to make the transition from one notion into the other look smooth. In Figure 14, integration is illustrated by the horse's tail being glued to the bike frame. Integration is a necessary step and cannot be skipped; else things would fall apart.

It could also be that integration cannot be done immediately and is preceded by the adaptation of features (attributes as well as rules of interpretation). This literally may involve going back to the workshop and hammer attributes into the desired form or reshaping certain aspects of theories so that they might fit together (Hoorn, 2002, p. 190). Examples of data-oriented adaptation are stretching, shrinking, flipping, rotation (cf. Figure 14), shading, adding attributes (e.g., eyes), recoloring, reordering, paraphrasing, making variations on a theme. A concept-driven

form of feature adaptation is to change the (genre) rules under which a creation is acceptable (e.g., people can have three arms). An example of adaptation to create new theory is the “folding together of geometry and physics” to generalize special relativity to situations of acceleration (Miller, 2000, p. 316). Whereas integration makes connections among different feature sets tighter, adaptation changes the features itself or sometimes changes the structure in which features are put together. And although adaptations may be severe, they always carry an aspect of continuity because they do not dismiss attributes from the design nor do they ignore rules of interpretation.

The most drastic alteration is the selection of features (including attributes and rules) because certain features are discarded from the design altogether. Selection is the most outspoken form of Evaluation whereas integration is the least. Selection is about the dissection and separation of features from an entity. In Figure 14, the complete horse is dismissed from the design except for its physical tail. The bike also loses about all of its attributes except for the frame, the cog, and the cranks. An example of selection of theoretical rules is Einstein’s dismissal of Newtonian compound velocity of light in favor of constant light speed (see Miller, 2000, p. 30).

Selection and adaptation may be executed for optimal fit but the features used for that may be pre-selected to satisfy “creativity-exogenous” rules and norms. The more a creator wants a work to be successful in the outside world, or satisfactory, useful, apt, etc. the more s/he should select and adapt the features according to the norms of a group, the field, the discipline, the referees, the stakeholders. Appreciation of the creation by others is a goal-oriented matter of usability and acceptance (e.g., Venkatesh et al., 2003), perceiving and experiencing cultural products (e.g., Van Vugt, Hoorn, & Konijn, 2009), or requirements change (e.g., Hoorn et al., 2007).

After possible selection, possible adaptation, and at least integration of entities (else, they would fall to pieces) the work is checked for similarity again, which should now be closer to the optimum of q due to the edits (Hoorn, 2002, p. 190). If not, more rounds of selection, adaptation, and integration are done. The looping continues until q is satisfied. Now the creator can claim to have made a ‘creation’ (ibid). The novel combination is added to the store of knowledge and beliefs that the creator holds and is susceptible to the processes explained in *Epistemics of the Virtual* (Hoorn, 2012). The creation is ready to be used in new combinations with other entities.

8. Requirements on a creative simulator

In the top left corner of his black board, Richard P. Feynman wrote: “What I cannot create, I do not understand.”¹² Taking this adage to heart, it means that if we

12. See, for example, <http://sylviecerise.files.wordpress.com/2010/02/feynman-blackboard.jpg>

want to understand creativity, we should be able to simulate it. Ergo, it means that right at the outset of a theoretical model of creativity we should start doing simulations and see whether it can create novel out-of-category combinations.

Therefore, the second half of this chapter is devoted to making a wish list that tabulates what ideally the requirements are on a novel-combination-making machine and to the first attempts of making that machine work. With the outline of a process model in mind (Figure 14), we may formulate the first tentative principles for a simulation of the creative act with Insight as its core part.

I will start by summing up a bulleted list of what must or could be on the system. At the end of that list, you probably cannot tell the forest from the trees, but all the ensuing sections are there for explanation. Subsequently, a creativity simulator should encompass:

- A knowledge-base ('ontology') with adjustable category boundaries (from crisp to fuzzy), allowing narrow and wide category membership
- An adaptable association generator (from narrow to wide) based on set theory or semantic networks
- Additional random feature generation and connection (a serendipity sub-system), providing links to unrelated domains
- A measure of familiarity, indicating how well acquainted the creator is with the content matter
- Goal-dependent feature-weights. Features are "laden" with emotions, preferences, salience, etc., which derive from the creator's concerns
- An estimator of associative distance between categories to determine how large the creative jump is
- An adjustable feature matchmaker (from crisp to fuzzy feature comparison). There should be something estimating which features fit or can be made to fit
- Set dependent estimates of (dis)similarity (including set size, weights, etc.). The intersection reflects similarity, the remaining features dissimilarity
- An electric flash and shock simulator (a fun gadget). The flash to indicate insight, the shock to indicate surprise
- Metaphor and analogy production units (optional)
- Signal detection and decision making
- Perception biases. The estimates of similarity and dissimilarity are affected by, among other, attention focus, direction of comparison, or proportional relationship
- An abstraction algorithm to represent concrete objects as, for instance, geometrical forms so to make them better comparable
- Detection of void addresses. When compared with stereotypes, it becomes clear what features are missing on a certain entity, which can be filled in creatively

- A selection and deletion tool with multiple undo
- An extended range of adaptation devices (e.g., orientation, color, size, rule transformation)
- An integration tool; something that seamlessly stitches pictures, words, etc. together
- A measure of physical distance to prove that entities are concretely brought together
- A frequency counter of combinations relative to sample size to indicate the degree of novelty of the creation

8.1 Database with crisp and fuzzy ontology

During Preparation, people become acquainted with a number of domains, which they explore through association and feature comparison. From the knowledge sources they consult, they extract an ‘ontology’ about the state of affairs in that domain. Many domain ontologies together may form a general ontology or belief system about the way the world is (Hoorn, 2012, Chapter 6). Domain ontologies may be represented by a number of databases in which the contextual information of the knowledge sources and the uncertainty of information is modeled while using fuzzy sets (e.g., Lau, Li, & Xu, 2007). The ontology should be such that category boundaries can be crisp to represent someone who works with a two-valued logic in a deterministic setting. They should be fuzzy when representing someone who works with uncertain information and uses multi-valued logics in a probabilistic setting (cf. Hoorn, 2012, Chapter 1). Therefore, it should be possible to adapt databases from taxonomic crisp to non-taxonomic fuzzy relationships or correlations. These correlations between features should be updated with the availability of new knowledge sources. Inversely related, the degree of uncertainty of information should feed into the measure of familiarity of an entity (Section 8.4).

In addition, a measure of associative distance (δ_A) between the categories from which exemplars are combined should be computed (e.g., Weber & Osherson, 2010) for later use in the creativity calculus (Section 9). The idea is that in bridging associative distance, it is more creative to construe similarity between, for instance, the letter I (sub-set of straight letters) and the letter O (sub-set of round letters) than it is between an I and a T or a C and an O.

8.2 Adaptable association generator

To simulate the elicitation of a narrow or a broad feature set, fuzzy queries should generate an association path (cf. information retrieval) through the fuzzy relational database. The generation of associations, then, is represented by an information

retrieval algorithm (cf. Calegari & Sanchez, 2008) that allows to derive a unique path among the entities involved in the query to obtain a minimum of features in the knowledge domain when someone is in a deterministic and analytic mode of thinking (just the close associates) or a maximum of features when that person is in a mode of brainstorming and defocused attention (including rare and far-fetched associations). Features closer to the queried entities increase its familiarity value more than those further away. Thus, familiarity also is a function of percentages of set membership (Section 8.4) and it follows that the long narrow detailed feature list of the specialist expresses more familiarity with the topic than the shorter but broader unspecific feature list of the generalist.

8.3 Random feature generation and connection

There should be a serendipity sub-system or a random feature generator that creates sets of randomly retrieved features. Whereas the narrow or broad range of feature associations are still connected to the entities in the queries, here the features need not be connected at all according to the domain ontology. Yet, features can be subject to certain restrictions (cf. selection), such as 'being blue' or 'having six legs.' As an additional utility, the serendipity sub-system should be capable of generating all possible combinations within or between feature sets (cf. the feature matchmaker), for example, dressing up the spiny quills of a porcupine with peacock feathers (a 'peacupine' or 'porcock'). Checking with reference ontologies can automatically ensure that features are qualified as artificial (novel) or 'real' (conventional, familiar). The construction of artificial features should be customizable to enable the generation of random variations of a feature (blue feathers, red feathers, yellow, etc.) (cf. adaptation).

The degree to which features of an entity match with the reference ontology may determine the percentage of set membership and, hence, the size of the contribution to the familiarity of that entity (Section 8.4): A blue peacock feather more than a red one; artificial features less so than 'real' ones. Thus, a degree of artificiality or realism contributes to the level of familiarity.

8.4 Familiarity measure

To a certain extent, familiarity of an entity is determined by the entity's frequency of occurrence in a community or perhaps better by the frequency that someone is exposed to it (frequency of exposure). Exposure may be in whatever form, whether real or representational. However, an entity may be encountered often without knowing much about it (e.g., streptococcus) or may be encountered seldom but with a lot of knowledge in store (e.g., an ostrich). Thus, familiarity is not only

sensitive to the frequency of exposure but also to the number of features that it elicits (i.e. feature set size).

Yet, features themselves also have a frequency of occurrence or ‘activation value.’ Certain features come to mind more easily, have different strengths of association (e.g., Shiffrin, Huber, & Marinelli, 1995), or are regarded as more important. The list of variables that may inhibit or facilitate feature activation is near endless. Therefore, each feature should receive a weight. That weight can be interpreted as a single or composite value. As a single value, it could represent a frequency number, an association strength, salience, or emotional relevance (Hoorn, 2002, p. 188). As a composite value, the weight of a feature could be made up of all variables deemed pertinent for Evaluation. Whether this should be the sum of weights, the mean weight, or something else is an open question. As an engineering solution, Lulham et al. (2011) provide a Familiarity Discrimination Toolbox,¹³ which represents feature sets as patterns in a network. The system is capable of feature extraction while discriminating entities as novel or familiar. This tool allows features to correlate while weights can be adapted.

Whether single or composite, feature weights change with the change of goals, concerns, perspectives, focus of attention, biases, group pressures, and other conditionals that affect the creator. In a fuzzy sets approach, information uncertainty and percentage of set membership are also functional for the weight of a feature (see previous sections). In sum, familiarity of an entity is determined by frequency of exposure, feature set size, and (composite) feature weights. In its turn, the measure of familiarity loads on the perception of continuity in a creation or in a line of innovations.

8.5 Associative distance estimator

The entities that may potentially be used in a creation each receive a familiarity value. If entities are part of each other’s feature sets and thus positively affect each other’s familiarity value, the percentage(s) of (mutual) membership are inversely related to associative distance (δ_A). If entities are not features in each other’s feature set and, more importantly, if they cross category boundaries of the belief system (i.e. connect previously unrelated databases), the perception of associative distance is increased. The larger the associative distance that is bridged by the novel combination, the larger the disruption that is experienced. In a crisp categorization (i.e. in a mindset focused on determinism), the creativity of a novel combination will be experienced as larger than in a fuzzy categorization (i.e. in a mindset focused on probability). Put differently, in a fuzzy representation, associative distances

13. <http://www.cs.bris.ac.uk/Research/MachineLearning/FamTool/>

generally will be perceived as shorter than in crisp representations. Fixated analyticians are shocked more easily by boundary violations than flexible creators.

The higher the familiarity of entities (visible in long detailed feature lists of close associations) and the smaller the associative distance that is bridged by the novel combination, the less creativity is experienced (cf. incremental change: “Nice addition”). The higher the familiarity of entities and the larger their associative distance, the larger the experienced creativity (i.e. disruption as expressed in the strengths of flash and clash: “Why didn’t I think of it?”). The lower the familiarity value and the smaller their associative distance (things unknown and hardly different), the smaller the level of creativity that will be attributed to a novel combination (“What’s the fuss? Nothing changed”). Low familiarity in combination with large associative distance will lead to neutral assessments of creativity (“Fine. I can’t judge it”).

8.6 Feature matchmaker

Actually, the feature matchmaker should be called an entity matchmaker but because the matchmaking is based on activated feature sets, we stick to the first. The feature matchmaker propagates combinatory exhaustion. It mines the activated feature set of an entity for comparison with the activated feature sets of every other entity in the general ontology, starting with entities from unrelated databases. The feature matchmaker is adjustable in the sense that the algorithm may change from crisp to fuzzy comparison, allowing for exact as well as partial identity or sameness of features to establish an intersection.

The combination of combinations shall lead to one big overall combination. If this is undesired (e.g., the homogeneity dilemma, Chapter 5, Section 5), a limiter could be designed (cf. selection) that only allows first-order, second-order, third-order etc. combinations. Another way would be to have the reuse of a parent combination increase the frequency number of its occurrence, thus decreasing the originality or uniqueness of the child creation up to a critical point of rejection. One could also reduce the number of domain ontologies or the number of entities in a domain (cf. selection) as an indication of the creator’s limited view of the world. Yet another way is to prioritize features on the basis of their weights and only allow a selection to enter the comparison. For example, feature frequency numbers could decide to compare rare, low-frequency features first and leave mundane, high-frequency features out.

Likewise, the serendipity sub-system (Section 8.3) could generate all possible combinations within or between feature sets, thus maximizing the intersection. Without filtering (selection), distinctive sets are emptied. A limiter could be, for

instance, to only combine color features and no higher than to the second order and of no more than two entities. This could count as a kind of poetics.

Based on *a priori* predicated indices, feature matchmaker also could establish intersections between sub-sets of entities, for example, between literal and figurative features (see *Metaphor and analogy production units*). Thus, although combinatory explosion is intended but if for reasons of limited capacity this situation is not desirable, prioritization and selection may take place on the basis of feature weights or sub-sets of features (i.e. indices) for color, figurativeness, or any other type of index.

8.7 Unipolar estimators of similarity and dissimilarity

Basically, the (fuzzy) intersection is responsible for the estimation of similarity between two entities, whereas the (fuzzy) distinctive sets feed into estimates of dissimilarity. However, these two measures do not add to 1. Due to all sorts of perception biases, similarity is not 1 minus dissimilarity. For example, two Chinese people in a group of Arabs look more similar than in an equally large group of other Chinese people. Another example is that things put physically close together are compared for similarity more than things put farther apart (Dollard & Miller, 1950).

Therefore, an estimator of similarity and an estimator of dissimilarity should be based on the size and weights of feature sets but also should be adjustable as a function of a theoretically (not empirically) infinite number of perception parameters. Thus, the measure of similarity is influential for dissimilarity and vice versa but the correlation is partial, thus establishing two relatively independent unipolar scales. Bipolarity of scales ($\text{similarity} = 1 - \text{dissimilarity}$) is just one possible constellation in a range of unipolar resolutions. The combination of similarity and dissimilarity perception decides whether more selection, adaptation, and integration of features needs to be done to achieve an optimal fit between sets and, hence, to experience an optimal balance between the two scales (Figure 14).

The similarity estimate feeds into the experience of continuity whereas the dissimilarity estimate fosters the feeling of disruption. Just for the fun of it, a flash could be programmed when the creativity simulator establishes sufficient similarity between unrelated databases and a shock effect that is proportional to the level of perceived dissimilarity.

8.8 Metaphor and analogy production units

The previous section treated simple comparisons between remote entities such as atoms that behave like billiard balls or bikes that look like horses, where the second

entity (e.g., the billiard balls) introduces the fictional aspect or ‘possible world,’ serving as a frame of reference.

Analogies are more difficult than simple comparisons because they require the comparison of remote entities, the introduction of a fictional world, as well as logical reasoning. Metaphors are more difficult than simple comparisons because they do not only suggest a fiction world but also connect literal features to figurative meaning. Metaphors are less difficult than analogies because they are direct comparisons that need no logical inferences. On the other hand, an analogy can be entirely literal (see Box 3) whereas a metaphor always exerts figurative meaning as well.

Simple comparisons as well as analogies and metaphors can be used as creative devices. Whereas simple comparisons can be solved by feature matching, analogies also require a reasoning module, for which many examples exist (e.g., Goel, 1997; Ma, Yan, & Li, 2005). Metaphors can be created by matching not only the literal features of different entities but also literal with figurative (according to index).

8.9 Signal detection and decision making

A creativity simulator should be capable of flexibly switching from an associative, combinatory mode to an analytic and reasoning mode of information processing and vice versa. This may depend on the problem space at hand. In a mode of unfocused attention and low stimulus discrimination, the creativity simulator is similarity eager, deliberately searching for false alarms, where an entity under consideration (e.g., the bike) is related to or combined with an out-of-category other entity (e.g., the horse). That second entity forms a fictional frame of reference to perceive the first entity with (cf. perspective changing).

1. Searching for false alarms: The simulator sees a fictional frame of reference for every entity that according to its ontology or belief system is real even under circumstances of high variability (e.g., I see a horse in bikes even with wheels and saddles on them).
2. Turning false alarms into a hit: There are entities that according to the simulator’s ontological beliefs are real for which it finds a fictional frame of reference provided that variability is reduced but not completely (e.g., a modified bike frame looks like a horse).

When the creative simulator is not in an associative mode but rather in an analytical mode of information processing (cf. abstraction, selection) the likelihood increases that correct rejections will occur.

3. Correctly rejecting similarity: For every entity that according to the simulator's beliefs is real and that is perceived under circumstances of great variability, no fictional frame of reference applies (e.g., an intact bike does not look like a horse).

When the simulator is in a stressed-out, fatigued, or survival mode, chances for missing the signal are high.

4. Missing out on similarities: There are entities that according to the beliefs of the simulator are real for which no fictional frame of reference applies because variability is not reduced completely (e.g., a bike frame remains a bike frame no matter what).

During creation it should be possible to switch between the open and narrow mind set (cf. Meneely & Portillo, 2005).

8.10 Information abstraction

Information abstraction is applicable when entities cannot be put together physically. ACASIA suspects that when entities cannot be combined, they yet can be combined at higher abstraction levels. Algorithms should be capable of abstracting away features from entities by filtering out details in reference to prototypical forms. In the case of visual entities, the prototype shapes are blocks, circles, triangles, cylinders, etc. of variable size. In the case of non-visual data, the mining of models with strong adaptability and scalability could be used to extract semantic association patterns that generally belong to an entity (e.g., He & Zhang, 2010). That general model could be used as a reference ontology to (gradually) clear away the details of a given entity (also see Hoorn & Van Wijngaarden, 2010, pp. 314–315).

8.11 Detection of void addresses

With a reference ontology in the background, the simulator should be able to detect the omission of features that based on statistical occurrence can be expected to be part of an entity's feature set or semantic network. If it so happens that through matching, features of another entity can occupy a 'void address,' it should do so provided that the intersection grows and perceived similarity is enhanced. In combination with the selection, deletion, and adaptation tool, filling out void addresses equals a substitution tool.

8.12 Search and destroy

Selection and deletion of features should be oriented at enhancing perceived similarity and reducing perceived dissimilarity (criterion q) by enlarging the intersection and/or trimming the distinctive sets. It also should be capable of evading the goal state of optimal similarity for a while, preconceiving that an artificially void address can be filled out by features of another entity. In other words, the machine first maps the features of the one entity onto the other and then deletes what diminishes the distinctive sets and enlarges the intersection. The adaptation tool may transfer a feature from the one set to the other. Selection and deletion should have multiple undo in case the increase in perceived similarity is not achieved. On account of statistical frequency of occurrence, rare features that intersect should be preserved as much as possible, whereas common features that are distinct should be deleted without replacement.

Optionally, feature selection (and adaptation) can be related or compared to external goals to make the creation acceptable, useful, valuable, significant, satisfying etc. Such goals, concerns, norms, and standards typically include the value systems of others.

8.13 Adaptation devices

The list of ways to adapt a design seems almost endless. Among them are variants of features, expanding, contracting, bending, coloring, polishing. Adding new features does not only involve feature transfer from one set to the other but also contextualizing a creation by surrounding it with words, other pictures, sounds, or other people to bias perception into the direction of optimal similarity between the entities of the novel combination. Rule transformation such as changing the genre is a form of bandwidth tweaking, which can be used to achieve optimal similarity or acceptability to group norms. Rule transformation could also operate in combination with selection and deletion, so that certain rules may be abandoned.

8.14 Integration tool

The purpose of integration is to make two associatively disparate entities seem like one. Integration is about filling the voids between entities such that they do not fall apart or become separated again in time and space. Integration, then, introduces an external entity that has nothing to do with the entities in the new combination and is meant to keep them close together, physically. It means to apply screws and bolts, interlocking studs, glue, welds, chemical amalgamation, collaging, and

montaging. It may include shortening time intervals between occurrences of features (cf. music, film, or dance). It could require a carrier or a medium such as paper, a canvas, or a DVD. When integrated thoughts become materialized, words are put close together on the page, for example, 'quantum physics' assumes to describe the natural world whereas 'metaphysics' would describe the supernatural world. In unison, they become 'quantum metaphysics' (i.e. the idea that many worlds exist, inaccessible to sensory experience but nonetheless real).

8.15 A measure of physical distance

When two or more entities are put together, the original physical distance (δ_p) between those entities is reduced (Hoorn, 2002, p. 190). At time 1, there is a distance δ_{pt1} and at time 2 a distance δ_{pt2} , of which δ_{pt2} is the net result of the finished creation. In between δ_{pt1} and δ_{pt2} , there should be a point δ_p , where two entities are considered a combination or not (ibid.). Through the abstraction of concrete objects (making them a concept or representation), physically unbridgeable distance can be compensated for (ibid.).

Putting entities together or unifying them means that real physical distance needs to be bridged between (features of) entities (Hoorn, 2002, p. 187). After creation, then, physical distance between entities has become smaller: $\delta_{pt1} > \delta_{pt2}$. For the fusion of two ideas, we saw that as soon as those ideas materialize, for example, in writing or drawing, the words or images describing the two ideas are put closer together than before. As one of the biases that affect the measure of similarity (Sections 8.7 and 8.9), the focus switches from detecting dissimilarity to similarity the closer things are put together (Dollard & Miller, 1950; also Rothenberg and Hausman in Section 5.3.1).

When entities are combined, the associated features form a fuzzy intersection $\tilde{I}$ and fuzzy distinctive sets $\tilde{D}_{l,n}$. The more features enter the comparison; the higher the probability of finding matches until an optimum is reached. Features should be global rather than detailed to allow for partial sameness. Familiarity F is a reflection of frequency of exposure to the entity, feature set size, and (composite) feature weights. Perceived similarity s is a reflection of $\tilde{I}$ and is related to perceived dissimilarity d , which is a reflection of $\tilde{D}_{l,n}$. Up to an upper bound, increases in F cause increases in s and decreases in d . When the distance between entities is smaller than δ_p , the intersection $\tilde{I}$ grows and s increases (Hoorn, 2002, p. 190). As a result, two functions of δ_p on s and d may be described: Given a set with 'void addresses' or 'void features,' feature attribution (copy-paste) and thus s increases, whereas d decreases, the closer entities get (ibid.). Given the existence of approximately identical features, $\tilde{I}$ grows and thus s increases, whereas d decreases, the closer entities get. If entities are completely fused, δ_{pt2} and d approach zero, whereas s

approaches 100% (ibid.). However, complete similarity is not necessarily the optimum for creation: While $\tilde{I}$ grows, whereas $\tilde{D}_{1,n}$ diminish, a point q is reached where the judgment of “creative” reaches the top of its parabolic growth (ibid.). After that point, the creation has either become the one entity or the other (looking too much like either a real horse or a real bike). Before that point, the judgment will be “farfetched” or “incomprehensible” because there are too few interconnections. Obviously, perceivers more tolerant to deviations will allow more dissimilarity, more associative distance, and less familiarity than intolerant observers.

8.16 A frequency counter of combinations relative to sample size

A combination of associatively unrelated entities is regarded a creation if sufficient similarity between entities is established relative to the measure of dissimilarity and if originality expressed as the frequency of occurrence of that combination at the time of inception is close to 1 in a given (sub) sample. The larger the sample size, the more original such a unique creation is.

9. Creativity calculus

Figure 16 provides an overview of the variables needed and an indication of the way they relate to one another to make an estimate of creativity. If you plot creativity on a continuum of small to great, then small creativity demonstrates similarity between entities at smaller associative distances of their respective categories, whereas great creativity demonstrates similarity between entities at wider associative distances (i.e. across category boundaries). Yet, entities in principle may relate to categories at large associative distances but if their combination is commonplace (e.g., two toilet rolls taped together as binoculars), creativity is considered low. Thus, the measure of creativity increases the larger the initial associative distance between categories, the more the similarity function approaches the optimum of q , the smaller the numerator for the frequency of occurrence of the combination (the lower limit being 1), and the larger the sample size (i.e. the denominator).

Major biases in similarity perception are the measure of familiarity of the entities in the comparison. Familiarity has an inverted U-shaped function for similarity to be perceived, indicating that too much knowledge directs the attention to the detection of distinctive features. Another important bias is induced by placing entities at close physical distance, which shifts the focus of attention towards finding commonalities.

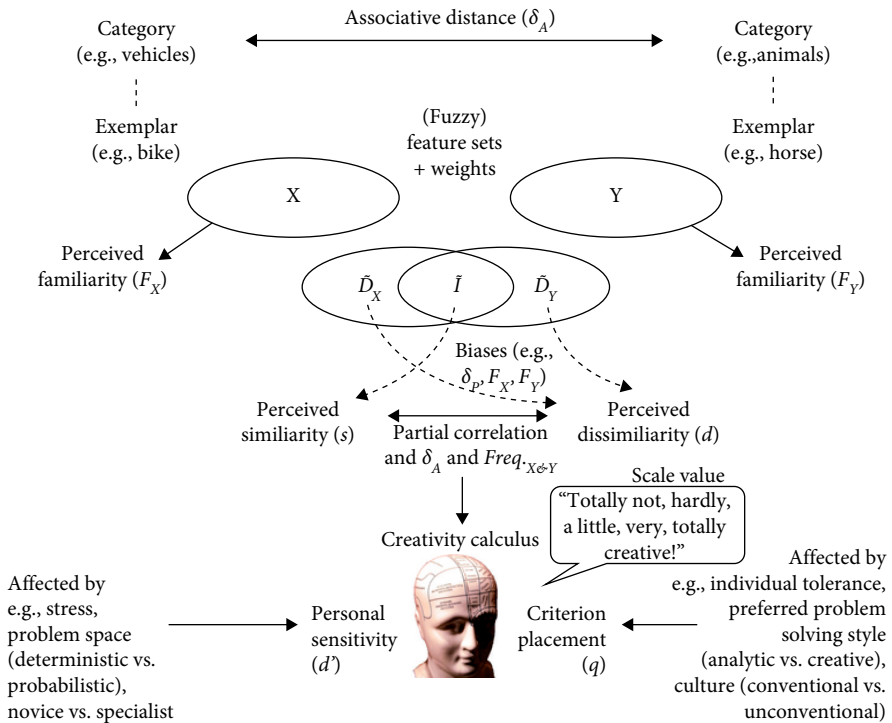


Figure 16. What a creativity calculus should be composed of

Figure 16 shows that the associative distance between categories (δ_A), fuzzy intersecting ($\bar{I}$) and distinctive sets ($\bar{D}_X$, $\bar{D}_Y$), the partial correlation between perceived similarity (s) and dissimilarity (d), and the frequency of occurrence of the combination ($Freq_{X \& Y}$) relative to sample size result into a scale value of creativity (e.g., "Totally not" or "A little creative"). Important perceptual biases result from familiarity with the entities (F_X , F_Y) and physical distance (δ_p). Personal sensitivity (d') and criterion placement (q) are conditional for decision making.

While signal strength is expressed as the size of the fuzzy features sets times feature weights, individual sensitivity is important to mitigate stimulus discrimination, which affects the scale value of creativity that is attributed to a creation and which in its turn is affected by levels of arousal and stress or the type of problem space that is relevant. Likewise, criterion placement determines the type of decision (a bike can be seen as a horse or not) and in its turn is subjected to factors such as problem solving style or rigidity about truth. The latter does not mean, however, that there is an either-or in thinking style that will lead to higher creativity. Because certain stages of the creative process are more intuitive (e.g., association)

whereas other are more analytic (e.g., selection), being able to change repertoire in thinking styles is most recommendable (cf. Meneely & Portillo, 2005).

Thus, creativity is relative to a community, depends on the association structures available to that community, and connects associatively distant domains. It can be calculated for single ideas, for works as the sum of creative ideas, and for people as the sum of the creativity of their works.

10. Creativity simulation

Section 8 and 9 summed up the requirements on a creative system as if it were to emulate the way humans are creative. As Boden (2009) rightfully remarked, however: “Contrary to what most people assume, the creativity that’s most difficult for AI to model is the combinational type” – as you will see in the remainder of this chapter.

For certain people, to nail creativity down to a model and then quantify it will feel a bit awkward. After all, the ‘world of measurement’ seems to be at odds with creation itself (Zander & Zander, 2000, pp. 17–19). As André Breton (1924/1994, p. 19) in his *Manifeste sur Surréalisme* so eloquently put it: “The incurable mania which consists in reducing the unknown to what is known and classifiable, lulls the mind. The desire to analyze outweighs feeling.”¹⁴ However, science not only creates; it also controls and evaluates and drives probability into determinism. In that sense, formalizing a creative scientific idea so that it is fit for empirical testing indeed pushes creativity towards the asymptote (Chapter 5). End of innovation.

10.1 Under construction

It may seem that making computers creative is the craze of the day but that is actually not so: It is at least more than half a century old. After World War II, physicists, engineers, and artists became interested in computer-generated artistic output, reaching as yet its summit in 1968 at the Cybernetic Serendipity exhibition of the Institute of Contemporary Arts (ICA) in London. To date, ample examples exist of art based on fractals, algorithms, software, robots (Figure 17),^{15,16} poetry machines,¹⁷ or programs that can re-discover scientific breakthroughs.

14. *L'intraitable manie qui consiste à ramener l'inconnu au connu, au classable, berce les cerveaux. Le désir d'analyse l'emporte sur les sentiments.*

15. <http://www.designboom.com/weblog/cat/16/view/9163/aikon-drawing-robot.html>

16. <http://www.thepaintingfool.com>

17. <http://nodebox.net/code/index.php/Flowerewolf>



Figure 17. Portrait by Aikon drawing robot (Leymarie, 2004-2012)

Boden (2009) provides an excellent overview of the field. For example, the BACON lineage of computer programs can apply scientific heuristics and principles of problem-solving to search for certain patterns and relations that are implicit in a data set (Langley et al., 1987). Among other findings, BACON was able to re-discover the third law of Kepler in a data set of planetary motion. Another example is a joke-generating machine called JAPE (Binsted, Pain, & Ritchie, 1997), capable of producing puns through a semantic association network. Riddles are of the kind: “What do you call a depressed train? A low-comotive.” In the musical domain, the Emmy system (Cope, 2006) could compose music in the style of Bach, Chopin, and others,¹⁸ using a tremendous database with musical features typical of a certain composer.

Recently, Bhattacharyya and Ohlsson (2010) simulated the creative exchange of individual software agents in several types of collaboration networks to seek out the rate of invention and information diffusion in creative collectives. One of the conclusions was that the rate of inventions increases even when agents are low-connected as compared to a situation of “lone geniuses” – the unconnected individuals. The explanation is that when partial results are communicated to other agents, cognitive workload for all individual agents decreases, pushing the entire collective forward in the search space.

With respect to the modeling of combinatory creativity, Boden (2009) sees the ultimate challenge in producing novel combinations that are ‘apt’ and representational for the subtleties of human association (she cites Shakespeare to make her point). One of the weaknesses of simulated combinatory creativity, she continues, is that computers have too limited a knowledge-base and lack cultural sensitivity to know whether a combination is appropriate or not (a problem of selection).

True as it may be, that a pun machine like JAPE cannot compare to Shakespeare’s verse does not discredit the proceeding of artificial creativity. At least JAPE is more creative than the ELIZA chat bot of the 60s (Weizenbaum, 1966),¹⁹ which does not do much more than string substitution and returning scripted responses based on keyword recognition. Already in the mid 90s, NETMET could interpret Shakespearean metaphor such as “Juliet is the sun” and generate novel metaphors such as “The mind is an intellectual womb” (Steinhart, 1995).²⁰

18. <http://artsites.ucsc.edu/faculty/cope/mp3page.htm>

19. <http://linux.softpedia.com/progDownload/Chatbot-Eliza-Download-25322.html>

20. <http://www.ericsteinhart.com/ANALOGY/netmet.zip>

The latter example may not be ‘apt’ or ‘appropriate’ but that is a matter of fine-tuning the selection criteria and explicating the perceiver’s goals attached to them (see Section 6). That selection should be optimized is not a theoretical issue by itself. Moreover, selection criteria and judgments such as beautiful, useful, or apt are not at the heart of combinatory creativity. Likewise, if the knowledge-base is not wide and sophisticated enough, it is a matter of time to enrich it with more entries and relationships. Boden (2009) is right when she says that it is not easy to have a rich and subtly structured stock of concepts that is searched according to the rules of human association. Yet, this is the challenge taken up in the next section, knowing we will come up with a result that may be no more than partial (cf. Bhattacharyya & Ohlsson, 2010).

10.2 The Creator Simulator

Next we will examine the basic principles that lie at the heart of creativity. Therefore, we necessarily restrict ourselves to what Lowcre (2013) called *physical creativity*, which is pure combination making without ‘intelligence.’ In Figure 14, this is the part of the creative process consisting of association and insight, excluding all the organic preoccupations of selection, adaptation, etc., which are there to get a result that is ‘apt.’ We will arrive at matters of selection later in the book.

Therefore, we devised a small, rudimentary system that produced novel combinations. The only database structure it used was that categories (e.g., animals) contained exemplars (e.g., elephant), which had features (e.g., trunk). The application closely modeled the associative process so to generate ideas in the following way:

1. Draw two exemplars from different categories
2. (Fuzzy) compare the sets of features of each exemplar
3. Generate a similarity score as well as a dissimilarity score
4. If a specific ratio is met (criterion q), the new idea is accepted
5. Go to 2

Note that between 3 and 4, selection, adaptation, etc. may take place to optimize the ratio between similarity and dissimilarity to satisfy q .

For the sake of simplicity, we worked with words to generate the novel combinations but the same can be done with visuals or other stimuli. The machine took two exemplar words (e.g., ‘elephant,’ ‘mountain’) from unrelated categories (e.g., ‘animals,’ ‘objects,’ ‘seasons,’ ‘environment’). Each exemplar came with a set of features (e.g., ‘big,’ ‘bright,’ ‘long’). The feature sets of both exemplars were compared and a judgment was made as to whether or not the exemplars could be combined. The ratio between the measure of similarity and the measure of dissimilarity had to satisfy the preset criterion q to accept or reject a combination. In other words,

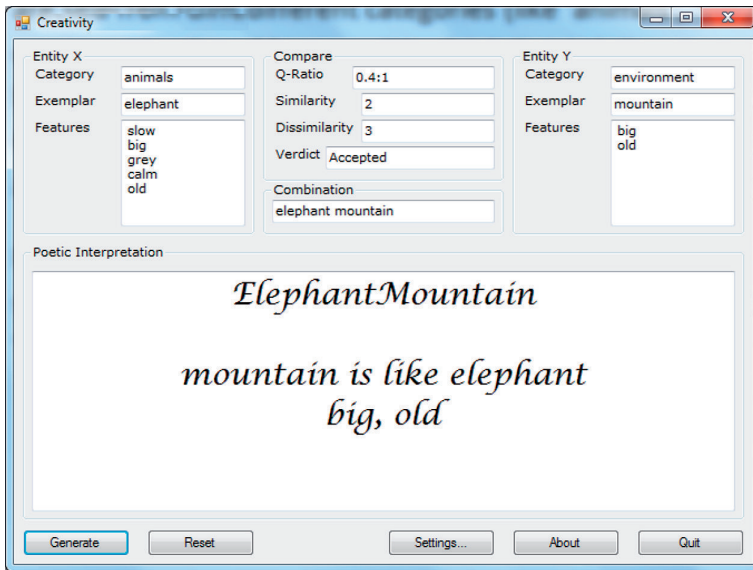


Figure 18. The creativity application

the machine was not erratically running through the Yellow Pages to randomly pick a word (cf. Tzara's Dada poetics) but was looking for an optimal "sameness in diversity." The accepted combination was formatted as a collated noun ("Elephant-Mountain"), rephrased as a simile ("A mountain is like an elephant"), and explained by the features that both exemplars shared ("Both are big and old") (Figure 18).

The features that were associated with 'elephant' were {'slow', 'big', 'grey', 'calm', 'old'}. Features associated with 'mountain' were {'big', 'old'}. In Figure 18, this is listed by the boxes 'Entity X' and 'Entity Y'. While comparing, the intersection and symmetric difference of the sets were calculated. The intersection was {'big', 'old'} and the symmetric difference was {'slow', 'grey', 'calm'}. As value representations of similarity and dissimilarity, we took the number of features in both sets. This is shown in the 'Similarity' and 'Dissimilarity' items in the center of Figure 18. The ratio between the number of features in the intersection and the symmetric difference was then calculated (here 2/3, or 0.667). When this ratio exceeded the specified value of q , the combination was accepted.

Elephant and mountain were deemed an acceptable combination because q was set to a middle value of 0.4 (top center item named 'Q-Ratio'). When the value of q was lower (e.g., 0.1), the system accepted any combination that had some similarity, even the very strange ones. Examples of dissimilar, divergent, and disruptive combinations generated in this way were:

ThunderFox	–	A fox is like thunder	–	tough
SunLily	–	A lily is like the sun	–	beautiful
PencilWind	–	The wind is like a pencil	–	sharp
VenusRose	–	A rose is like Venus	–	feminine
SwordRoad	–	A road is like a sword	–	long
AutumnElephant	–	An elephant is like autumn	–	old

When the value of q was set higher (i.e. 0.7), only the very obvious combinations were accepted (much similarity, convergent, incremental). In all cases, combinations that faced a high threshold of acceptance stayed within category boundaries and had large intersections:

SunshineDesert	–	A desert is like sunshine	–	clear, light, dry, hot
SunSunshine	–	Sunshine is like the sun	–	light, white, clear, beautiful, hot
SnowSkiing	–	Skiing is like snow	–	white, cold
EarthSea	–	Sea is like Earth	–	big, blue

These examples show how limited the feature sets were – and hence how little this creator simulator ‘knew.’ It did not know, for instance, that mountains can be grey as well; just like elephants (Figure 18) or that the Earth is blue because of the sea. Concurrently, the examples also show that even with little knowledge but great tolerance to crossovers ($q = 0.1$), one can come up with novel combinations that yet are not purely random. In its core, breakthrough creativity seems to be that simple.

10.3 How the *Circle of the CobraSpoon* came into being

As shown, our simple algorithm could find novel combinations across diverse ontological categories based on (fuzzy) matches between features of exemplars. At the Lorentz workshop on creativity (Sept. 13, 2011),²¹ we demonstrated our creator simulator (Lowcre, 2013). It was dressed up like a robot monkey and it stated in synthesized speech that “A snake is like a spoon.” The robot monkey based itself on the common feature of both snake and spoon ‘being round.’ Then it clapped its hands.

The monkey’s antics were received with mixed feelings. Particularly the assembled computer scientists were moaning about the lack of intelligence and one even became aggressive because this was way too simple. Indeed, it was (see Boden, 2009). The artists and designers, however, were humored and said they recognized the way the monkey came to its funny combinations.

Whether simplistic or not, through computer generated ‘insight,’ the robot monkey accomplished a conceptual combination. Not completely random, because the algorithm worked according to minimal structure (i.e. an individual ontology) and criteria, in particular, a certain balance between sameness and difference between entities. Then, human optimization took place.

21. <http://lorentzcenter.nl/lc/web/2011/470/info.php3?wsid=470>

Henriette Jensenius adapted the concept of snake to cobra because of the round flaps on the neck of the animal, which fitted the scoop of the spoon better than the neck of any other snake. I then proposed to make a small statue out of a cocktail spoon bent in the form of a snake, standing on its spiral tail, with an abstract snake head welded on top of it. Jeroen Werner bought a spoon and made a first prototype, as a symbol of our joint creativity.

On the Internet, I found a cocktail spoon with neck flaps²² and drew a metal head on top, keeping the spoon intact. Desmond Germans suggested that it should remain possible to put the head on the tail and keep the spoon separate so that the conceptual blend could be demonstrated time and again. Over Christmas, I had a goldsmith create a head and tail for the cocktail spoon, resulting into the design depicted in Figure 19.

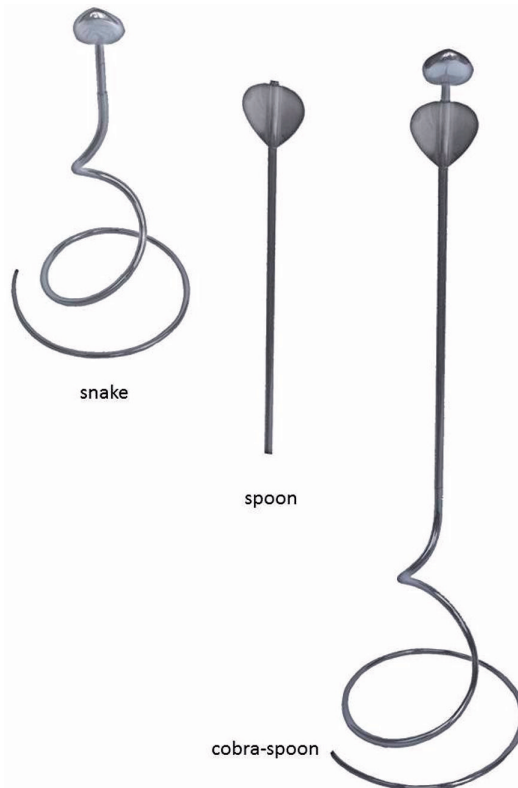


Figure 19. CobraSpoon (Lowcre, 2013, p. 19)

22. Retrieved Sept. 16, 2011 from http://www.wmf.com/wmf/upload/images/article_images/250x250/1288686040_Cocktailloeffel-Set_Bistro.jpg

To get a feel for its novelty, I typed in Cobra Spoon to search the Internet and found that there was a sterling silver cobra spoon ring already out there (Figure 20). First of all, this teaches us that the originality of an idea decreases when we encounter a prior example and second that, on a conceptual level, the monkey machine emulated the creativity of a human designer (i.e. the ring maker), except that its ontology was limited to 'snake' and did not have 'cobra' in it.



Figure 20. Sterling silver cobra spoon ring

Marco Otte put forward that we should have a community of people working on creativity in the spirit of the workshop. We called it the CobraSpoon group, later changed into *The Circle of the CobraSpoon* because of the spiral tail of the statue. To make a statement, I returned to the Lorentz Center, placed the CobraSpoon on the desk of Hendrik Lorentz, and took a picture (Figure 21): Physical creativity.



Figure 21. CobraSpoon at H. A. Lorentz' desk

From the story of the CobraSpoon we may realize that making the novel combination perhaps is not that hard (1% inspiration) and can be simulated by a machine relatively easily. It is the upgrading of a plain snake to a cobra or the ordinary spoon to a cocktail spoon, which then is refined to a cocktail spoon with a more triangular scoop and a straw for a handle, a tail taking the form of a spiral (symbolic!) that is the thing machines cannot do too well. Humans can. They have the proper knowledge to fill up the niches of evolution with the most sophisticated incremental improvements (99% transpiration).

With some human help in the incremental improvement, a simple creator simulator can suggest productive ideas. Here are a number of further examples that the robot monkey put forward during our workshop session. Imagine the synthesized monkey voice saying:

A spoon is a snake	–	Like a cobra is when it's agitated
A rose is joy	–	You celebrate the moment
A shark is like Earth	–	They will both be destroyed by mankind
A beach is winter	–	It blinds your eyes when the sun shines
A desert is like Mars	–	Red is its color and no life exists there
Sleeping is like the sun	–	It's comforting and you feel good afterwards
Envy is like a forest	–	It clouds your view and you get lost in it
A day is like love	–	You start afresh and by the end you are tired
Death is like winter	–	Every ending brings a new beginning

In fact, the interpretations following the computer-generated similes were written by Martijn Arts, one of the workshop participants. He construed in hindsight what the monkey never had in mind beforehand. But then again, this is no different from interpreting human creations. While writing the 18th chapter of *Ulysses*, James Joyce never had in mind the dozens of pages with meanings of the word 'yes' that Jacques Derrida (1992) conjured up for Molly Bloom's soliloquy. As Gilot (2001, p. 176) put it: 'The viewer is co-creator.' A story, art work, or a theory evokes different interpretations in one head or the other. Van Rosmalen (Sept. 13, 2011) stated that each member in an orchestra may produce their individual notes but it becomes a symphony only in the head of the perceiver.

If we loosely follow the principle of the book spine poetry (Chapter 2) and stack the computer-generated creative output together with its human interpretations on top of one another, we arrive at some multi-authored cyborg poetry:

Venus Rose

(a cyborg poem)

A rose is like Venus
 A rose is joy:
 You celebrate the moment
 A lily is like the sun
 because both are full of beauty
 The day is like love, starting afresh
 by the end you're tired
 Sleeping is like the sun
 and death is like winter:
 Every ending
 brings a new beginning

10.4 Gible the land shark

Broadly speaking, the mind classifies the data it observes in all kinds of categories (e.g., animals, heavenly bodies). Each category consists of exemplars (e.g., sharks are animals), and exemplars have features (e.g., dorsal fin). In an analytical mode, the mind will do just that: Look at the features and classify incoming data correctly. In a creative mode, however, the mind does not classify but makes connections across categories based on commonalities or distinctive features that are complementary (e.g., 'shark' plus 'land' make Land Shark). Actually, the combination of 'shark' and 'land' was realized as a Pokémon creature named Gible (Figure 22), which can swim through the ground while its dorsal fin stays above the surface.



Figure 22. Gible the land shark (Pokémon playing card)

Although based on different features than Gible, a comparable combination of 'shark' and 'earth' was generated by the said computer program ("A shark is like Earth"), simply based on matching features between exemplars that were not in each other categories. From a viewpoint of physical creativity, the computer was creative just like the designer of the Pokémon character was, except that the human creator optimized the combination to present Gible in a more acceptable form. Just like human creativity, physical creativity can come up with combinations that can be perceived by humans as novel after which humans may give meaning to that perception by generating more information (i.e. context) to make the combination acceptable (i.e. swimming through the ground). As Ward, Smith, and Finke (1999) found out, rather than designed from a predefined plan, novel

combinations become more creative when interpreted in retrospect. It is the human explanation in hindsight of the weird combination that was established physically.

Acknowledgements

The five steps of the creative process (Section 2) were elaborated together with Diana Krabbendam and Agnes Willenborg. I am grateful to Desmond Germans for not only formalizing and implementing but also for joining me in thinking through the consequences of the ACASIA model.

The Creative Sigmoid

“The virtual increase of the population is ... limited by the size and the fertility of the country. As a result the population gets closer to a steady state.”
(Verhulst, 1838)

Owing to its combinatory nature, ACASIA outputs an accumulation of innovations, described by the Creative Sigmoid. More and more diverse information leads to bigger creative leaps. Due to the scope of information that can be processed, however, the size of the cumulative steps decreases, describing asymptotic growth. This chapter formalizes ACASIA as a self-similar, partly stochastic process of creative advance, explaining that at all scales S-shaped growth curves start apparently spontaneously out of the top of the previous one. In creative progress, a new field starts with a jump from a previous rather stable situation: Knowledge was growing very slowly if at all, actually the field was stagnating, the totality of knowledge approaching a horizontal asymptote. The jump creates an opportunity for growth which at first stimulates more new ideas and knowledge increases more and more rapidly, but then slowly starts to slow down again, stable growth, finally again stagnating, stuck in its own preconceptions (cf. high culture). At bigger as well as at smaller scales, the same happens but also the process in individual brains can be modeled like this, in research groups, in artistic domains, in all of technology, in all of civilization, i.e. at bigger and bigger aggregation levels. The sudden jumps are triggered by communication of similarity between different components (i.e. seeing unity in diversity).¹

1. The forces that drive the sigmoid

In this chapter, we will learn more about ACASIA and its formalization. For starters, the first and second law of thermodynamics are reiterated and found fundamental for a continuum of combination making and decomposing them again into separate elements. All works of creativity are susceptible to those two forces. The build-up of a creative work or concept goes through combinatorics. It is a non-linear process that can be represented by a sigmoid growth curve of cumulative change.

1. Richard Gill, personal communication, Nov. 25, 2010.

In its infancy, the bandwidth of behaviors is wide. Many different combinations are allowed. During acceleration, the number of possibilities shrinks as choices are being made. At maturity, the bandwidth of behaviors is small as all is properly regulated according to demands of feasibility and effectiveness. When unchecked by decay, every creation consists of other creations and becomes part of yet other creations (cumulative growth) – in that sense, creativity is self-propelled. We will then look into organizational structure and see how innovation power is distributed across the various layers. After that, we attempt to formulate the requirements on a rule for creative development and run a couple of simulations to see whether ACA-SIA can produce the innovation S-curve or “Creative Sigmoid” as expected.

2. Creative development

In Lowcre (2013), the idea was developed that combinatory creativity on a physical level was transferred and adapted to the biological and then later psychological level. Lowcre assumes this is nature’s way to accelerate innovation as to find evolutionary niches much quicker and more efficiently. For millions of years now, the development of creatures like the Horseshoe crab (Chapter 1) or Tuatara (Chapter 2) remains at a standstill, whereas human creativity can easily jump from such plateau onto a new line of development and combine, for instance, robots with organisms to create bionic animals.² The current chapter attempts to formulate a systematics in creative development in probabilistic as well as deterministic settings. The idea is that combinatory creativity works its way through a universe of chaotic information that through creativity becomes more organized until it reaches a steady state where development stops. And then jumps over.

3. Creative combinatorics

Arthur (2009, p. 2, p. 107) poses that inventions do not come from nowhere and that new inventions are built from existing technologies. Likewise, K. Kelly (2010, p. 8) states that each technology is built from the components of other technologies. Technologies incorporate one another so that they grow exponentially (*ibid.*, p. 38).

Actually, there are two forces working against each other that are both important for creativity to occur: combination and decomposition. Things are built up and broken down again so that parts can be used in a new way. Chapter 1 explained that combination making was governed by the 1st law of thermodynamics: A

2. <http://www.youtube.com/watch?v=VN9NILCCUbw>

temporarily hot spot of chaos reshuffling entities that cooled down to assume structure. Decay was governed by the 2nd law of thermodynamics: When left alone, structure would fall back into entropy again. That means that the accumulation of creations is not merely exponential; the line may drop sometimes. Moreover, creations may incorporate prior art but once all possible combinations are exploited, the accumulation is not exponential in a linear way but becomes asymptotic.

Suppose the information universe or a sub-set of it consists of n freely floating entities. These are the objects and concepts that go through the ACASIA process. Those entities can be combined into r different groups of $k_1, k_2, \dots, k_r = n$ number of entities. Combinations may be composed of two or more entities but with each combination created, the number of options for the next combination decreases: For the first creative combination of k_1 entities there are n over k_1 possibilities. For the second combination of k_2 entities, the remaining number of entities is $n - k_1$, for which there are $n - k_1$ over k_2 options. An innovation line has to stop some time because according to the production rule (Figure 1, left to right), it runs out of options.

When almost all options are depleted, the information universe has locally become near-deterministic or 'crystalline,' that is where the system has formed. It can only rejuvenate if it is broken down again by entropic forces (cf. anarchy or 'creative destruction'). Without maintenance and restoration, the combinations are turned into separate entities again (cf. 2nd law of thermodynamics), which do not necessarily have to be the same as before. This is illustrated in Figure 1 by reading the production rule from right to left. These principles work for physical creativity and continue to work for organic creativity. However, organic creativity can do one more thing. It does selections on what to use or not in view of certain goals or concerns.

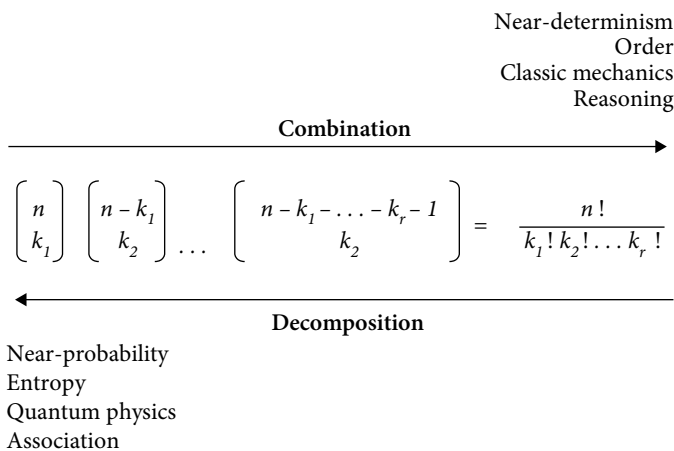


Figure 1. Combination-decomposition continuum

We often see that some parts of an idea are used in a new line of innovation whereas other parts are left behind. Those parts may not be completely forgotten but they are temporarily out of focus. For instance, the steam engine that the Greek scientist Hero of Alexandria invented was never put to use but the idea of using steam for locomotion survived through the ages. In other words, a combination or “idea” can be divided into two pieces: A part that has creative potential (P) and one that is creatively dysfunctional (D). The part that is defunct stays at the museum unless it is combined with a part that has creative potential (cf. selection), which does not have to be the original counterpart (e.g., one can use steam for disinfection).

Suppose that the near-deterministic information universe is built up of n combinations of entities. What follows next is based on Catcheside (1948), who formulated a rule for radiation damage on biological cells. If we translate radiation into entropic forces such as neglect and demolition, the n combinations break down in $2n$ pieces; namely n pieces with creative potential ($P_1, P_2, \dots, P_n$) and n pieces that are defunct ($D_1, D_2, \dots, D_n$). From here, a host of new combinations can be developed again because the super-combination of $2n$ pieces can be divided into separate combinations of two in $((2n)! / 2!2! \dots 2!) * 1/n! = ((2n)!/2^n n!)$ different ways.

Whether these new combinations stay alive depends on how many times the $2n$ super-combination can be divided into pieces that do and do not have creative potential. If we work from the $P_1, P_2, \dots, P_n$ entities that do have creative potential and look in how many ways we can distribute n parts of dysfunctional entities $D_1, D_2, \dots, D_n$ over n potent entities, then the answer is $n!$. The chance that an innovation line continues in some way, then, is $n! / (2n)! / 2^n n!$.

4. The shape innovation takes

Creative combinatorics describes at an abstract level how innovations accumulate over time and decay again. And because the likelihood decreases that after a while another combination can be made, this growth is asymptotic. However, how does this relate to human inventive behavior?

Creativity is said to progress over time in a nonlinear fashion; in arts and science (Cech, 2001, p. 14), technology (Savransky, 2000, pp. 120–122; Arthur, 2009, pp. 107–108), as well as in biochemistry and physics (Lumsden, 1999, p. 157). Lumsden emphasizes that the forces that hold an organism together form a nonlinear system: What comes out may wildly differ from what you put in (ibid.).

Most cumulative or growth processes describe a sigmoid or S-shaped curve as first observed by Verhulst (1838). This logistic function describes exponential

growth that approaches some maximum and is applied to, for instance, innovation diffusion (e.g., Rogers, 1962/2003), industrial life cycles (e.g., Porter, 1980), and organizational development (Kaplan, 2009). Like an organism, a development follows a slow start-up phase (its infancy), rapid growth (acceleration phase), and then faces decline and decay (maturity).

Figure 2. Anachronism showing that prior art also is contemporary



However, because people select which part of a creation has potential and which part is defunct, innovation lines may be abandoned. For example, steam engines were replaced by combustion engines and Romantic art was replaced by Modernism. This bends the original S-curve into a bell shape although the bell shape is not Gaussian (i.e. symmetric): According to K. Kelly (2010, pp. 50–51), an invention may be abandoned but hardly ever is completely forgotten (e.g., Figure 2). Sometimes it even survives as a hobby (e.g., flint stone chipping) or is reused in later technologies (e.g., a cellular phone with hand dynamo). In the same vein, Christian (2011, p. 133) states that when species occupy new territory (cf. the creative jump to another domain), population growth often shows a development of “migration, innovation, growth, overexploitation, decline, stabilization (MIGODS).”

5. The sigmoid growth curve of cumulative change

Let us see whether all kinds of observations, cultural and physical, that relate to creation and innovation can be placed somewhere along the sigmoid line. Figure 3 places the S-curve on the continuum from probability in its infancy to determinism at maturation. The development of creativity from infancy and acceleration to maturity turns a probabilistic situation into a more deterministic one. In other words, a development in its infancy has numerous open ends and plenty of options to choose from. Association and creativity are the best way to approach such underdetermined questions. In its end phase, the problems become well-defined and can be solved almost completely automatically.

When there is no line of invention, there is but free floating information of the most diverse kind, all behaviors are possible; the problem space is in utter chaos or entropy. On the other end, at the asymptote of creative development, where all becomes repetition and there are no differences any more among particles, associations, features, artifacts, and people, creation hardly happens anymore. In

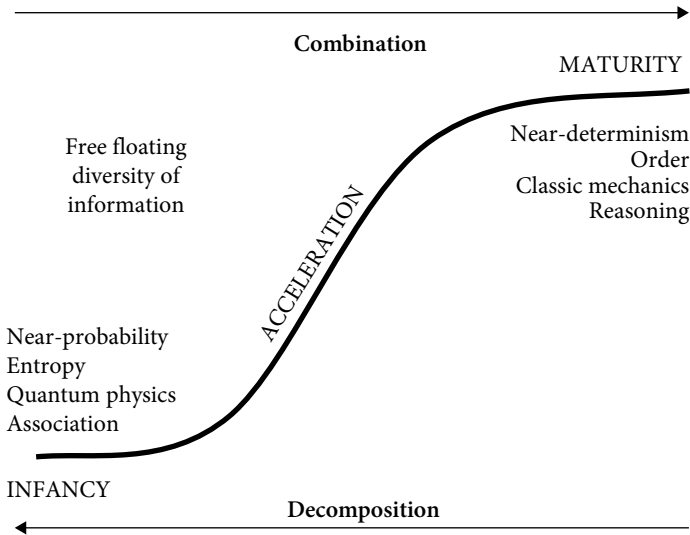


Figure 3. Sigmoidal growth in the information universe

Schrödinger's view (1944/2010, pp. 59–60), gases are amorphous, whereas molecules are solid or crystalline. Probability is the gaseous state of creativity, whereas determinism is its solid state, the acceleration phase being 'liquid.'

Because breakthrough creativity first causes chaos and, through incremental development, brings back the order, being creative is energy intensive during its infancy whereas behavior in accord with order costs less effort. If a system that potentially can generate novel combinations becomes fully regulated, it is in a well-defined, deterministic, "super-cold" state, where no variation occurs and, hence, nothing new and unexpected happens. No variation, no creation; no creation, no change. Chaos opens up the opportunities. Randomness generates diversity (Mandelbrot, 2001, p. 205), and diversity of information is crucial to provoke a combinatory explosion of creative cross-fertilizations.

When chimpanzees poke a stick into an ant's nest or crack a nut with a rock, they use a 'naturfact,' artifacts that can be used as a tool right away (cf. Basalla, 1988/1999, p. 50). This is innovation in its infancy: The stick can become anything, from an ant angler to a fishing rod. In art and religion, people may stumble across *objets trouvés* or readymades that need no further elaboration to make an idea concrete (e.g., a rock that looks like a face). To have a diversity of information available is most convenient in this stage to obtain a multitude of serendipitous crossovers.

Situated at the foot of the Creative Sigmoid is low culture (Figure 4, lower left). Lines of behavior are not formalized yet, anything goes, variability is high, and so

is optimism, so that early invention takes place in an active, agile, chaotic, energetic, and probabilistic environment. Nietzsche (1872/1972) would call this the sphere of Dionysus where chaos, confusion, and disharmony are preeminent. It is what Törnqvist (2004, p. 234) calls “an unstable phase.” Lone innovators accumulate novelties at a slow pace, which may only be used by some early adopters (Ogburn, 1922; Rogers, 1962/2003, p. 11, p. 150). Such people typically establish a brokerage network where others may tell them where to find what. This guarantees the exposure to a diversity of information. For sustenance, they need Maecenas and venture capitalists who believe in their ideas.

In the early stages (Figure 4, lower left), creativity brings meaning to chaos but this heavily relies on chance. After that “the species has found out in which direction its chance in life lies and pursues this path” (Schrödinger, 1944/2010, p. 110). After creativity has made sense out of chaos, intelligence is required to bring shape to the new solutions (see Chapter 2, Figure 5).

Then a point of development is reached where the slope of innovation rises steeply. Acceleration (Figure 4, mid part) starts as more innovations become available and people have understood what features to add and how to make variants of the new solution. The collaborative network around the innovator becomes tighter and starts to show cohesion apart from brokerage. Regulators such as business managers, publishers, and galleries select what they consider ‘useful’ or ‘valuable’ and keep the risks in check. Patent offices decide what is new and worth protecting. While acceleration increases, language becomes dominant (Figure 4, mid part) because the host of new and related inventions should be communicated to the many participants in the innovation line and the vast influx of users (see Chapter 2, Figure 5). The uptake of an innovation by a majority of users also stimulates rapid growth (Ogburn, 1922; Rogers, 1962/2003, p. 11, p. 150).

The acceleration phase shows creative development of a continuous kind, going through smaller hops and steps but not through jumps. The strive for optimization, better efficiency, improvement, co-creation as well as the occurrence of minor accidents and inexact replications give rise to “micro-innovations” and “numerous, continuous incremental inventions” (Elvin, 1973, pp. 312–315). In terms of Savransky (2000, p. ii), perfection, diagnostics, trimming, analogical use, and synthesis of known elements characterize the course of continuous innovation but not the discrete genesis of fundamental novelty found in the early stages. Creators start to think convergently, making new combinations within the line of continuity.

And although new knowledge is gained also by incremental, random variations of routine patterns of action that proved to be successful in practice (Davids, 2008, p. 441), creators who think divergently may already depart from the innovation line and start combining it with more remote out-of-category domains (Figure 4, block arrow). For instance, microprocessors were not near the end of their development when the jump to biology was made to create biochips (Beigel, 1979).

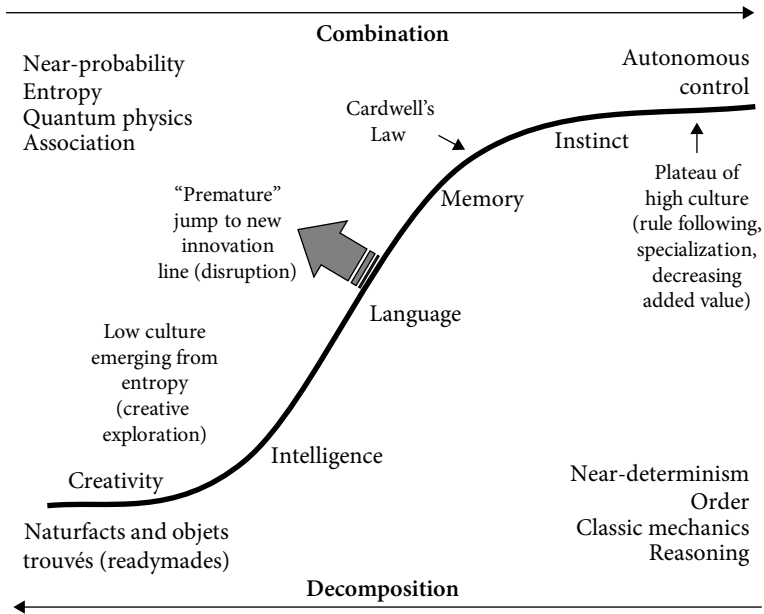


Figure 4. Sigmoidal growth and functional dominance

The amount of disruption is small in a continuous line of development and large in a discontinuous one (cf. Byron, 2011). How small or how large that jump is, is a matter of cultural values and perception (Basalla, 1988/1999, p. 34, pp. 57–59).

At the point of maturity (Figure 4, upper right), the increase in innovation slowly declines, the brokerage aspects of the network fade, the community becomes more closed and coherent. At the shoulder of the sigmoid, a tradition may reach such a high level of coherence and refinement that chances for new departures by internal forces are reduced to almost nil (Davids, 2008, p. 9). This is where Cardwell's Law of stagnation comes into operation (Mokyr, 1994). At this point, memory functions become eminent because the rules that regulate the innovation line are learned by heart and need not be interpreted individually (cf. handbooks, guidelines, standards, design principles) (Chapter 2, Figure 5). Total usage of the (once) innovation is high because the “laggers” finally accept the new ways they resisted before (Ogburn, 1922; Rogers, 1962/2003, p. 11, p. 150). The innovation has become part of the social structure.

When a culture is repressive and the once innovation now becomes common or even obligatory practice (“compliance”), people start to rely on instinct because all other behaviors are regulated (Figure 4, upper right). Deviant others may be attacked or avoided mainly because they are different. If even instincts are taken care of by, for instance, machines, all that remains for humans to control is the most basic autonomous system (Chapter 2, Figure 5).

Box 1. Re-recorded, simpler, and loud!

As a “key cultural expression,” Western popular music of the past 50 years underwent a progressive homogenization of the musical idiom. In analyzing the structural regularities in the Million Song Data set, Serrà et al. (2012) discovered that, increasingly, old tunes are re-recorded while simplifying the chord progressions and turning up the volume. Pitch transitions are restricted and the timbral palette homogenized. The authors claim that what contemporary listeners perceive as novelty is merely in the use of common harmonic progressions, different instrumentation, and increased average loudness.

At the asymptote of the sigmoid, high culture is the climax but also the end of many preceding innovations, a “high-level equilibrium trap” (Elvin, 1973, p. 179, p. 314) or what Törnqvist (2004, p. 234) calls “a stable phase.” At the end of the sigmoid, the density of ideas is higher than in the beginning – of old ideas, that is. Exhaustive combinatorial creativity in its final phase produces homogeneity of the initially diverse information space (Box 1). There are no options any more to make new combinations: The system has become near-deterministic. It is the realm of Apollo, of total rationalization (Nietzsche, 1872/1972), where ‘normal,’ ‘accepted,’ and specialized behavior can reasonably be deducted from and evaluated on the basis of explicit rules and clear instructions (cf. Weber, 1922). Solutions shy away from mistakes, require less initiative, less energy, and have a ceiling effect on innovation (asymptotic optimization).

In this phase, it is hard to decide to jump to another line of innovation because many rules and restrictions stand in the way. For the majority, it may be easier to stay at the asymptote of invention while it approaches zero (“count your blessings”), tending to infinity with decreasing added value. When the curve becomes (asymmetrically) bell-shaped, indicating that an innovation line is abandoned, museum exhibition and the cry for restoration commence.

5.1 The bandwidth of behaviors

At its infancy, the variety of behaviors that can be expressed is wide because nobody knows yet what the right way is (Figure 5, lower left). In Chapter 6, *Conditions of Creativity*, the factors that widen the bandwidth of behaviors and, hence, that are conducive to creativity are, among other, freedom, internal motivation, a relaxed atmosphere, and thinking in terms of opportunities.

At the shoulder of the Creative Sigmoid is high culture, dominated by a fully regulated set of behaviors and rules of conduct (e.g., etiquette, occupational moral, codes of honor, clichés, templates, jurisprudence, contracts). The bandwidth of acceptable behaviors is small because routine procedures and stereotypical reactions are the common way to proceed, even when new challenges are faced. The

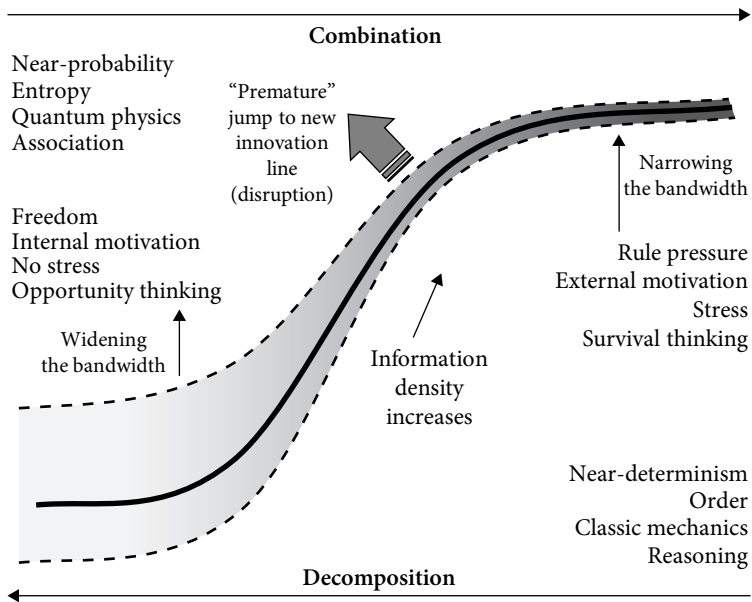


Figure 5. Creative Sigmoid and the bandwidth of behavioral variability

standard deviation of the average behavior minimizes: Everybody has the same corporate identity (Figure 5, upper right). Chapter 6 points out that factors such as rule pressure, external motivators (e.g., money, punishment), stress, and survival thinking minimize the diversity of behaviors that can be expressed. These circumstances favor the meticulous execution of well-defined tasks.

The bandwidth of behaviors coincides with the standard deviation of the average behavior. The upper bound indicates extreme progressive behaviors, exploring the unknown, whereas the lower bound indicates more conservative trends which nevertheless may be part of the innovation line (from natural laws to skeuomorphisms). Figure 5 shows that breakthrough jumps (block arrow) happen at the upper bound of the standard deviation and can be considered extremes or outliers.

Accessing information of the most diverse kind opens up more conceptual space, which allows new knowledge to enter the equation so that the novel can be combined with the familiar. Yet, the higher up the sigmoid, the denser the information becomes. The lighter colored area of the sigmoid in Figure 5 signifies information that floats freely (chaos, entropy) and the darker the color, the more information has been taken in and the more fixed the structures and systems have become (ordered, crystalline state).

Whereas internal motivation pushes the bandwidth of behaviors from the inside out, rules and regulations push the outside in. Yet, relaxation of rule pressure

may avoid the occurrence of sudden jumps or ‘disruptions.’ When the rules are bent such that the bandwidth is broadened, creators may become an agent of change, an “intrapreneur,” changing the system from within (Williams & Yang, 1999, pp. 383). Both breakthrough disruption and rule transformation (Boden, 1999, pp. 352–353; Boden, 2009) are meant to access the universe of free floating information. Changing the rules in time may keep people from (violently) breaking through the standard deviation of average behavior to yet reach new information sources. Leniency keeps from starting a revolution.

5.2 Surfing up the sigmoids

Pfenniger and Shubik (2001, p. xi) state that “creative thinking is breaking through the barriers posed by dogma, and reaching beyond the limits of established patterns of thinking to discover what is new and useful.” Creativity comes from new leaps of the mind, recognition of new relations, and new adventurous inquiries (Rogers, 2001, p. 48).

When people break through the ceiling of innovation, they increase the variability of behaviors again. They bring back probability into the near-deterministic system so to revitalize creativity with a new development (Figure 6). This is the

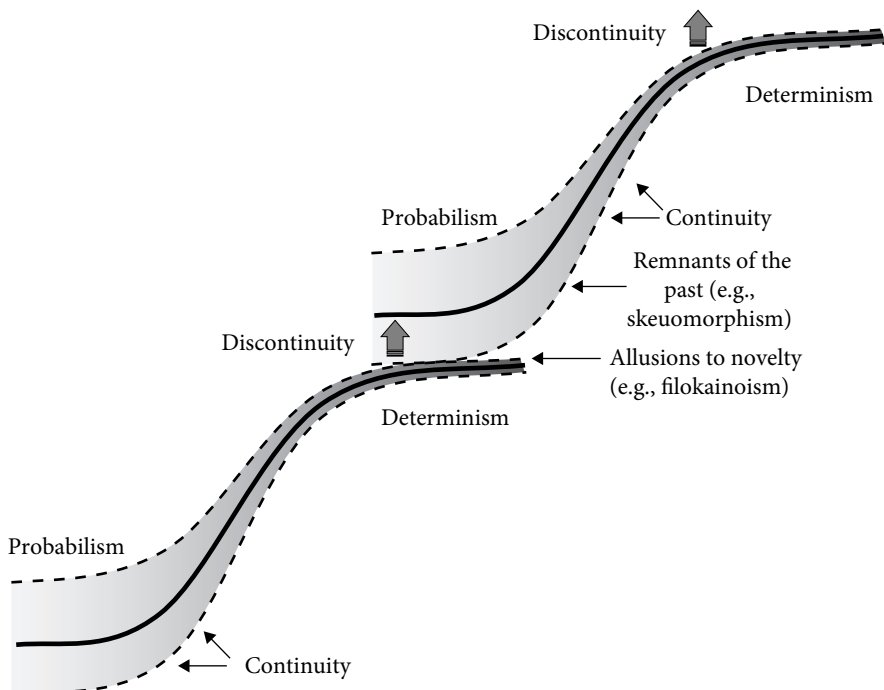


Figure 6. Surfing up the sigmoids

cycle of chaos, evolution, disruption and chaos again.³ Divergent thinking, risk-taking, courage, and an attitude of positive action help to penetrate the diversity of free floating information again.



Figure 7. *Head of a Bull*. Picasso (1943)

Creators combine remote domains on the basis of perceived similarity between associatively unrelated entities (the ACASIA process, Chapter 4). Grain stalks look like hair so a mechanical reaper receives clippers (McCormick, 1831), a bicycle seat and handlebars create a bull's head (Picasso, 1942, Figure 7), the combination of a scanner and a printer makes a photocopying machine (Savransky, 2000, p. 84), etc.

The jump between seemingly remote domains is a kind of phase transition at the asymptote (cf. Schrödinger's quantum leap), instigating a phase of low or primitive culture once more in which 'Dionysian' behaviors prevail. The Coliseum, for instance, Rome's pre-eminent symbol of high culture, was demolished by Vandals, Goths, and Lombards and its stones were used to build their barbarian shacks. But this chaotic and uncertain period of low culture slowly gained unity again through Christian monks and priests, installing a new medieval mix of Judaism and Germanic rites that yet showed skeuomorphisms of the collapsed culture (e.g., church Latin, Rome as the seat of power). Today, even the vandalism of the Northern European punk rock scene of the 20th century is incorporated into the establishment of high culture, in Rome, that is (Box 2).

Box 2. Punk at Villa Medici

Vivienne Westwood's clothing of the Sex Pistols, Jamie Reid's poster of the British queen with safety pin, the buttons of the Rondos. Street art seen as vandalism at first may slowly evolve into museum pieces. Eric de Chasse, director of the Académie de France located at Villa Medici in Rome, turned the collection of two middle-aged Amsterdam punk fans into the Exhibition Europunk (Jan.-March 2011), *La Cultura Visiva Punk 1976–1982* (www.villamedici.it). Chasse approached the punk movement not from a musical or societal but rather from a graphical and fashion point of view, having made a lasting impact on our culture. Although many of the radicals of the seventies and eighties resisted being part of the establishment, they are now incorporated into art history as true modernizers of style. *Hey! Ho! Let's Go*

3. To see the repeating cycle of evolution-disruption-chaos in action, check out these four artists working on the same canvas at <http://www.youtube.com/watch?v=y89XvMZdjHg>

Every determinism is a local decrease in entropy (2nd law of thermodynamics). Therefore, if the set of rules that tightens the bandwidth of variability at the plateau of innovation is not maintained or reinforced, natural decay of homogeneity or homeostasis opens up possibilities for creativity again.

5.2.1 *Jump size depends on narrow-mindedness*

Of course, creators can make the jump at any given time during the development of an innovation, resulting into multiple lines that progress in parallel at differential rates of development. However, when they do this at the asymptote (Figure 6, block arrow), in a period of maturity or high culture, the deviation will be perceived as most disruptive, perhaps repulsive, and as ‘big’ creativity in hindsight although the associative gap that was bridged may not even have been that wide (see also Section 7, Figure 8). In other words, the narrower the bandwidth of behaviors a perceiver allows, and the smaller the span of associations that the perceiver can produce, the larger the creative breakthrough seems to be. It is harder to be considered creative among open-minded people.

5.3 Many means merging

The Creative Sigmoid develops from infancy through acceleration to maturity, that is, order emerges from chaos. At each phase, both chaos and order are present but variance is more dominant at infancy and a more stable mean occurs at maturation. Actually, the development of the Creative Sigmoid is designated by many means merging. What were rather small independent groups at infancy becomes a large homogeneous group during maturity.

Variance is in the details. The smaller the sample size and the more individual the components that make up a combination, the higher variance becomes, ending in chaos when all individual parts are decomposed. Each extra element in a combination exerts a force on the other and so they limit each other’s opportunities to show random behavior and hence start to take direction. Laws only rule the masses (cf. Schrödinger, 1944/2010, p. 10, p. 17).

Many smaller sigmoids develop, then, when a sample of the information universe is in chaos and combinations happen due to serendipity. But when more combinations are combined, the multiple unstable means merge into ever increasing larger means, thus stabilizing the innovation line. In other words, the Creative Sigmoid is built up over many smaller sigmoids, which are composed of even smaller sigmoids and so forth, the lower bound being complete entropy and the upper bound being crystalline order (also see Section 13).

At the micro-level of data aggregation (i.e. infancy), individual variance is high and serendipitous combinations kick start an innovation line (cf. particle physics). At the meso-level of data aggregation (i.e. acceleration), larger group means stabilize numerous trends, although individual outliers may cross over or even disruptively jump to another domain (cf. psychology). At the macro-level of maturity, evolution of an innovation line takes place while the average, more obvious, creative combinations and routine solutions take control and establish continuity (cf. Big History).

Whether through coincidence or human insight, whenever a (disruptive) innovation takes on, is adopted, or gets followers who work on incremental changes and who try to perfect the invention or the new style, chaos diminishes whereas average group behavior emerges. Probably, the evolution of innovation and the disruption due to individual variance (whether coincidentally or deliberately) looks similarly at all planes except that on a large scale (e.g., cultural tradition) the mean of creative development is more stable than in the mind of the inventive individual.

Despite decline and stabilization or individual variance, the accumulation of creative combinations overall increases towards a crystalline end state: The asymptote of each growth curve or the onset of its downward flank lies higher than the onset of its rising flank because the older innovations are not completely lost or incorporated in the new (cf. K. Kelly, 2010, pp. 50–51; Christian, 2011, p. 133).

6. Autocatalysis of creativity

The earliest forms of life were self-organized, self-regenerating, autocatalytic structures, evolving through a communal exchange of innovations (Gabora & Kaufman, 2010, p. 290, p. 293). As Schrödinger (1944/2010, p. 109) pointed out, initially simple forms gained complexity over time and evolved from general to highly specialized features. According to K. Kelly (2010, pp. 276–277), complexity increases as a system combines more elements through self-organization.

Provided that chance opportunities are likely to occur, creativity cannot be stopped from happening. In view of the rule of rules (Chapter 2, Section 13), a state of total determinism occurs but sporadically. That perfect order happens in fact is coincidental. Practically speaking, then, creativity will happen occasionally even under the most unfavorable conditions.

The incidence of insight, the sudden perception of similarity between associative disparities, cannot be suppressed; it can merely be ignored afterwards. In that sense, the creative process is autocatalytic. It ignites automatically at the physical/

physiological level and instigates a chain reaction of related and more deliberately thought-out ideas. Autocatalytic similarity seeking may be incremental within a domain as it may be disruptive between domains.

The Creative Sigmoid, then, is built up through the autocatalytic reaction of similarity seeking between weaker (continuity) or stronger (disruption) disparities. That is, finding one meaningful connection is the catalyst for the creator(s) to seek more connections. Finding one connection incites searching for more until the combinatorial possibilities are drained – limited by available information, sense perception, memory, association strength, or knowledge base. In co-creation, one idea may lead to another so that finding meaningful connections by a group of creators can be said to be “collectively autocatalytic.” Autocatalysis ends when all possible combinations of combinations are exhausted.

7. ACASIA propels the Creative Sigmoid

The Creative Sigmoid develops in a universe of freely floating information of the most diverse kind. The ACASIA process (Chapter 4) is supposed to be the driver of creative output and over time therefore should be generating sigmoid growth curves. Moreover, ACASIA is autocatalytic as it keeps on going whenever similarity is detected or construed between disparities.

When ACASIA keeps within the bandwidth of accepted behaviors, it contributes to the continuation of the innovation line (Figure 8, situation ①). When ACASIA bridges extremely large associative distances between domains or categories, it disrupts the initial sigmoid and can start a new one (Figure 8, ②). And although the creator keeps combining entities from categories at similar associative distances (δA), this activity will be perceived as more creative in a deterministic setting than in a probabilistic one (Figure 8, ③).

Aspects of ACASIA that foster continuity are associative closeness of different categories, familiarity of entities, the (fuzzy) intersection of features and the similarity that transpires from it, the unoriginality of the combination (i.e. high frequency of occurrence). Aspects that feed into the feeling of disruption are associative distance of categories, unfamiliarity of entities, the randomness of features, the (fuzzy) distinctive sets and perceived dissimilarity, the originality of the combination (i.e. a low frequency of occurrence in large sample sizes) as well as the figurative features in case of a new metaphor.

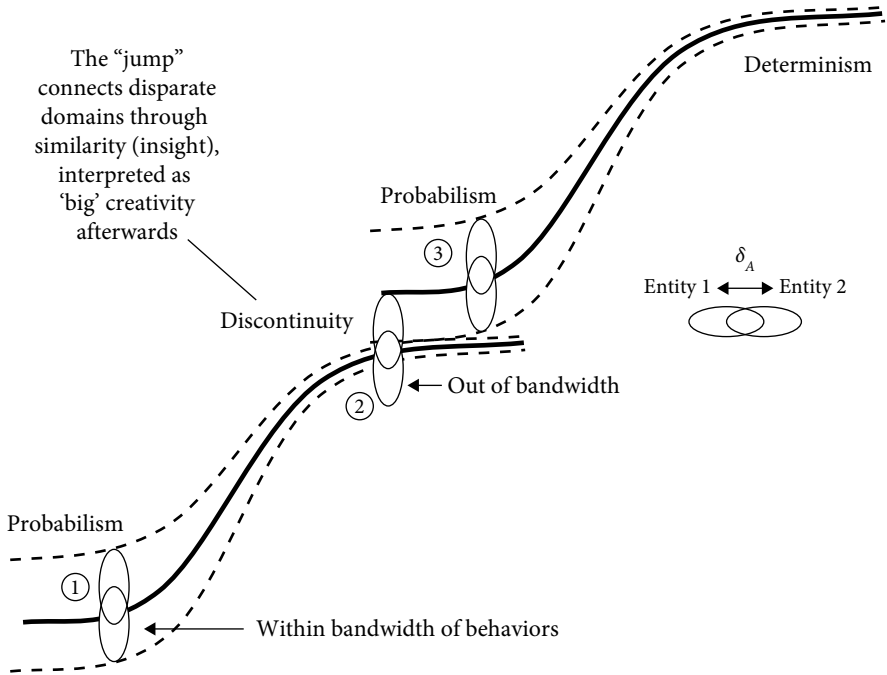


Figure 8. Perception of categories at similar associative distances (δ_A)

If the variables that ACASIA outputs do not satisfy the similarity criterion q , the slope of the Creative Sigmoid becomes less steep or the curve reaches its ceiling and stops. ACASIA will become impeded the more the Creative Sigmoid enters determinism by means of rules and regulations, applying standards, models, and templates, or by an exhausted or debilitated community (see Chapter 6). If ACASIA is not stopped by rule pressure, autocatalysis stops when the combination of combinations is exhausted and homogeneity of information is reached. In absence of information diversity, the system has become fully harmonious and dead.

8. Snakes at the pyramid

The Creative Sigmoid basically describes a bottom-up process that happens spontaneously and with its own dynamics (i.e. autocatalysis), more like a creativity push than a demand pull, although the latter may steer the direction of the innovation path or the bandwidth of tolerated behaviors and combinatory possibilities. In hierarchic organizations, however, the need for innovation may occur top-down as a management requirement to adapt to changing circumstances.

In an adaptation and extension of Laudon and Laudon (2006), Chapter 3 introduced a framework that related organizational hierarchy to problem spaces, decision making, and level of automation. If we collapse the Creative Sigmoid (the 'snake') with the organizational pyramid and we flip it to align the poles of probability and determinism of both pictures, we see that top-down implemented creativity is a funneling process (Figure 9).

By reducing the bandwidth of behaviors, that is, by formulating goals and targets and making more rules, regulations, processes, and procedures to achieve them, the vision that was ingested from probability by the leadership becomes manageable. The more the vision is translated into operation on the work floor, the better structured and measurable output can be produced, which can be almost fully automated in a near-deterministic system. In other words, innovation power decreases the more we get to execution. It also tells us that new vision of the leadership plunges the organization into low culture whereas the work floor creates so much refinement that it brings the organization back to high culture.

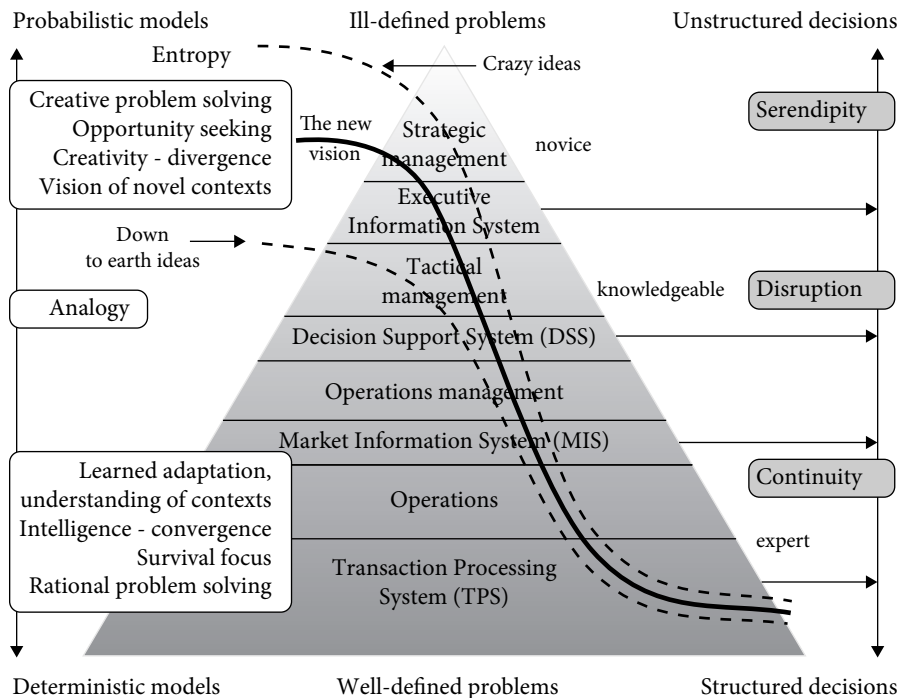


Figure 9. Big snake at the pyramid: The head swallows ideas from entropy, digests them through management, and produces mechanistic output

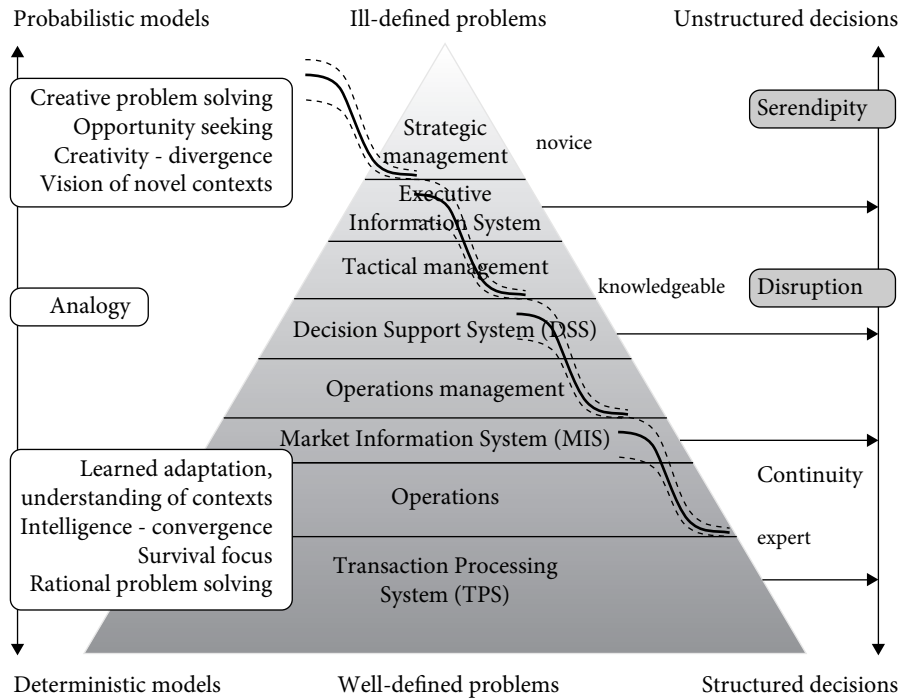


Figure 10. Snakes at the pyramid. The funneling from creativity to mechanistic execution requires that the more deterministic layer in the organization stretches its imagination and the more probabilistic layer binds its imagination by rules

Zooming in on each layer in the organization, the big snake hatches an offspring of many smaller snakes (Figure 10). Suppose the leadership formulates a new vision of hospitals that function as a care village instead of a clinical factory. The visionary leadership has to translate this novelty into a set of requirements that middle management can use to make a specifications list.

Yet, middle management will not be able to do so if it does not stretch its imagination to the upper bound of the variability it allows so to catch the already downgraded vision of the leaders. The operational people have to do the same, trying to leave near-determinism to connect to the – to them – more fuzzy specifications of procedures and goals that middle management proposes.

In other words, the lower bound of variability (biasing to determinism) of the higher organizational level should connect with the upper bound of variability (biasing to probability) of the lower organizational layer. The big Creative Sigmoid of Figure 9, then, is composed of the many sigmoids depicted in Figure 10 and therefore does not have a smooth surface but is ‘fractal’ (Section 13).

9. Requirements on a rule for creative development

With ACASIA, we could simulate how two entities from remote categories could be combined into a new concept. In this section, I would like to pursue the consequences of that process for producing a sigmoidal growth curve of accumulated creations.

This time, therefore, the wish list presents the requirements on the simulations of the Creative Sigmoid. What behaviors should the sigmoid show under what circumstances? The shape of the simulated sigmoids are shown as a function of manipulating the factors that constitute ACASIA.

Next goes a bulleted list of what must or could be on the sigmoid-simulation system. The sections thereafter are used to explain the backgrounds of that list. After all, this system is the equivalent of a rule or a set of rules that describes creative development. But as a summary beforehand, the Creative Sigmoid system should be simulating:

- Complexity. The number of applicable rules and known variables should be adjustable to establish (degrees of) probabilistic and deterministic problem spaces
- Random information flow and differentiation maximization. How much and what kind of information is available at what time should be variable (from very uniform to very diverse)
- Sigmoid growth. ACASIA's output should follow an S-shape growth curve, in which previous creations are component parts of subsequent creations
- Bandwidth tweaking. It should be possible to adapt the number and force of variables that narrow or widen the bandwidth of behaviors in which the sigmoid develops
- Scale-independent invariance between nearly self-similar sigmoids. The Creative Sigmoid should be built up from sigmoids related to the smaller component parts. All sigmoids should look like near self-similar replications.
- Scale-dependence of variability within sigmoids. Although S-curves should be self-similar, at lower scales the variability is higher than at higher scales, where more sigmoids are joined into one
- Multiplicity. Sigmoids should be allowed to develop in parallel at different points of departure
- Serendipity. Particularly in the early stages, simulations should allow sufficient chaos to the system to kick start creative development
- Combinatory resolution. The motor of building up a Creative Sigmoid is combinatorics
- Autocatalytic propulsion. The system should not stop after having made a creation but should continuously search for new combinatory options, exhausting the design space

- Evolution and disruption. Apart from serendipitous findings, the system should show gradual increments as well as new lines of development stemming from certain outliers
- Innovation diffusion (downward, upward). At maturity, the upper bound of the standard deviation of average behaviors should border or slightly overlap the lower bound of the standard deviation of the next set of behaviors at their infancy

In the next sections, I will offer the specifications of a formal model, which will be worked out mathematically and tested in the remainder of this chapter.

9.1 Complexity

To formulate a model that describes the development of creativity, we have to assume a complex system that is not entirely random and not entirely regulated. It is a continuum between near-determinism and quasi-chaotic probability. A formal representation of creative advance should account for the deduction that over time the number of applicable rules in deterministic settings can increase infinitively (the system can reach a super cold crystalline state) but is never definite because error remains. By contrast, the formula should allow that the number of applicable rules in probabilistic settings is never smaller than 1 (never zero) because even in a state of entropy (super heat), the rule of rules applies and occasional order transpires (Chapter 1, Section 13).

From this model, it should be possible to predict that when complexity decreases, ingenuity decreases. The more deterministic the problem space, the more precision increases with decreasing creativity. The more probabilistic the problem space, the more precision decreases whereas creativity increases. The model should be capable of predicting that the more idea formation is transformed into idea execution (ingenuity decreases), the lesser the disparity between units of information becomes (complexity decreases).

9.2 Random information flow and differentiation maximization

The medium in which creativity or a series of innovations develop is a universe of randomly floating information that expands to the greatest differentiation inherently possible in that universe (cf. particles of mixes of gasses). The model should allow for variables that can affect the density, distribution in time and space, and the diversity of the units of information in that universe. It should be possible to identify these variables as attractors and repulsors and adjust their force.

9.3 Sigmoid growth

Creative advance should be modeled as an S-curve, emerging from chaos with (multiple) instable mean(s) and great variance; plateauing into stagnation after all combinations within a critical number of rules or stressors are exhausted and the bandwidth of combinatory possibilities of information units is narrowed down (peak smoothing or active regression towards the mean). Theoretically, the S-curve describes the rising flank of what actually is a usually imperfect bell-shaped curve (not necessarily a Gaussian function) of creative advance that also includes decline when creativity deteriorates (i.e. turning back to previous solutions): After the sigmoid, resonance may occur, the curve going up and down at decreasing amplitudes.

9.4 Bandwidth tweaking

Creation stagnates the more and the stricter rules or the more and the stronger stressors are operative on the combinatory possibilities of information units. Therefore, it should be possible to identify variables that are directed at narrowing or widening the bandwidth of possible combinations. It should be possible to set the strength of such variables and affect the way the S-curve grows.

9.5 Scale-independent invariance between nearly self-similar sigmoids

A calculus of creative development should allow for sigmoid growth with recursive symmetry at all scales. It should describe a pattern that predicts continuity of near self-similar replications (the mean) averaged over the disruptions and errors of all replications (variance) at all scales in time and space. Self-similarity is merely approached and not complete because random noise is always present due to inexact replications or deliberate deviations. The deterministic (rule based) aspects produce the average of near self-similar replications. The probability of random choice produces the variance of novel combinations. Order fails at the lowest aggregation scales. Therefore, the model should regulate that at the far end of probability where entropy starts, the S-curve does not consist of other S-curves anymore and at the far end of determinism, where almost all behaviors are predictable, the S-curve is not accompanied by neighboring S-curves but becomes all-encompassing.

9.6 Scale-dependent variability within sigmoids

A model of creative advance should incorporate that the effects of chance increase the smaller the scale of aggregation or the smaller the sample size is of nearly

self-similar sigmoids. Put differently, chaos in a higher-level sigmoid diminishes the larger the number of lower-level sigmoids it is an average of. The smaller the level of aggregation or sample size, the jitterier the mean S-curve is. The larger the sample size, the more systematic the variance of the S-curve becomes.

9.7 Multiplicity

A calculus for creativity should provide ways to show that a new sigmoid does not necessarily erase the previous one. Sigmoids can branch off, develop simultaneously, can be partly based on the same features, or grow back into one another and merge.

9.8 Serendipity

Disparate entities may be brought together on the basis of pure chance. In fact, a model of creative advance should demonstrate that without coincidental connections creativity does not happen in the physical world and becomes crippled in organic creativity. People who have serendipitous insight, then, probably have such a brain architecture and mindset that finding similarities across associative remote domains happens easily.

Because chaos is bigger at smaller scales, combinatory possibilities increase accordingly. The formula should allow that novel combinations occur more at lower level than at higher level scales. In organic creativity, at the lowest scale of aggregation, only naturfacts and readymades can occur as combinatory resolution.

9.9 Combinatory resolution

Making combinations is at the heart of creativity. A model of creative development should show that combinations are made on the basis of a similarity calculus and balanced by dissimilarity or difference (Chapter 4, Section 9). Because combinations are entities that can be combined with other combinations, combinatory explosion stagnates when all possible combinations have been made. The design space has become homogeneous. Because of the requirement of novelty, another limiter of exponential growth is the frequency of occurrence of a combination, which preferably is close to 1.

9.10 Autocatalytic propulsion

The S-curve grows according to the self-catalysis of finding novel combinations of entities, thus increasing similarity. Finding one combination ignites a series of variant combinations. Self-catalysis stops if the combinatory possibilities are drained (or perceived to be drained).

9.11 Evolution and disruption

A formal model of creative advance should calculate that incremental changes (small variance) occur significantly more frequent than disruptions (peak variance). The model should formalize that disruption is caused by an outlier of the average sigmoid growth curve, which gains momentum when it attracts a mass of followers. The mean S-curve establishes continuity; disruption roots in the variance from that mean. Thus, replication errors increase chances for disruption to occur.

An incremental step is defined when a new combination (frequency $\cong 1$) is not significantly different from an existing S-curve. A disruptive jump takes place when the new combination does not fit an existing S-curve (the outlier). Incremental is the innovation that combines different entities within the bandwidth of the S-curve (similarity high, dissimilarity low). Disruptive is the innovation that combines at least one entity that lies outside the bandwidth of a given S-curve (similarity low, dissimilarity high). In other words, it is easier to be perceived as creative at times of narrow bandwidths.

A formula of creativity should show that disruption is a phase transition from determinism of the previous S-curve to the probabilistic state of the subsequent S-curve. Disruption at the asymptote will be perceived as great creativity, at the rising flank of acceleration it may be judged as premature recalcitrance. The model should indicate that the asymptote of the S-curve signifies stagnation and approaches zero *ad infinitum* with decreasing added value. When the S-curve takes a bell-shaped form, it means that the innovation line is (temporarily) abandoned.

9.12 Innovation diffusion (downward, upward)

A model of creative advance should formalize that to bring an idea into existence, the variance that tends to deterministic or rule-following behavior of the smaller aggregation scale (which is more chaotic on average) should partly overlap the variance that tends to probabilistic or uncoordinated behavior of the larger aggregation scale (which on average is more regulated). The same pattern of connections should be used by the model when existing practice is brought back to the level of ideas.

10. A rudimentary model of ACASIA

Full implementation of the requirements laid down in the previous section would take a complete research program to execute. We therefore selected the minimal requirements on a system that provisionally could produce the Creative Sigmoid. We designed a simplified computer model for ACASIA (Figure 11), which

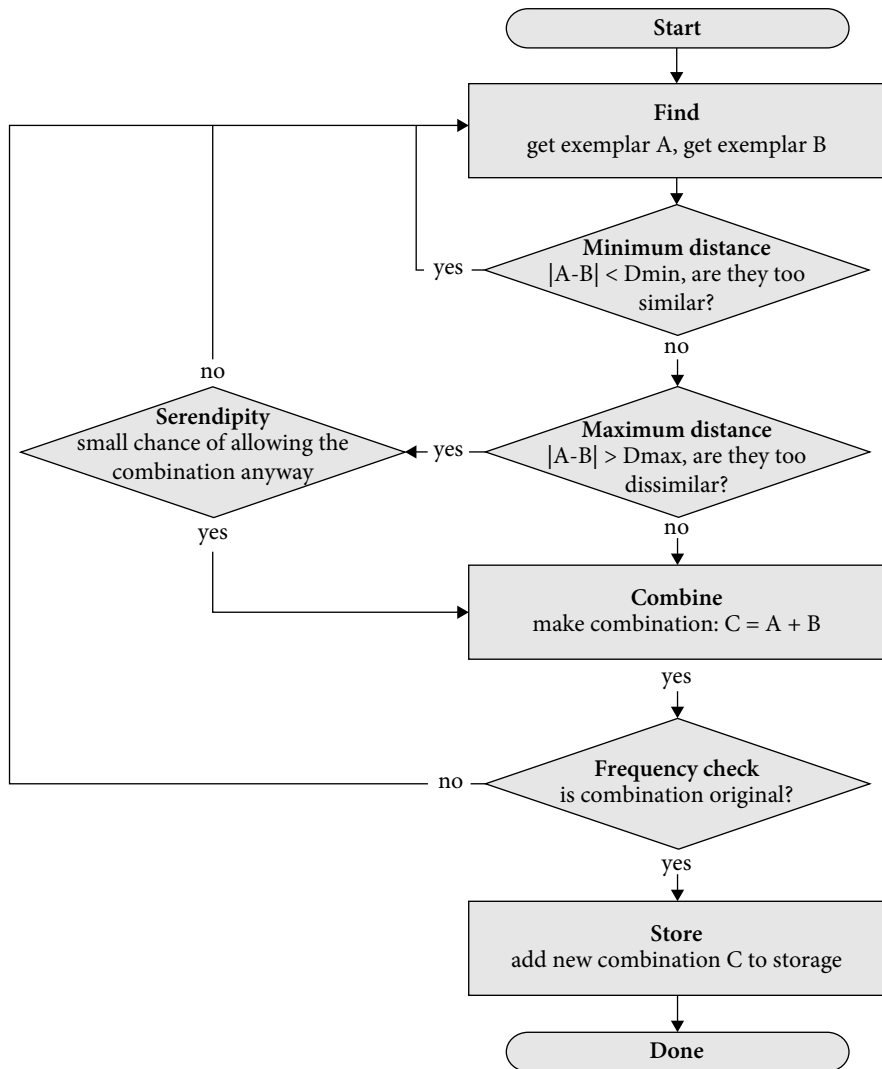


Figure 11. ACASIA's physical variant of combinatory creativity

performed naive exploration of linear vector combinations, resulting in cumulative sigmoid behavior.⁴ Without the selection and adaptation modules, this model could be said to represent the physical aspects of organic creation (Lowcre, 2013) as outlined in Chapter 4.

4. Courtesy Desmond Germans.

Similar to Figure 1 in Chapter 4, Figure 11 treats creativity as a combination of two out-of-their category exemplars (A and B), except that the optimization through abstraction, selection, adaptation, and integration is left out. The only evaluation that takes place is the check for the balance between similarity and dissimilarity, where $|A-B| < Dmin$ means that entities are too similar and $|A-B| > Dmax$ means that they are too dissimilar. The other evaluation concerns the frequency of occurrence of the combination C (its novelty or originality) given the sample size.

For matters of convenience, we treated the features of entities as a vector space and the difference between entities as Euclidian distance. This suffices to see the key principles work, which later on can be replaced by more sophisticated metrics.

We modeled entities as n -dimensional vectors, where each feature is mapped to a dimension. Vectors have straightforward numerical properties that allow for an unambiguous and rather intuitive definition of ‘difference’ and ‘combine’ operations. ‘Difference’ can be defined as Euclidian distance and ‘combine’ can be defined as linear combination (Figure 12). The reader should see n as the number of dimensions (features), $a[]$ and $b[]$ as two n -dimensional vectors, and $c[]$ as the resulting combination.

The information extracted from the universe and stored in each vector is limited by the perspective of the creator on the given entity. Table 1 shows an example of various entities (e.g., Car, Truck, House, Rabbit) that can be mapped to 3-dimensional vectors with dimensions for ‘wheels’, ‘hairy’ and ‘speed’.

$$difference = \sqrt{\sum_{i=0}^n (a[i] - b[i])^2}$$

$$combine: \forall i \in 0 \dots n: c[i] = (a[i] + b[i])/2$$

Figure 12. Euclidian distance as ‘difference’ and linear combination as ‘combine’ operations

Table 1. Various entities with features mapped as vectors

Entity	‘wheels’	‘hairy’	‘speed’	vector
Car	1	0	1	(1,0,1)
Truck	1	0	0.7	(1,0,0.7)
House	0	0	0	(0,0,0)
Dog	0	1	0.4	(0,1,0.4)
Carpet	0	0.7	0	(0,0.7,0)
Rabbit	0	1	0.3	(0,1,0.3)

In applying the difference and combine operations of Figure 12 to the feature sets or vectors of Table 1, the difference between Car and Truck turned out to be 0.3, the difference between Car and Rabbit was 1.22, and the difference between Dog and Rabbit was 0.1. As expected, similar concepts were closer together (e.g., Car and Truck or Dog and Rabbit) and dissimilar concepts were further apart (e.g., Car and Rabbit). Additionally, the linear combination of Car with Dog would result in a vector of (wheels = 0.5, hairy = 0.5, speed = 0.6). This created an entity exactly half-way between a car and a dog (a DogCar or CarDog), which was not as wheeled as a car, not as hairy as a dog, but faster than the canine (cf. Figure 13).



Figure 13. DogCar from *Dumb and Dumber* movie (Peter Farelley, 1994)

To simulate the output of the creative process over time, we constructed the algorithm shown in Figure 14, encompassing a loop that tracks the accumulation of innovation at each individual step⁵. The plot of this cumulative innovation line should pursue the anticipated sigmoid growth curve.

We focused on the integration between evolution and serendipity and their effect on the combinatory resolution of creativity, hoping this would lead to breakthrough jumps at or right after the asymptote. Because creativity is the unique combination of entities drawn from remote domains, entities should neither be the same nor be very similar and their combination should not occur all too often. A combination should be ‘original’ and at best would be the first time occurrence in a sequence.

The step()-function of our algorithm for simplified combinatory creativity works as follows. The whole procedure is an extreme abbreviation of the ACASIA process (Chapter 4). The creator (randomly) selects two entities from a set of entities she knows (Car, Truck, etc.) and calculates the dissimilarity between them. In our case, dissimilarity is represented by Euclidean distance. If this distance is below a minimum, the entities are considered too similar so that the combination is rejected: In the eyes of this creator, combining a truck with a car is not original enough.

If the distance is above the maximum tolerated, the entities are considered too dissimilar. In other words, the creator may have tried to combine two remote entities but lacked the insight to detect or construct sufficient similarity between them. In signal-detection terms, the maximum represents a criterion setting for tolerating dissimilarity in a combination. Beyond criterion, entities are perceived as dissimilar; within criterion, as sufficiently similar. Great insight, then, may develop into sigmoid growth only if dissimilarity is temporarily more acceptable. Stimulus

5. Courtesy Desmond Germans.

```

step():

    a = get random entity from I

    b = get random entity from I

    diss = distance (a,b)

    if diss <= MINIMUM, return 0

    if diss > MAXIMUM and serendipity check fails, return 0

    c = combine (a,b)

    if c too close to any other entity in the entity list, return 0

    insert c into I

    return diss - MINIMUM

main:

    total = 0

    loop:

        total = total + step()

```

Figure 14. Pseudo code for simplified combinatory creativity

discrimination goes down and tolerance goes up for a while. This may be a function of alleviating stress levels, reverie, or an appreciative innovation culture (see Chapter 6). Thus, *serendipity here is modeled as the chance that a by default out-of-bound combination coincides with enhanced tolerance*. This may pertain to the creator's own tolerance or that of the community.

To determine originality, the novel combination is checked against the entities or combined entities already known to the creator (e.g., DogCar). If the novel combination is found to be too close to any (combined) entity already stored in the creator's knowledge base, it is rejected (not unique enough, unoriginal). If accepted for originality, the novel combination is added to the creator's knowledge base and a measure of novelty is returned. We chose this measure quite arbitrarily (just the difference minus the minimum) with 0 as 'not new' and 1 as 'very new.'

10.1 Inventing the motorhome

To get a feel of what the simulation program does, let us look at four entities (Generator, Car, Home, and Carriage) and two features: ‘motorized’ and ‘wheeled.’ With a minimum distance set to 0.25 (cf. originality, novelty) and maximum distance of 0.8 (tolerated dissimilarity), the information universe looks like Figure 15 during the initiation phase or infancy.

Note that in Figure 15 none of the entities are close enough. Their combination exceeds the maximum dissimilarity that is acceptable. While entities are randomly picked from Table 2, distances are calculated.

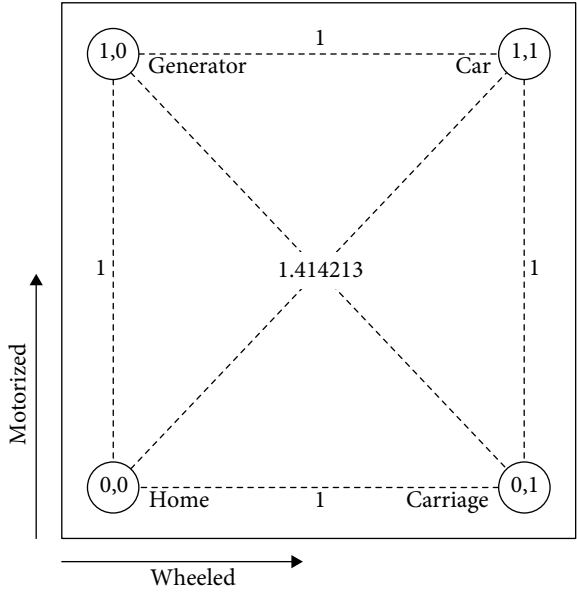


Figure 15. Information universe of entities (e.g., Generator, Car) and features (i.e. ‘motorized’ and ‘wheeled’)

Table 2. Distance (representing dissimilarity) between combinations of entities

Entity1	Entity2	Distance
Generator	Car	1.0
Generator	Home	1.0
Generator	Carriage	1.414213
Car	Home	1.414213
Car	Carriage	1.0
Home	Carriage	1.0

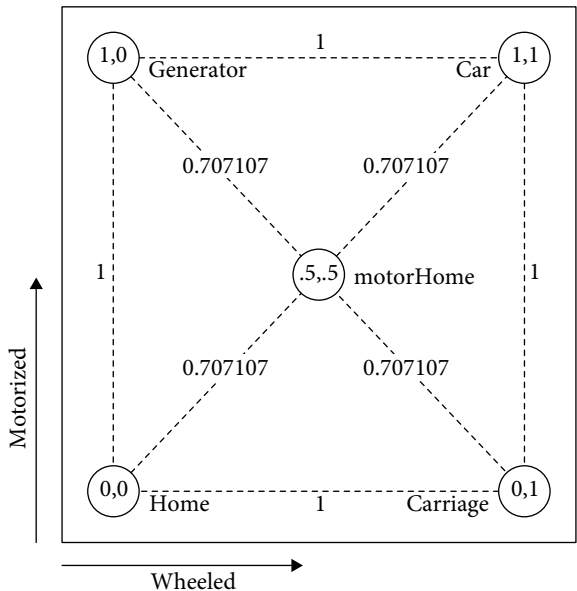


Figure 16. Disruptive idea formation of a motorHome

All of these combinations yield a distance above the maximum tolerated. Out-of-bound values are marked by gray rows in Table 2. In this case, nothing happens. Occasionally, however, the maximum dissimilarity tolerated may increase because the creator had a serendipitous insight, for example when she is in a playful, associative state or when stress levels are low. If in such moments, for instance, Generator and Home are combined, they are literally mixed through a component-wise average. This way, the new idea of motorHome was formed (Figure 16). This may be regarded as a great creative leap considering that homes supposedly are immobile, having neither wheels nor motors.

The novel entity of a motorHome is added to the database and a new series of comparisons starts. The new database that the creator can work with looks like Table 3.

With the introduction of the motorHome, four new combinations could be made. All of them yielded a distance below the maximum (cf. the white rows in Table 3) so they were seen as normally acceptable. In other words, the big motorHome insight boosted the formation of an extra number of increments, bridging associatively less remote entities. One of the increments was Car plus motorHome, which is something closer to a Car than to a motorHome, let's say, like a CamperVan. This idea was added to the information universe as exhibited in Figure 17.

Table 3. Distance (i.e. dissimilarity) among entities, one of which is a novel combination

Entity1	Entity2	Distance
Generator	Car	1.0
Generator	Home	1.0
Generator	Carriage	1.414213
Generator	motorHome	0.707107
Car	Home	1.414213
Car	Carriage	1.0
Car	motorHome	0.707107
Home	Carriage	1.0
Home	motorHome	0.707107
Carriage	motorHome	0.707107

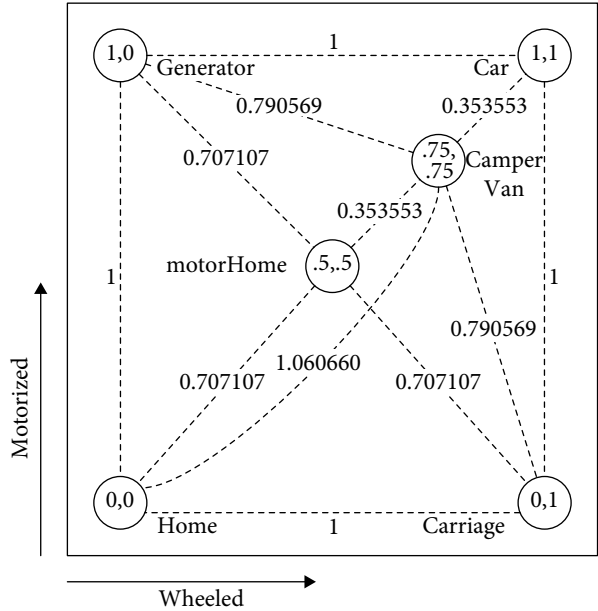


Figure 17. Incremental idea formation of a CamperVan

With the new combinations added to the database, the new range of possible combinations is listed in Table 4.

While developing, the novelty of the increments became smaller. In Table 4, the combination of Car plus CamperVan yielded a new but even smaller incremental idea somewhere between a Car and a CamperVan. The distance between

Table 4. Distance (i.e. dissimilarity) among entities with extra combinations added

<i>Entity1</i>	<i>Entity2</i>	<i>Distance</i>
Generator	Car	1.0
Generator	Home	1.0
Generator	Carriage	1.414213
Generator	motorHome	0.707107
Generator	CamperVan	0.790569
Car	Home	1.414213
Car	Carriage	1.0
Car	motorHome	0.707107
Car	CamperVan	0.353553
Home	Carriage	1.0
Home	motorHome	0.707107
Home	CamperVan	1.060660
Carriage	motorHome	0.707107
Carriage	CamperVan	0.790569
motorHome	CamperVan	0.353553

CamperVan and Car was 0.176777, which is below the minimum distance required towards prior ideas: It was an unoriginal idea. A CamperVan pretty much *is* a Car and so the CarCamperVan was dismissed as an innovation.

Likewise, Home plus CamperVan resulted in a new incremental idea somewhere between a Home and a CamperVan; somewhat of a motorHome, but more like a Home. This new idea would be at 0.375, which is too close (0.212) to motorHome to be regarded original enough. Even though this novel combination was generated from two different entities such as Home and CamperVan, it came too close to the just invented motorHome. Thus, this idea was not considered ‘new’ and it was not added to the database.

11. Simulation of the Creative Sigmoid

In applying the rudimentary ACASIA model (Section 10), we investigated whether we could produce the Creative Sigmoid under various parameter settings. This resulted into nine simulations that varied matters such as the level of serendipity or the width of the information universe.

11.1 Simulation 1: Disruption on plateau

As an extension of Table 1, each entity Car, Dog, House, etc. received 6 features so that each vector had 6 coordinates. With merely 6 features per entity, the simulation results plotted in Figure 18 already showed the sigmoid growth of innovation. This was achieved with MINIMUM = 0.1, MAXIMUM = 0.8, chance of serendipitous insight = .01%. The vertical spikes represent the relative distances bridged through insight: from large (very creative) to small (not creative).

The horizontal line indicates the maximum distance the creator (or community) finds normally acceptable, that is, the combination is perceived as not too dissimilar. In the graphical output, most spikes that went beyond the horizontal line were not plotted. This means that normally great insight was not acknowledged because too much dissimilarity remained in the proposed combination. These ideas were not stored but ignored. The spikes that were depicted represented cases of serendipity where insight coincided with moments of more tolerance, accepting much dissimilarity because the creator saw a sufficient connection one way or the other. In our simulations, these moments were based on a certain level of chance.

Each simulation consisted of 50,000 runs of idea formation, representing the number of attempts to combine entities. This also included the combination of combinations (cf. DogCarHouse or CamperVan).

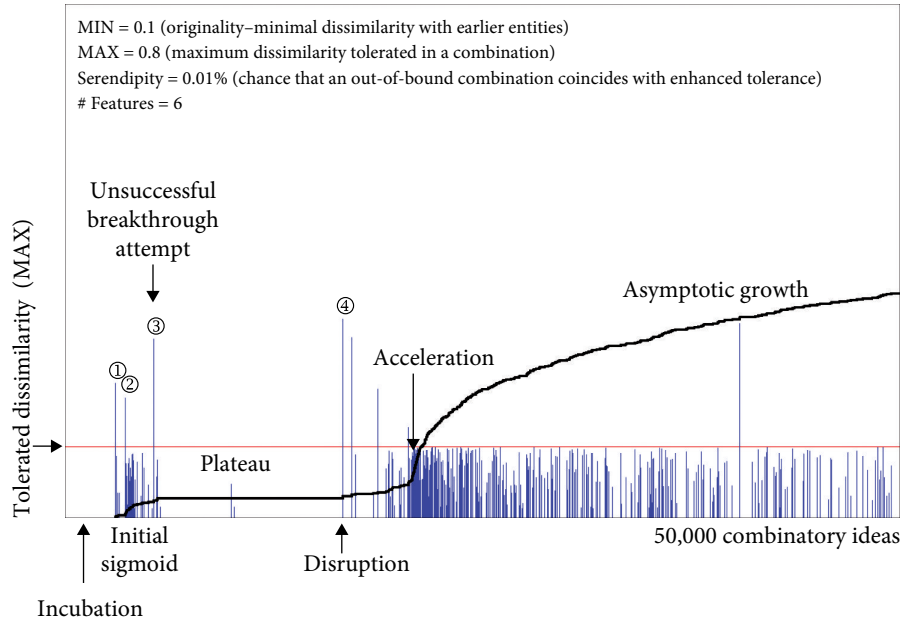


Figure 18. The Creative Sigmoid of accumulated innovations

At the infancy of innovation, during creative incubation (Figure 18, utter left), our creator simulator only found things she regarded as too dissimilar to combine (distance > MAXIMUM). The Creative Sigmoid took on the moment the first large distance was bridged between two very remote entities. This resembled a very very creative idea that was momentarily tolerated although normally it would have been regarded as too far-fetched. Allowing this first moment of serendipitous insight to proceed (the first spike ①), kick-started the accumulation of combinations of a more incremental kind.

Acceleration of the initial sigmoid took on after making a second out-of-bound combination ②, momentarily tolerated, until this development bent into an asymptote. There, a third great serendipitous finding ③ went off limits but did not do the trick of breaking through the ceiling of innovation. Although the wild combination was temporarily accepted, it did not inspire new findings. The curve plateaued for a while, designating a period of relative high culture or stagnation if you will with few new ideas happening.

It could also be said that the plateau was another period of incubation. At a certain moment, the craziest idea of them all ④ bridged the most associative distance. Normally, this would have been completely unacceptable. Once tolerated, however, it disrupted indolence and ignited a new series of incremental ideas that accelerated steeply thereafter. This development slowly curved into asymptotic growth again, approaching plateau, but at a far higher level of development than the first time, that is, incorporating more combinatory solutions than ever before.

In the maturity phase, the creator exhausted almost all possibilities within her perspective on the information universe. Therefore, new combinations became fewer at each step and the growth of innovation became asymptotic. The size of the spikes, which indicate the measure of insight needed to compensate perceived dissimilarity tended to be large in the beginning and decreased towards the end. In other words, the bandwidth of possible creative behaviors (i.e. making novel combinations) shrank over time.

It seems that initially, only strong creative minds in a tolerant environment will be able to make successful combinations. Towards the end, the steps become incremental changes to known practice. Disruption occurs when serendipity strikes at the asymptote with another large spike that instigates a new line of novel combinations with features from an uncharted domain (Figure 18, point ④).

11.2 Simulation 2: Postponed acceleration

With the same parameter settings, the same 50,000 attempts to create novel combinations obtained quite different results. Owing to pure chance (e.g., what is combined first, second, etc. and the fluctuation of tolerance levels), the

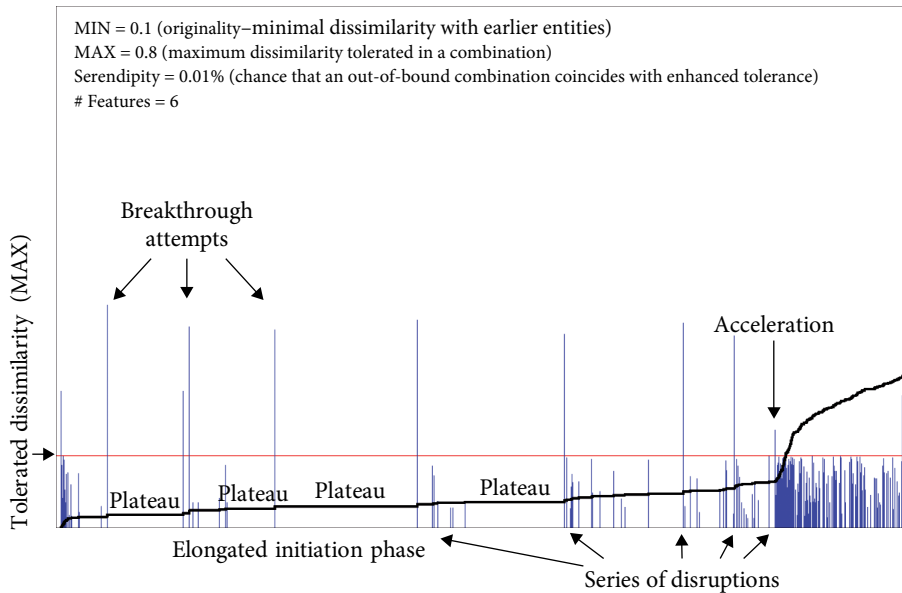


Figure 19. Creative Sigmoid with late acceleration

simulation results of Figure 19 show that in this case, it took a long period of time to find ideas that departed from plateau. In between two great insights little happened. The new combinations seemed to be isolated insights that did not spark acceleration. However, each great idea did accumulate to a higher level of plateau and after a series of breakthrough attempts, sufficient new combinations could be made to create the ‘killer combination’ that at a moment of increased tolerance triggered acceleration. This was a disruptive insight but it reconciled less dissimilarity than the earlier ‘no burners.’ Again, it can be observed that towards maturity, ideas become incremental (within default acceptance) and that the density of new idea formation decreases along the way (i.e. the number of new combinations becomes exhausted).

Figure 19 teaches us that original ideas that, on their own have little chance of happening (cf. unused patents), together may form a sensible innovation that can be brought to life. Due to the partially stochastic nature of the creative process (i.e. serendipity), the time it takes before the acceleration phase takes off is hardly predictable. Broadening the acceptance range may help reducing the initiation phase, shortening the foot of the Creative Sigmoid (see Simulation 6).

11.3 Simulation 3: Evolution within the boundaries

Another simulation under the same parameter settings showed that chance also may prohibit the abrupt and overwhelming accumulation of innovations, favoring a steady and more conservative evolution. Figure 20 displays that after the initial sigmoid, an idealess period commenced but that the serendipitous breakthrough did not kindle acceleration but rather a slow increase of incremental improvements (cf. the development of stone tool innovation). After disruption, a number of insights occurred that resolved great dissimilarity. However, these ideas may have been very creative but not very effective: The evolutionary line was not broken. Although in this example, growth did not become asymptotic, it has to in the long run as the possibilities of making new combinations decreases.

Figure 20 illustrates that due to chance, departing from plateau does not mean that acceleration has to take place or that very creative ideas are taken up by the creator or by society. In other words, the emergence of a conservative or a revolutionary innovation culture, that is, whether new insights lead to the departure of the current innovation line, may be based on chance fluctuation alone.

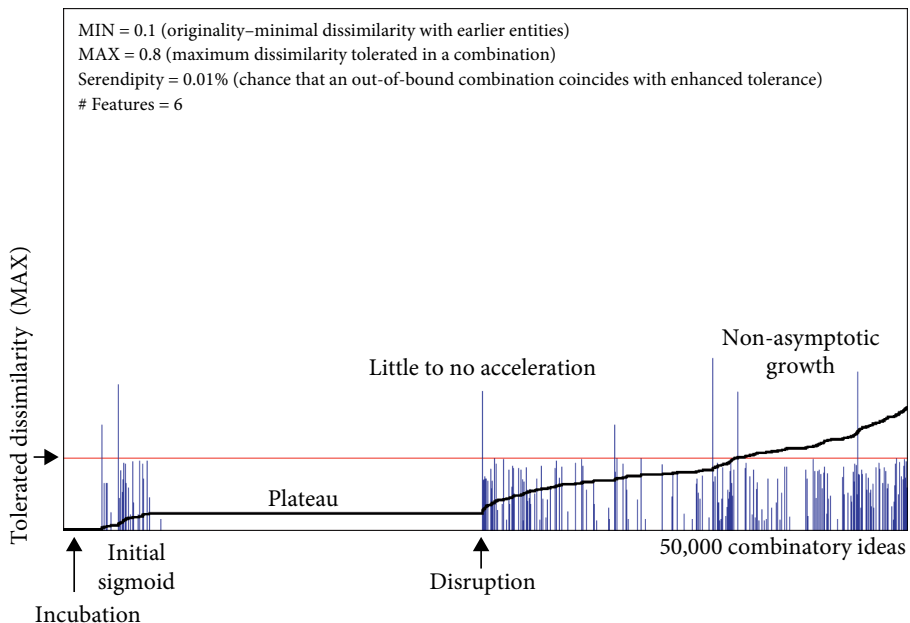


Figure 20. Creative Sigmoid showing evolutionary growth

11.4 Simulation 4: Dead culture

The situation produced by the previous simulation can be so extreme that even evolutionary incrementation remains absent. Figure 21 exhibits a series of plateaus caused by a dramatic decrease of finding novel combinations. In the last epoch, the creator actually found none. Running into a dead end happened despite accidental, greatly original, serendipitous insights but these did not render the combinations upon which new combinations were founded. This simulation also shows that great insight perhaps may instigate an innovation line but that incremental ideas are needed to realize growth (i.e. the final plateau).

Figure 21 is indicative of lack of initiative. Over time, attempts to create novel combinations simply stopped. Such a situation may occur when the criterion of acceptance is such that all new ideas are rejected (cf. Savransky's, 2000, p. 167, innovation killers). An original finding is not picked up because according to criterion, wild ideas may not pass. However, simulation 2 (Figure 19) shows that inspiration may still come and that homeostasis may be broken. But how long it takes before such coincidence occurs cannot be answered.

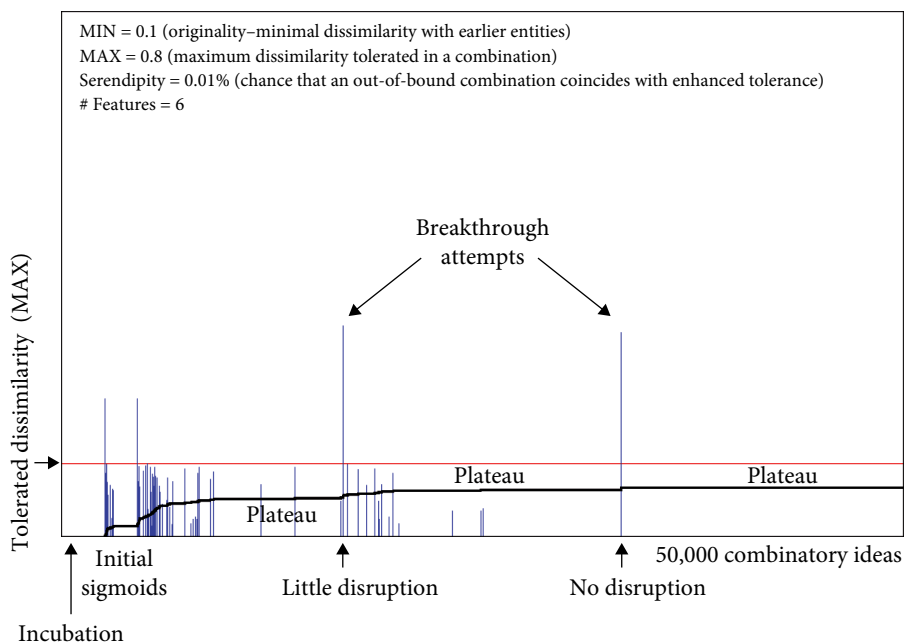


Figure 21. Creative Sigmoid, heading for homeostasis

11.5 Simulation 5: Lacking good fortune

To check the previous simulation, all parameter settings were the same as before except that we kept a tight rein on the role of chance, which we reduced from .01% to .001%. A lucky finding was almost impossible because only seldom would tolerance to dissimilarity be high. Figure 22 shows that the lack of benevolence had a dramatic effect on innovation, which hardly got off the mark despite three “blinding” attempts.

Figure 22 shows that luck is not only important for the breakthrough ideas but also for the incremental steps afterwards. When chances are few, improvement ceases to happen and insight hardly occurs at all. A repressed political region that suffers from brain drain because artists, engineers, and scientists move away probably shows the same picture. Talent needs plenty of chances to flourish (see Chapter 6).

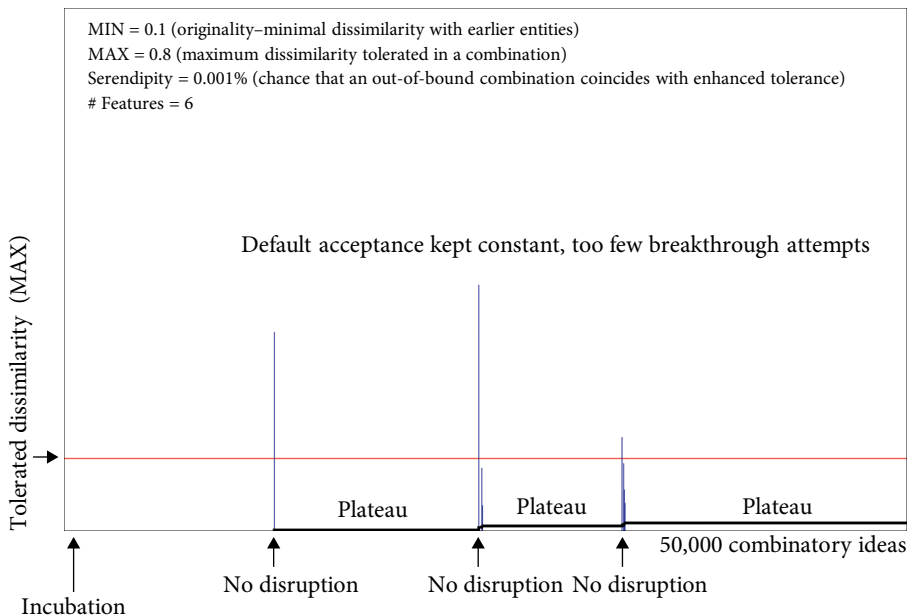


Figure 22. With little serendipity, the Creative Sigmoid falters

11.6 Simulation 6: Increasing the chances for luck to strike

By contrast, we enhanced the level of chance to .1%, keeping all other things equal. As compared to the previous simulations, the density and immediateness of serendipitous findings increased sharply, with short incubation time, almost instant acceleration, and asymptotic growth under a steep angle (Figure 23).

Figure 23 shows that late great creativity has little impact on the asymptote. That the level of acceptance was temporarily elevated did not matter, because development was sustained by a multitude of incremental steps, which outperformed the one big leap. This illustrates the power of crowdsourcing, where a multitude of smaller ideas may generate more added value than a lone genius.

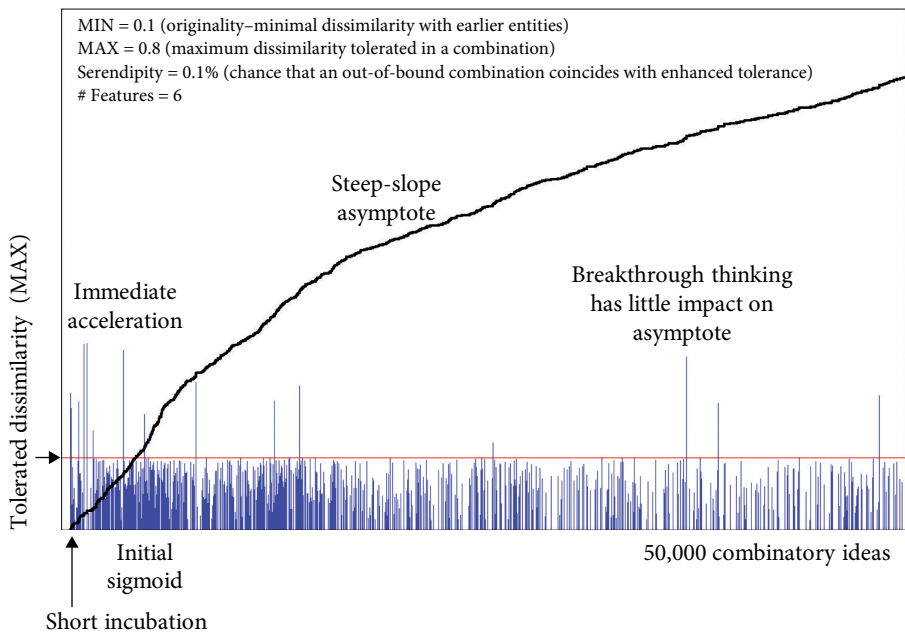


Figure 23. Creative Sigmoid with high serendipity

11.7 Simulation 7: Daring creativity

For this simulation, we set the chance level back to .01% but increased the tolerance to dissimilarity between disparate entities ($\text{MAX} = .9$). Put differently, stimulus discrimination became weaker.

Alleviating critical analysis and thus allowing more dissimilarity between entities to combine had an energizing effect on the build-up of the sigmoid. After a few initial attempts, a disruptive insight lifted off from plateau and a series of incremental ideas accelerated growth. These increments themselves combined entities with more dissimilarity than the increments in previous simulations. In other words, optimization of a great idea itself was based on more insight. A second disruption brought an exponential increase in innovations, all sustained by increments of greater creativity. To stimulate innovation growth, then, strict analysis and regulatory behaviors should be banned from the site, stimulus discrimination should be reduced, imagination and daydreaming should be stimulated.

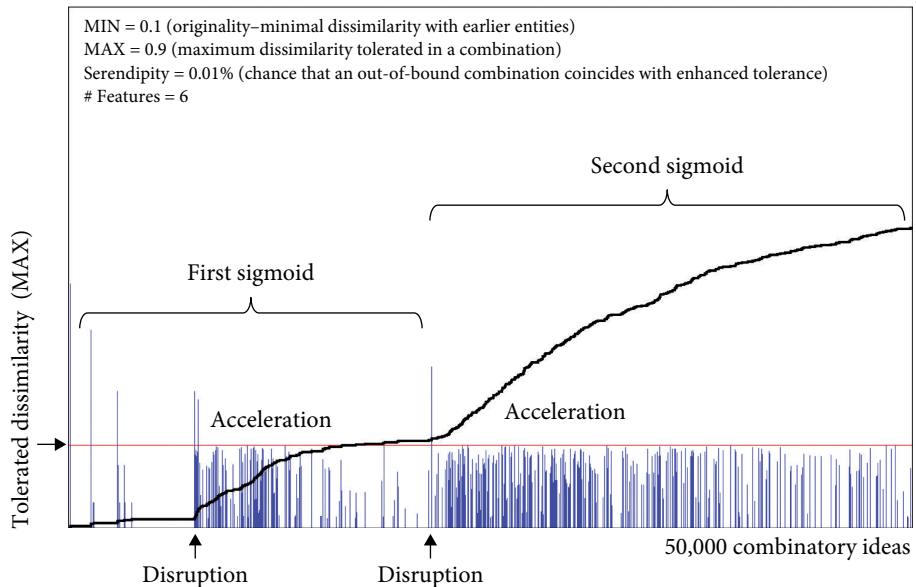


Figure 24. Creative Sigmoid with high tolerance to dissimilarity

11.8 Simulation 8: Must be original

With a stronger demand of originality (MINIMUM = 0.2), many combinations that were regarded as too close to earlier ideas were rejected in this simulation, drastically reducing the accumulation of innovations (Figure 25). Despite various attempts of breakthrough thinking, great insights did not make it through because the increments were not regarded novel enough to satisfy criterion (MIN). With higher minimum distance required, small innovations were dismissed, so that acceleration never really took off.

The simulation results exhibited in Figure 25 reveal that a person or community can have great ideas but they remain idle if they have no follow-up (cf. unused patents, museum depots filled with paintings). Originality may be key in creativity but being too demanding on novelty weakens innovation strength. Without the succession of incremental improvements, the ideas of original minds in the vanguard remain isolated events.

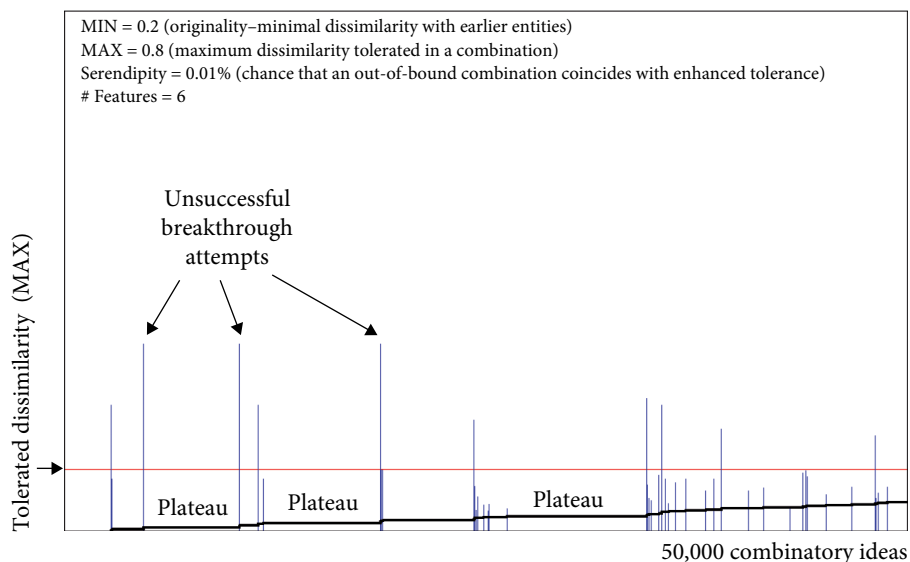


Figure 25. Incidents of insight with few incrementations

11.9 Simulation 9: Expanding the information universe

The last simulation in this series was performed with the standard settings of originality = .1, maximal tolerated dissimilarity = .8, and the chance for serendipitous insight = .01%. The difference was that the information universe was expanded from 6 to 20 features that could be compared and combined into novel creations. Particularly during the first stages of innovation, increasing the number of features had a spectacular effect on the size of the creative leaps that were made. With more information to explore, more combinations could be made and moreover between more remote entities. In other words, chances were increased that one of these insights started an innovation curve.

Figure 26 shows that the first great ideas did not fire up the expected acceleration. However, these extreme ideas were beneficial for making combinations that were less far-fetched, inciting the Creative Sigmoid. When the long and lazy asymptote of incremental offspring tended to flush out, yet another disruptive but not-so-crazy idea drove the curve again into acceleration. Then a sequence of incremental ideas caused steep growth but the great and crazy ideas of the early days were over.

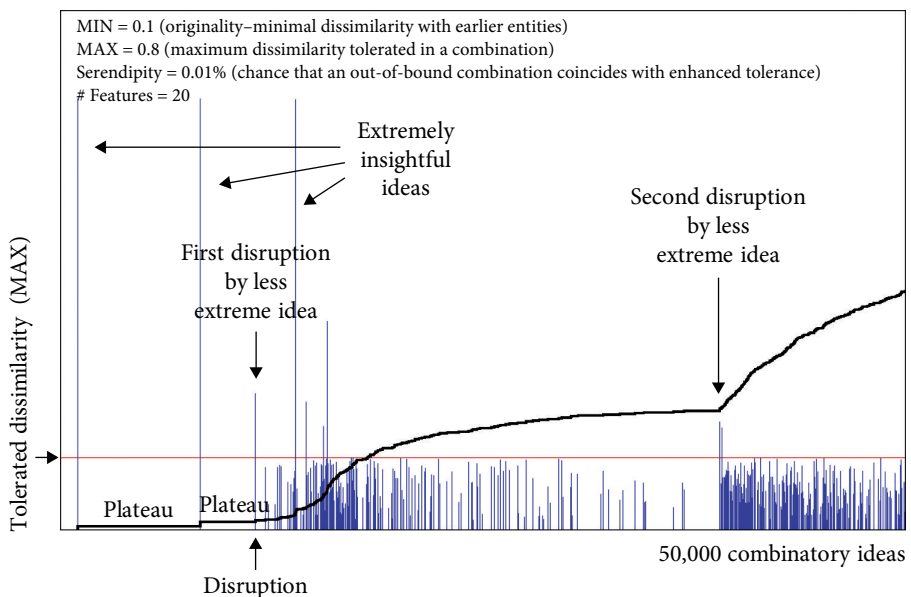


Figure 26. More information leads to bigger insights

11.10 Simulation conclusions: As luck would have it

With merely a few lines of ACASIA code, it seems possible to produce a variety of scenarios in which the Creative Sigmoid comes to expression as expected (e.g., Simulation 1), remains absent (e.g., Simulation 5), or becomes overheated (Simulation 6). With only a handful of variables and limited parameter settings a range of creativity-related phenomena can be described in terms of evolution, disruption, and serendipity. The interplay between originality, dissimilarity, combination, number of features, and chance produces realistic innovation stories that may serve as test predictions for empirical explorations. Given the number of features, chance level, acceptable dissimilarity, etc., the simulation code can show the host of results that may be expected from theory. There is not just one outcome confirming theory but a range of outcomes that may be in line, which may differ on the surface, but are manifestations of a deeper systematic.

With merely nine simulations, evolving from the same code, many aspects of creative cultures and people could be mimicked. The chance happening of creative insight may be the central issue but there are many fortunate and adverse events that affect such serendipity. For instance, the access to an abundance of diverse information (Simulation 9) exerts positive effects, particularly in the beginning of innovation.

12. Simulations including selection and adaptation

Chance and insight may be aspects of what we termed physical creativity – connections between entities were established without much appraisal or evaluation going on. ACASIA insisted that selection and adaptation were done by organisms to optimize a creation for certain purposes (usefulness, aptness, etc.). Next we will use ACASIA code to simulate the effects of selection and adaptation on the development of the Creative Sigmoid.⁶

As previously outlined, we defined an exemplar from a category as an n -dimensional vector. The complete space of all possible exemplars was defined by an n -dimensional (hyper)cube. Each coordinate represented a feature, ranging from -1 to 1 , which simulated bipolar features (i.e. long = not short, high = not low). Although a bipolar approach is not conducive to creativity (Hoorn, 2012, pp. 147–151), this way the similarity operation could be sharply defined as the Euclidian distance between two vectors. Additionally, we defined a minimum distance below which two exemplars were regarded the same. Also, we defined a maximum distance above which two exemplars were regarded as too dissimilar. Serendipity (coincidental combinations at times of high tolerance) allowed

6. Courtesy Desmond Germans.

crossing distances beyond the maximum regardless. To explore the effects of selection and adaptation on the thus produced growth curve, we extended the simulation software. Adaptation and selection modules were added to optimize each vector combination.

To model the optimization, we defined an ideal distance setting. This models the 'perfect' ratio between similarity and dissimilarity that a creator may strive for. We selected this mechanism because it is very straightforward and easy to understand and analyze. Both the selection and adaptation stages modified the vectors towards this optimal distance. Figure 27 shows ACASIA's combinatory creativity with organic optimization stages added (i.e. selection and adaptation).

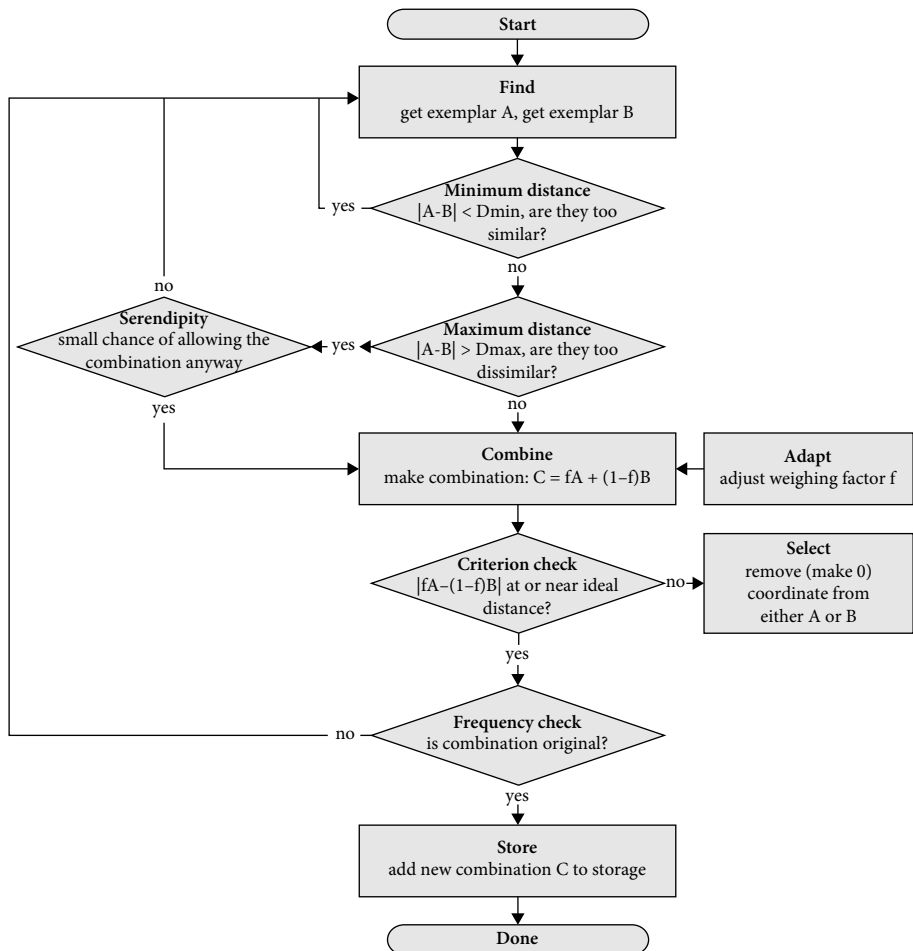


Figure 27. ACASIA variant with optimization (i.e. selection and adaptation)

Selection is assumed to ‘remove features.’ In our simulations, then, the selection stage simply removed (made 0) the most suitable coordinate of the exemplar vector. The most suitable coordinate was the one that yielded a distance closer to the ideal distance. Adaptation was assumed to make ‘small adjustments.’ For our simulations, the adaptation stage modified the weighing factor f , as shown in Figure 27. When f was 0, the combination consisted of only the exemplar B. When f was 1, the combination consisted of exemplar A alone.

We did not explicitly model the integration and abstraction steps as suggested by ACASIA in Chapter 4. Integration means that entities are physically positioned and connected, for instance, by gluing them together. In the current simulations, this would be meaningless because the entities were vectors in an abstract n -dimensional space. Including the abstraction step would be meaningless as well because a hierarchical specification of entities is absent if every vector is equally abstract.

We used a setup in which we traced the accumulation of successfully generated new combinations over 80,000 iterations. Every time a new combination was generated, the graph showed an upward curve (i.e. infancy of the sigmoid). A sample curve as produced during simulation can be found in Figure 28.

During infancy, the process had trouble finding new combinations. Only serendipity allowed combinations of exemplars that were otherwise deemed too dissimilar. When yet a sufficient number of new combinations were generated, new combinations from earlier combinations were formed at an increasing rate (i.e. acceleration). After acceleration, the curve slowly died out (not entirely visible in the figure) as the complete vector space became exhausted.

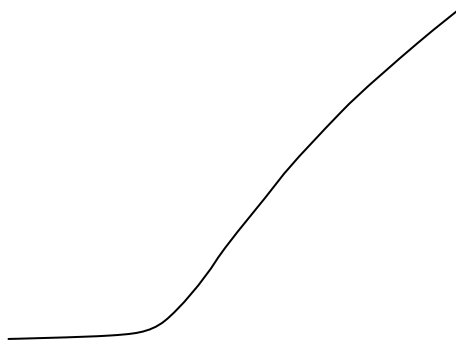


Figure 28. Creative Sigmoid produced by ACASIA. Steady infancy based on serendipity followed by acceleration (i.e. a higher rate of new combinations)

12.1 Comparability of sigmoids

Due to the random effects of serendipity, every curve is expected to be different, even when the algorithm parameters (minimum distance, maximum distance) are the same. This obscures the comparison of two curves with different parameters. To get an idea of comparability, we repeated the same simulation multiple times, and averaged the resulting curves.

Figure 29 shows how the traces look when we repeated the simulation once, 10 times, and 50 times. On the left, the 5 curves each represent exactly one iteration. In the middle, each of the 5 curves is the average over 10 iterations. On the right, the 5 curves each represent the average over 50 iterations. The curves converge when averaged over more repetitions, so that we can safely compare results from different simulation experiments. Every graph in the remainder of this chapter was generated by repeating the same experiment 50 times and averaging the resulting curves. Note that in Figure 29, axis units are meaningless, as long as two graphs use the same scales when they are being compared.

After having established that the algorithm generated reproducible results for specified parameters, we performed a series of comparisons. Both the selection and adaptation modules can be switched on or off. When both mechanisms were disabled, this equaled the situation of Figure 28. We maintained a minimum distance of 0.2 and a maximum distance of 0.8, because this generated the clearest picture of the curve's aspects of interest.

12.2 Including adaptation

Figure 30 shows the effects of adaptation on the Creative Sigmoid (drawn) as compared to its development without adaptation (dotted). The drawn lines represent

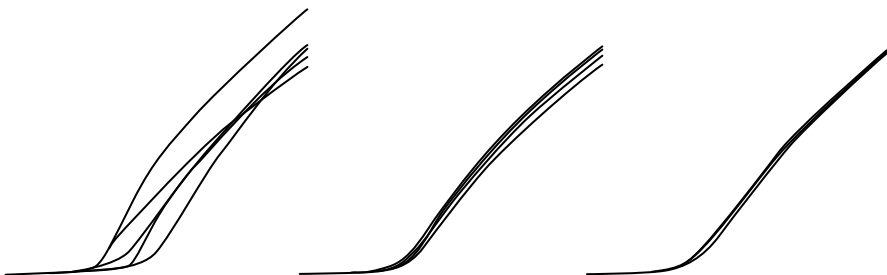


Figure 29. Creative Sigmoids unrepeated (left), repeated 10 times (middle), and repeated 50 times (right)

‘physical creativity,’ whereas the dotted lines represent a variant of organic creativity (i.e. physical creativity plus adaptation of features).

As a main effect, the curves with adaptation (drawn) were shallower than those without (dotted). Towards the right, creating more distance between combined entities made the curves with adaptation become steeper. Thus, physical creativity accelerated quicker than organic creativity (version with adaptation) but this difference was mitigated when larger associative gaps were allowed to be bridged.

12.3 Including selection

The next experiment shows the effects of selection on producing the Creative Sigmoid. Figure 31 shows a version of ACASIA’s organic creativity that merely included selection (drawn) compared to ACASIA’s physical variant (dotted).

Creative Sigmoids with selection-only were shallower than those for physical creativity, particularly when small associative distances had to be bridged. Further, there seemed to be an optimum for an ideal distance of around 0.7 (2nd curve from the right). With selection included, moreover, acceleration appeared to be triggered *earlier* than without (3rd from the right), particularly at moderately large associative distances between entities that were to be combined.

12.4 Including selection and adaptation

Next, we looked into the combined effects of selection and adaptation. Figure 32 shows the output curves of ACASIA including selection-and-adaptation (drawn) in contrast to ACASIA excluding selection-and-adaptation (dotted).

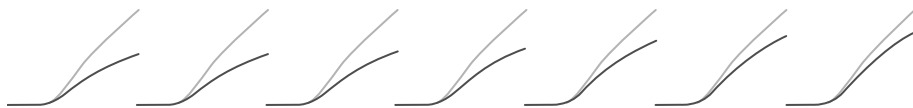


Figure 30. Creative Sigmoids when ACASIA includes adaptation, aiming for an ideal distance of 0.2 (far left) up to an ideal distance of 0.8 (far right)

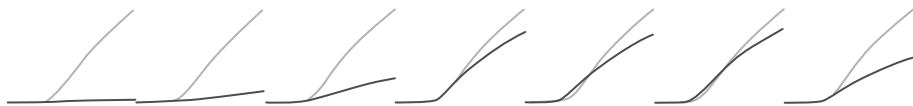


Figure 31. Creative Sigmoids when ACASIA includes selection, aiming for an ideal distance of 0.2 (far left) up to an ideal distance of 0.8 (far right)

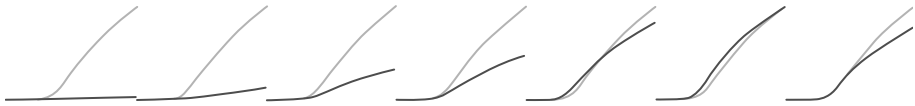


Figure 32. Creative Sigmoids when ACASIA includes selection-and-adaptation, aiming for an ideal distance of 0.2 (far left) up to an ideal distance of 0.8 (far right)

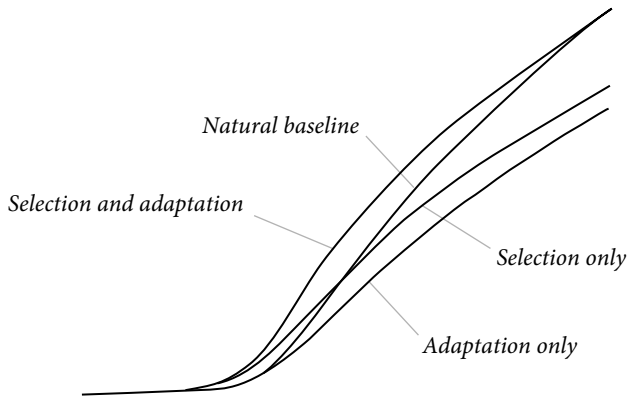


Figure 33. All simulation results at ideal distance 0.7

Observe in Figure 32 that the optimum lied around an ideal associative distance of 0.7 between entities (2nd curve from the right). Similarly to the selection-alone simulations (Section 12.3), acceleration happened earlier with than without selection-and-adaptation at larger associative distances.

12.5 Organic creativity outperforms physical creativity

Figure 33 shows the results of all simulations at an ideal associative distance of 0.7. Take notice of the inhibiting effect of adaptation and the facilitation of acceleration through selection: The adaptation-only curve is shallowest and both the selection-only and selection-and-adaptation curves start earlier.

If in Figure 33 we take the sigmoids produced by physical creativity as the ‘natural baseline,’ the following effects of selection and adaptation can be observed:

- Physical creativity accumulates more creative output than adaptation-alone. The natural baseline rises earlier and continues longer before stagnation bends into asymptotic growth

- Adaptation-only slows down acceleration. Apparently, painstakingly making small adjustments, doing incremental improvements, and modifying details hampers creativity
- Selection-only makes acceleration happen sooner than natural baseline but also suffers from early burn-out.⁷ Physical creativity continues longer before asymptotic stagnation occurs. Selection picks out those entities that make a good fit (hence, early acceleration) but also ignores many less obvious options (therefore, early stagnation)
- When both selection and adaptation work together, instead of canceling each other out, the selection effect appears to be balanced by adaptation. The combination performs better than natural baseline in terms of early acceleration and continuous growth. It seems that organic creativity is more efficient and effective than purely physical creativity (cf. Lowcre, 2013)

Note that these simulation results merely show that the theory is consistent and indeed predicts what logically was expected. It is by no means an empirical validation. A next step would be to use the formal model as a tool to analyze real-world data with.

Moreover, the choice of representing entities by vectors was arbitrary, mainly done out of convenience. More natural results are obtained if entities such as words, images, or sounds are used. Additionally, defining criteria for selection and adaptation to achieve optimal aesthetics, usefulness, appropriateness, and so forth will greatly improve results and also will be vastly more complex.

13. Fractal recursion

Complexity theory derives the development of organisms and non-living systems from a set of fundamental concepts (Miller, 2000, p. 444). Although history may repeat itself, and in spite of timeless archetypal patterns, there is the “paradox of return” (ibid., p. 119), indicating that an apparent reprise is never an exact copy (cf. Basalla, 1988/1999, pp. 103–104).

13.1 Theory alluding to fractality

Theories of diverse background hinge at the fractal development of innovation and creativity. Fractal systems show a near-infinite pattern of almost self-similar

7. The locust effect: Eat everything at once, leave nothing for later.

details, which are repeated on increasingly smaller or larger scales of data aggregation (Mandelbrot, 2001).

At the largest scales of data aggregation, Christian (2011, p. 245) observes that social complexity and urbanization resemble patterns of galaxy formation. K. Kelly (2010, p. 12) envisions a self-reinforcing system of creation. He points out that the flow of bits of information through the global information network exhibits self-similarity, a kind of fractal pattern (*ibid.*, p. 14). While accumulating, information slowly gains order through self-organization (*ibid.*, pp. 63–64). He states that ‘the physical and chemical constraints create forms, the self-organization directs and redirects them to recurring forms’ (*ibid.*, p. 120). Complex systems acquire their own inertia, creating recurring patterns that the system tends to fall into (*ibid.*, p. 123). Kelly envisions a compound of S-curves (K. Kelly, 2010, p. 170).

At the mid-scale, Binnig (2002, p. 254) speaks of fractal Darwinism or fractal interactions. Entities incorporate other entities and while interacting, they change one another. A creative person, Binnig assumes, can be creative only if the larger unit such as a research team is creative, embedded in an even larger unit (e.g., the organization) that wants to be creative, and so on. Savransky (2000, p. 340) points out that the form of the general trends of design-method evolution is an S-curve, composed of smaller jagged S-shaped stages of development. He suspects the existence of a fractal Hausdorff dimension (*ibid.*, p. 347). Taylor, Micolich, & Jonas (1999) and Taylor et al. (2007) were capable of identifying fractal patterning in the drip paintings of Jackson Pollock.

At the smallest scales, Goswami (1997, p. 86) contends that self-organization can be found in certain chemical reactions, that chain reactions show self-maintenance, and that certain machines can reproduce themselves. But what is distinctive for a living cell, he argues, is a system that is self-referential and shows creative evolution (*ibid.*, p. 98) as ruled by quantum dynamics (*ibid.*, p. 95).

13.2 Abstracted into sigmoids

Because the assumed fractality of creative development ranges over so many kinds of data, we should “visualize the universe as an incredibly complex *set of nested abstractions*” (Pfenniger & Shubik, 2001, p. 224). In this way, we can investigate the overall organizational pattern of nested abstract systems, their non-linear interactions, and the causes that govern this order (cf. Pfenniger & Shubik, 2001, p. 226). As Gell-Mann (1995) proposed “... the basic pattern is one of complexity emerging from very simple rules, initial order, and the operation, over and over again, of chance.”

In the case of the Creative Sigmoid, the abstractions that should show fractal behavior are the S-curves, ruled by simple code (e.g., Figure 14). ACASIA and the Creative Sigmoid explain the self-organization of chaos through creativity. In its infancy, the system is in chaos, then through combinatorics an evolutionary line of near self-similar repetitions emerges, disrupted by similarity with information other than expected from 'good continuation' of the evolutionary line, temporarily causing chaos again, leading to evolution through combinatorics, incorporating earlier trends, etc. A fractal search pattern (Lowcre, 2013).

The sudden connection of different physical matter or the jump to another knowledge domain could be considered a moment of quantum chaos where the curve can change itself or alter the course of its development (cf. Goswami, 1997). Chapter 4, Section 5.3.4 explained how the quantum leap between synapses happens during breakthrough thinking. This quantum jump is the lowest level of creation where the scale of sigmoidal growth is not present any more because the jump is discrete or 'binary.' After the jump, fractal search commences for optimizing combinations against the criteria provided by the environment: Minimal creativity followed by fractal pattern discrimination (cf. Bird & Stokes, 2007).

Due to its noisy determinism, every next sigmoid is near self-similar. Because the nearly self-similar sigmoids are nested, their shape should be scale independent with the lower bound at quantum level and the higher bound at all-encompassing crystalline structure (i.e. the end of the final Creative Sigmoid).

13.3 Eyeball inspection of simulation output

If we are right that the Creative Sigmoid is composed of other sigmoids at smaller scales, the simulation output should show fractal patterning. For example, the curve of the simulated sigmoid of Figure 18 is far from smooth and shows hops, steps, and jumps, suggesting a build-up by smaller sigmoids. However, although each simulation of the Creative Sigmoid may suggest a fractal repetition of smaller curves developing, this patterning is partly given by the program: Because ACASIA combines combinations it by definition has repetition inbuilt. Moreover, the scale at which our simulations took place was so small that jitter and variance was plenty: One simulation result may seem to include fractal patterning (Figure 18) whereas another does not (i.e. when the curve remains on plateau for a while). A possibility might be to calculate an average across simulation results (cf. Figure 33) but that is an artificial way to remove exactly that variance that theory predicts for the smaller scales. In other words, we should engage in more simulations on larger scales to find out whether we can isolate a fractal number. Even better, we should use existing data on creative development and innovation to see whether we can identify the Creative Sigmoid at all and in addition detect some fractal recursion

in it. As stated earlier, such an endeavor takes a complete research program and is beyond the scope of this book.

Acknowledgement

I am greatly indebted to Desmond Germans for profound discussions on the ACASIA model, for formalization and programming, setting up experiments, and helping to analyze the simulations of the Creative Sigmoid.

Conditions of creativity

“... systems are ... resistant to the nurturing of creativity” (Collard, 2011)

So far, we discussed the inner workings of the creative process of ACASIA and the development of the Creative Sigmoid it produces. It was emphasized that many factors influence the course of this process, for example, the size of the available information universe, the range of permissible behaviors, or the criteria for selection. The present chapter examines the factors that influence ACASIA and the resulting Creative Sigmoid to conclude that, by and large, a negative outlook on the world harms creativity and that an appreciative attitude stimulates creativity. We also see that openness is the main facilitator of creativity. This is because open access to the information universe increases the likelihood that unrelated domains become connected. Some of the findings in this chapter lead to the recommendation of a leadership style that invigorates creativity in people and counters the stifling effects of managerial rule-making madness.

1. Contexts of creativity

This book on creativity started with nature's creativeness, with combination making at its core, which is perceptible in the way matter takes shape, how organisms come about, and in the way the human brain works; capable of imagining combinations that have not yet and perhaps never will be materialized. It was then argued that a survivalist world view was less conducive to creativity than an outlook on opportunities. The first would pertain to focused behaviors in a more deterministic problem space; the latter to unfocused behaviors in probabilistic settings. Rational, rule-oriented, problem solving and creative problem solving naturally would flow from the two respective conditions. In zooming in on how the creative process works and what it produces, the previous two chapters discussed ACASIA in relation to the Creative Sigmoid.

Via combination making, ACASIA works its way through the information universe, drawing in a diversity of data and molding it such that its output adds to a certain line of creation, then at one time disrupts and mutates into another direction. This search of the information universe probably has a fractal patterning:

Whereas the combination making as such is the physical aspect of creativity and may give rise to wild jumps, the organic part attempts to optimize a combination through the evaluation of, for instance, novelty, usefulness, aesthetics, etc. Due to these forces, the number of entities that can be combined diminishes and hence the accumulation of combinations assumes the form of an S-shape: the Creative Sigmoid. Consequently, over time, the more entities are selected, adapted, and integrated, the smaller the bandwidth of possible behaviors (deviation from the mainstream becomes less). On its turn, this bandwidth or standard deviation can be made smaller or larger by a host of internal and external factors and this is what the current chapter will be about: The conditions under which creativity may flourish. Or decay.

Thus far, ACASIA's combinatory creativity and the resulting Creative Sigmoid were discussed as a self-propelled mechanism and only superficially we touched upon the factors that impede or facilitate its progression. In the literature, many stimulating and obstructing factors of creativity and innovation are mentioned (cf. Sternberg & Kaufman, 2010; Plucker & Renzuli, 1999, pp. 35–61). In fact, this number is so vast that it is infeasible for an overview to give a fair account of each of them. Yet, the sheer number of delimiters and catalysts raises the suspicion that each of the designated factors contributes but little to the amount of explanation provided by the combination of remaining factors. Instead, it may be that we are dealing with a number of moderators (cf. Nickerson, 1999, pp. 406–408, also Davids, 2008, p. 454, p. 477) that impinges upon one big mediator of creativity, a necessary precondition, standing in between the drive to create and the actual act of creation. That *mediator* is access to the universe of the most diverse free-floating information.

Next, I provide an inevitably incomplete overview of the factors mentioned in the literature, ranging from socio-economic conditions to personality traits. I will then argue that the one aspect that keeps returning as the main *moderator* of creativity is “openness” (or reversely, the absence of rules) as it affects the access to the free flow of information (cf. Basalla, 1999, p. 78). That information should be richly available and as diverse as possible (cf. Damasio, 2001, p. 65) so to increase the chances for lucky combinations to strike.

2. Moderators of creativity

Contextual investigations of creativity examine the circumstances that favor or hinder the occurrence of creativity and innovation. From these studies, it becomes clear that a culture of freedom, tolerance, openness, diversity, playfulness, and an exploratory mindset, appreciative attitude, and of visionary leadership propels creativity.

By contrast, rules, regulations, restrictions, target setting, extrinsic rewards, templates, control, fear, sadness, social exclusion, hierarchy, status-seeking, formalities, process and program monitoring, and managerial procedures are detrimental to creativity and innovation. Within the ACASIA framework, they would affect the number of criteria and the leniency or strictness by which those criteria are applied to select, adapt, and integrate features in a creation or to judge its novelty.

2.1 Culture

Because creativity breaks away from ordinary ways of conduct as to acquire novel insights, it inevitably stands in close relationship with the culture it is a part of. Culture is a shared system of knowledge, behaviors, customs, values, rules, symbols, and ways of interaction with the social and natural environment (Lubart, 1999, p. 339). Culture may channel the kind of creativity that is exposed (*ibid.* p. 342).

Obviously, Arab artists are not supposed to depict humans or animals and therefore draw on abstract motives and symbols for decoration and illustration. Lubart (1999, p. 342) points at certain cultures where the measure of seriousness of a topic determines whether novelties are allowed or not, the rule being that the more serious the topic, the less innovative the artistic expression is permitted to be. Individualism of Western Europeans and their American offshoot tends to self-expression and deviation from social rules whereas collectivist cultures such as the Asian value authority and commonly accepted rules of conduct (Lubart, 1999, p. 345).

Savransky (2000, p. 63) points out that innovation is hampered when current political or economic practice is “sacred” and their limitations remain unrecognized, when change is suspect, or when there is a different goal orientation (e.g., visible in the occidental vs. oriental world view). Multicultural exposure exerts a direct positive effect on creative-idea generation, on producing novel analogous solutions (Lubart, 2010, p. 275), as well as on divergent thinking, given sufficient openness of mind (Runco, 2010, p. 438). Cultures with an optimistic view on the future are more likely to produce change and novelty than cultural pessimism (Savransky, 2000, p. 63).

A culture of homogeneity leads to groupthink (Simonton, 2009, pp. 146–147, p. 154) while isolation leads to cultural stagnation and decadence (*ibid.*, p. 157; pp. 194–195). Civilization can be revitalized by opening up to other cultures (*ibid.*) and let diversity in, which is crucial to, for instance, technological development (K. Kelly, 2010, pp. 291–292). Heterogeneity in politics and diversity of groups foster a creative culture, which may even be provoked by revolt and rebellion.

Cultures and highly ordered societies collapse when they rigidly follow tradition or religion and are not inventive enough to adapt to change (e.g., Pain, 1993; Tainter, 1988). In other words, a culture that tolerates the violation of rules and allows multiple perspectives (cf. the ‘multiplists’ and ‘relativists,’ Chapter 2, Section 1) is more likely to find innovative solutions than restrictive cultures (cf. ‘dualists’). As an effect, letting go of restrictions while people can freely seek out novelty rears large-scale prosperity and influence:

For all their enormous differences, every single world hyperpower in history – every society that could even arguably be described as having achieved global hegemony – was, at least by the standards of its time, extraordinarily pluralistic and tolerant during its rise to preeminence. Indeed, in every case, tolerance was indispensable to the achievement of hegemony. (Chua, 2007, p. xxi)

From a historical perspective, Davids (2008, p. 464) confirms that to stimulate creativity, there should be peace, goodwill, and tolerance in a society. Yet, Chua nuances this view by stating that tolerance may not be a truly felt cultural value as long as it is strategically or instrumentally employed to allow very different kinds of people to live, work, and prosper together.

2.2 Politics

As in all walks of life, in creativity also, the power issue is germane (Moran, 2010, p. 77). Those in charge designate which parts of society are allowed to innovate and be creative. Gaining control over resources, information, social networks, and funding has a direct effect on whether creativity prospers (e.g., Renaissance Italy) or not (e.g., Maoist China) and the direction it takes (*ibid.*).

In his treatment of the rise and fall of Dutch technological supremacy, Davids (2008, p. 377) contends that during the Golden Age political pluralism and diversity of interests were among the main success factors for releasing innovation potential. There was a striking innovation climate instigated by non-market institutions that favored risk-taking, certified quality or safety of products, and advanced the adoption of novelties, while encouraging rivalry with other economies and societies (*ibid.*, p. 379). Political diversity and openness, that is, the free flow of information and goals, was the origin of technological novelty (*ibid.*, p. 388). According to Davids (2008, p. 454), political diversity is a prerequisite of technology acceptance. At the downward slope of Dutch supremacy, civic duty took precedence over the openness of knowledge as a result of changes in policy and public mood (Davids, 2008, p. 476).¹

1. A trend observable again in The Netherlands.

Dauids (2008, p. 522) indicates that orthodoxy and radicalism may lead to stagnation and that too many rules and regulations of behaviors and ideas limit the freedom needed to create innovations. Not reaching remote and isolated, mainly rural, communities also exerts a retarding influence on the societal adoption of novelties (Dauids, 2008, p. 526).

2.3 Economy

2.3.1 *Coordinated and liberal markets*

Hall and Soskice (2001, p. 21) point out that coordinated and liberal economies have different ways to innovate. Coordinated markets in Western Europe depend on business associations and trade unions. Job mobility is relatively low so that it is worthwhile to invest in the training of trade-specific skills, negotiate wages collectively, and collaborate within companies or within the sector (*ibid.*, p. 34). In addition, coordination happens in relation with non-market stakeholders (*ibid.*, p. 8) and corporations have tight networks within firms that connect to similarly tight networks in other companies. Through these networks, firms share reliable information (*ibid.*, p. 23).

Liberal markets, as found in the Anglo-Saxon world, are more oriented to the individual that has general skills (*ibid.*, p. 32). Job hoppers easily traverse different domains. In liberal markets, knowledge transfer takes place through job mobility of researchers and engineers (*ibid.*, p. 31), moving from one company to another. Coordination problems are mainly settled through competition and hierarchical organization (*ibid.*, p. 8).

As I see it, the innovation strength of coordinated markets lies in knowledge acquisition and sharing throughout the collective. They have plenty of opportunities for co-creation. Because more stakeholder groups are involved, multiple perspectives are taken into account. Fixed wages could provide the stability needed to experiment and explore without getting focused too strongly on ‘making money.’ Drawbacks could be that the sector becomes self-occupied and that knowledge transfer does not take place across *disparate* domains. Investing in education is beneficial but the exclusive focus on specialization may interfere with solving problems creatively. Consensus seeking also will not stimulate divergent thinking. In all, coordinated markets will innovate along incremental and continuous lines without establishing many breakthroughs: They favor so called ‘seekers’ of innovations (cf. Galenson, 2001; 2006), experimentalists who show great continuity in their development and who improve with age.

Liberal economies have the advantage of passing on inventions across various domains, dependent on job opportunities. Moreover, there is more room for individual entrepreneurship and exploration, independent of collectivistic

agreements or even groupthink. Their general skills help them prevent from tunnel vision and overspecialization. This may stimulate the emergence of drastic innovations. However, creative behavior is limited by the hierarchies in which innovators have to obey and execute whatever comes from higher management. The emphasis on competition makes people focus on survival, protection, and aggression, instead of openness, sharing, and generosity. Liberal markets will show more occurrences of breakthrough creativity but have limited possibilities to make the collective more creative or to improve on earlier ideas: They favor so called creativity ‘finders’ (cf. Galenson, 2001; 2006), goal-directed conceptual innovators who plan for action, show great disruptions in style, and who radically change the rules of a domain.

2.3.2 *Protectionism*

Dauids (2008, p. 389) explains that there should be no restriction on communication of novelty. Open access to knowledge leads to cost reduction – people can see how things work – so there is less need for invention, for reinventing the wheel, that is. Openness facilitates “collective invention” (cf. co-creation). Free copying and exchange of technology leads to collective added value. Keeping things secret is expensive (e.g., security measures) (ibid., p. 395).

It would seem that rules and restrictions merely come from mechanistic and deterministic approaches, which is not the case. Protection of the unique individual achievement may raise barriers to the free exchange of information just as well. The patent system comes from discontinuous approaches to creativity (Basalla, 1988/1999, p. 60). Here we encounter human agency and the right of the (neo)-liberal, competitive, individual to defend its property in a free market.

Patent monopolies close off possibilities of additional inventions, slowing down innovation but the costs of openness are that the inventor does the investment while free-riders copy the creative work without charge (Dauids, 2008, p. 399). An alternative to patent monopoly could be so-called compulsory licensing (Taylor-Silberson) (Basalla, 1988/1999, p. 122), where the inventor is obliged to give a license against a reasonable fee. Anyhow, the economic history of Switzerland and The Netherlands showed that in periods where there *was* no patenting system, they were extremely successful innovation countries with a flourishing economy (Basalla, 1988/1999, p. 123).

Mercantilism and protecting the interests of corporate organizations are detrimental to creativity (Dauids, 2008, p. 526). On an equal footing, companies should make inventions and designs available to their competitors who can use these results to improve their own production facilities (Allen, 1983). Investment rates should be high because they positively affect experimentation and collective invention (ibid.). Anderson (2006) points out that with the rise of the Internet,

classic distribution problems and logistics have become less important so that mass production of mainstream products is no longer necessary. Without physical constraints, innovation is in user-generated content and the servicing of many niches with customized and personalized products.

Sharing risks facilitates innovation (Davids, 2008, p. 454). Protectionist measures such as patenting should be replaced by a reward system in which openness and personal gain are guaranteed and not a ground for competition (*ibid.*, p. 410). Registration and publication of ideas are fine but a market share in an invention is less effective to accelerate innovation than access to new knowledge. Competition should be moved away from prices into the direction of quality (i.e. better use of materials, work power, and improved design) (*ibid.*, p. 423). Mokyr (cited in Davids, 2008, p. 536) also avows that openness of knowledge is more conducive to technological advance than secrecy. Tapscott and Williams (2006, 2008) advocate that to be successful, enterprises should strive for global cooperation, interactive communities, and open source technologies such as Wikis.

2.3.3 *A new economy*

Mokyr (1990, pp. 4–6) states that historically, economic growth used to spring from growth in technological innovation, capital stock, increase in trade, and scale (so called size effects). Davids (2008, p. 366) adds that in return, technical change was governed by changes in prices of labor, capital, and land but also (*ibid.*, p. 369) energy and raw materials. Machines were mainly invented to save on labor, to improve product quality, to introduce a new product, to enhance performance, to reduce energy consumption, and to save on effort and cost (*ibid.*, p. 369).

Mokyr (2004) argues that economic growth in the past two centuries not only followed from novel technology as such but also from the broad access to new ideas in a networked society of universities, high-tech companies, publishing houses, and so on (*ibid.*, p. 284). One of the main consequences of the current knowledge economy, so Mokyr claims, is the inadequacy of the “factory system” (based on Adam Smith’s specializations, Taylorian planning, and Weberian hierarchies) as an organizing principle (*ibid.*, p. 119). Tapscott and Williams (2010) underscore this very idea and promote the redesign of institutions (e.g., health, finance, business, media) of advanced economies by stimulating mass collaboration on the Internet. The collective capabilities of massive online communities are now being harnessed to spur innovation and economic development (Tapscott & Williams, 2006/2008).

2.4 Organizations

World-wide, large corporations and institutions are modeled after Adam Smith's (1776) division of labor, Taylor's (1911) scientific management, and Weber's (1922) bureaucracy: a world of extensive formal rules, legal jurisdiction, hierarchy of offices, authority, stability, impersonal decisions, selection based on official certificates, path-dependent careers, and financial compensation.

Installing routine processes, managerial control, and organizational hierarchy takes care of arbitrary decisions and unwarranted privileges that are characteristic for more traditional organization forms such as tribal communities or family business. However, it also instills conservatism and stifles the creativity that is vital in a dynamic and organic society that constantly is open to the communication of diverse ideas (Williams & Yang, 1999, pp. 374–375; also Puccio & Cabra, 2010, p. 155).

Management focusing on failure of employees and apportioning blame eliminate exploratory behavior (see Section 6.3, Box 7); rewarding initiative and being generous with second chances instead make creativity thrive (Williams & Yang, 1999, p. 381; Zander & Zander, 2000, p. 27, p. 34, p. 70, p. 145; Puccio & Cabra, 2010, p. 165). According to Savransky (2000, p. 63), major innovation obstacles at managerial and organizational level are belief in an official method, certain leadership styles (Box 7), deadlines, and financial constraints.

Mokyr (2004, pp. 232–237) argues that “legal measures taken through the social control and economic regulation on the part of official and quasi-official institutions” are genuine innovation stoppers. Obstruction, prevention, and restriction of any kind foil the adoption of novelty. Today, organizations need to be open systems that exchange information, materials, and energy in a turbulent and unstable environment, in pursuit of multiple goals (Williams & Yang, 1999, p. 388). Formal organizational theory nonetheless often regards creativity in problem solving as a coincidence, disdainfully circumscribed as the “garbage can” model of solutions (*ibid.*, p. 377).

Notably Amabile and her co-workers (reviewed in Beghetto, 2010, p. 456) found that extrinsic motivation through reward and penalty is less conducive to innovation than intrinsic motivation such as curiosity, joy of discovery, personal growth, togetherness, and belonging (also Nickerson, 1999, p. 416; Williams & Yang, 1999, p. 381, p. 383; Mayer, 1999, p. 455; Zander & Zander, 2000, pp. 21–22; Borst, 2010). Striving for financial remunerations and avoiding punishment install a narrow focus on survival (i.e. risk aversion), which squelches the openness needed to embrace diversity and to look for new opportunities (*cf.* Bassett-Jones, 2005). Rentiers do not innovate (Davids, 2008, p. 515). “Having a lot at stake inhibits creativity. So does searching for the one right solution” (Fisher, Ury, & Patton, 1992, p. 11).

Studies on the social roots of creativity indicate that organizational teams do better than lone individuals (Wuchty, Jones, & Uzzi, 2007). Although individual enthusiasts may not need much financial rewards, the larger group of more “professional volunteers” is motivated by a moderate amount of money (Borst, 2010). Too large an amount of money attracts opportunists, who do not make serious contributions. Also reward by increasing reputation is less effective. (Borst, 2010). Csikszentmihályi (1996, p. 35) refers to the Italian Renaissance, where not only the winners but all finalists to art competitions were paid handsomely for their designs.²

Creativity flourishes under conditions of organizational flexibility and quick action, with integrative structures that embrace diversity, link up with intersecting domains inside and outside its boundaries, that nurture collective pride, faith in talent, collaboration, teamwork (Williams & Yang, 1999, p. 383; Puccio & Cabra, 2010, pp. 165–166), and grant plenty of time to achieve perfection (Csikszentmihályi, 1996, p. 35).

2.5 Social sphere

Broadly speaking, society plays three roles in creativity: benefactor, regulator, and consumer (Moran, 2010, pp. 78–79). In the early stages of creative advance, investors and funders provide the resources for innovation. Next, the regulators come in. They are the judges, critics, connoisseurs, and business advisors – the “gatekeepers,” who control risk and select what is ‘useful’ or ‘appropriate’ to society, weeding out what they assume is chanceless. As consumers, society finally accepts and adopts the creation as part of the “social fabric” (ibid.).

Cohesion within social networks is characterized by dense, reciprocal ties, and a feeling of trust. This aspect is important for the implementation of innovations and will be found in coordinated markets. Brokerage in social networks is about long distance connections extending sectors and communities that hold a diversity of information and novel ideas. This aspect will be most prominent in liberal markets. The best performing creative networks consist of a mix of cohesion and brokerage (Burt, 2005; Uzzi & Spiro, 2005). Fleming and Mingo (2007) indicate that brokerage between dissimilar social circles is important for creativity. Closed networks focus on strong relationships with a few others. Open networks have looser ties but connect more easily to networks that provide fresh information and new perspectives.

2. Compare this to the current practice of rewarding success and excellence only: Architects and scientists send in elaborated models and plans that, when not granted, disappear in file cabinets and paper shredders as wasted investments.

2.5.1 Judges and juries

The “systems theory” of Csíkszentmihályi (1996, pp. 41–45) advances that creativity is not only a matter of individuals producing novelty but also a matter of recognition by the field of experts, connoisseurs, critics, reviewers, or judges. As part of the social environment, Csíkszentmihályi particularly emphasizes the role of ‘the field,’ that is, the group of judges, juries, referees, and critics that evaluate the work conceived. According to him (Csíkszentmihályi, 1996, p. 38), preconditions of creativity not only are to have access to the cutting edge of a discipline, the centrality within a culture (“respect”), or accessibility to a domain, but also (ibid., p. 54) to the referees. He declares that creativity is as dependent on the individual as it is on its recognition by the field (ibid., pp. 27–33). For example, the work of Raphael is creative in one period and not in the next if art history so decides (ibid., p. 30). Csíkszentmihályi proclaims that there is good reason for any culture to be hesitant in accepting creativity: Conservative adoption of novelty prevents from chaos (ibid., p. 41).

Indeed, conservatism preserves known structures and guarantees continuity but that does not say much about something being creative or not. Resistance against novelty runs counter to innovation power (Davids, 2008, p. 376). Expert knowledge of connoisseurs and other specialists breeds tunnel vision (Chapter 3, Section 10). Sternberg and Lubart (1999, p. 10) explain that creative people are inclined to “buy low, sell high” in the realm of ideas, meaning that they are attracted to ideas that are currently not *en vogue* but that do have growth potential. The ‘field’ unwillingly created many examples of prophets unsung in their own time: John Donne, Galileo, Bach, Mozart, Van Gogh, the later Rembrandt. Early Cubist paintings by Picasso were acknowledged much later than when they were created (Pfenniger & Shubik, 2001, p. 219). The work of the mathematician Hausdorff was considered of minor importance at its publishing date. It provided Mandelbrot (2001, p. 195) a generalized definition that opened the way to fractal theory.

What is regarded as creative is subject to the evaluation of history and culture (Kaufman et al., 2010, p. 228). Basalla (1988/1999, p. 139) argues that the selection process is irrational, unsystematic, and not democratic. It is based on trial-and-error while judges are subjected to economic constraints, military demands, ideological pressures, political manipulation, cultural values, fashion, and fads (ibid.; also Kaufman et al., 2010, pp. 217–218). After having made a successful picture of celebrity Lady Gaga, the photographer Pieter Henket confessed (Groenteman, 2013, p. 17): “Actually, it is sad, because suddenly loads of people think you’re great. But I was just as good before. One such picture determines everything. When that photo was exhibited in the Metropolitan, my work became art. I could make free work and good galleries started to sell my work.”

If juries become the judges of creativity, then personal PR, self-aggrandizement, and networking become more important than divergent thinking and cutting across disparate domains. If specialists are to decide on originality, current developments in co-creation and crowd-sourcing would be dismissed (and are indeed rejected by Csíkszentmihályi, 1996, p. 50).

There is no standard to decide what is creative (Kaufman et al., 2010, p. 219) and standards of performance reduce creative exploration. The same holds for preset criteria that are installed by a jury or board of editors. For example, Ward, Smith, and Finke (1999) cite experimental evidence that goal-directed creativity (cf. a contest) evoked less creative inventions according to a group of expert judges (!) than not knowing in advance what the task was about. People created a larger number of inventions if material was randomly selected before they started to design. Interpretation in hindsight of what people actually produced resulted into more original inventions than starting from a given category (e.g., invent a medicine). One of the most striking examples was the idea of “viral cancellation.” From a selection of forms that participants could work with, one participant put a pipe inside a cube and placed a little cross on top of the tube’s entrance (Figure 1). Then participants received a random category word such as tool, furniture, or weapon and interpreted the structure they created. The participant with the structure exhibited in Figure 1 received the category name “medicine” and came up with the concept of “viral cancellation.” Two viruses would try to enter a cell where one cancelled out the other, thus curing the disease (Ward, Smith, & Finke, 1999, p. 207).

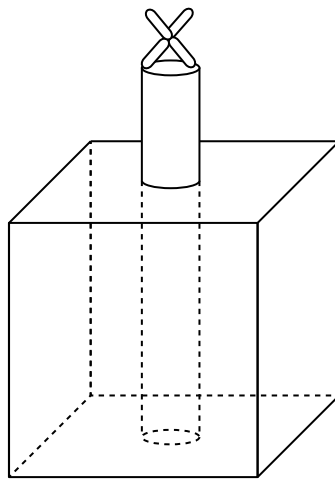


Figure 1. As a concept, “viral cancellation” was invented after interpretation of a “purposeless” structure (Ward, Smith, & Finke, 1999, p. 207)

It seems, then, that disambiguating or priming the meanings of a work *a priori* reduces the number of creative possibilities (Hoorn, 2012, Chapter 2). A creative attempt that has to comply with strict definitions and rules probably will be no more than a tiny incremental step in a well-established tradition (cf. the rule-based poetics of Classicism).

In other words, the field aspect of Csíkszentmihályi's systems theory is a hypothesis of acceptance and recognition, related to the evaluative, organic side of creativity. For physical creativity, the opinions of the field are of no concern. That also throws a different light on the often-heard definition of creativity as something that is novel as well as useful, apt, valuable, significant, appropriate, exemplary, or impactful (e.g., Simonton, 2009, p. 14, p. 23, p. 39; Arthur, 2009, p. 49; Kozbelt, Beghetto, & Runco, 2010, p. 20; Plucker & Makel, 2010, p. 49; also see Mayer, 1999, p. 450 for a listing of novelty qualifications). Such demands would wipe out the complete Japanese Shindogu tradition of doing hilarious nonsense inventions.³ Figure 2 shows a "purposeless" innovation. The extension of a hookah with a gas turbine installation may be regarded a mere filokainoism but its function is to have fun trying to maximize the bottle's under-pressure while inhaling.

Evaluation and selection occur, of course, but are not necessarily helpful in making a creative jump. In that sense, these definitions are additional to technology acceptance theories such as TAM (e.g., Venkatesh & Davis, 2000) and UTAUT (Venkatesh et al., 2003), which have perceived usefulness as their core concern. And



Figure 2. Hookah with Delta pressure gauge and turbine pipeline. Designed and built by Tom Spierieus

3. <http://freshpics.blogspot.com/2006/05/weird-japanese-inventions.html>; <http://www.youtube.com/watch?v=556zotQc-Qo>

although Csíkszentmihályi (1996, p. 108) does not think “present usefulness” should be a prerequisite of creativity, the field aspect of his systems theory comes close to such a definition (i.e. new and valuable, p. 23; new and impactful, pp. 27–28).

For the sake of being acknowledged and legitimized, the role of the field is unquestionable. On the other hand, Csíkszentmihályi (1996, p. 71) also contends that creative people know tradition well so as to be rebellious against it and that creative people should never do something because it is socially expected from them (ibid., p. 145). In addition, judges and referees are known for convergent thinking and relating new work to known practice. They typically are domain experts, who usually suffer from tunnel vision because they are excessively familiar with the subject matter (Williams & Yang, 1999, p. 384). In ill-defined problem spaces, experts make poorer predictors than open-minded non-experts (Tetlock, 2006, p. 67).

Creativity is foremost facilitated by the availability of as many options as possible, in personality, knowledge, cultures, and visions so that chances increase that unrelated entities can be combined. As Runco and Sakamoto (1999, p. 66) put it: no rigidity, no fixity. Strict instructions may impede creativity rather than stimulate it (ibid., p. 70). When focusing on the level of creativity, one could place serious question marks at the effectiveness of design contests, art and literature prizes, talent competitions, patent juries, the legal system, or scientific referees (Box 1).

Judges and juries may severely suffer from Koeslag’s (1990) *koinophilia*, a preferential bias to the known. Probably, judges and juries work best when performance requires the perfection of known skills under highly regulated conditions and with clear targets (cf. sports) instead of the fuzziness needed for novelty and discovery (cf. arts and sciences). Competition works well in deterministic settings and hence is unproductive for creative effort (Box 2). Personal growth (e.g., Lubart, 1999, p. 340) and self-improvement (i.e. competing with yourself) probably have

Box 1. Peer prediction of scientific quality

“Peer Review is one of the sacred pillars of the scientific edifice” (Goodstein, 2000) and is presumed to be a necessary condition in quality assurance for scientific publications. “Peer Review is central to the organization of modern science...” (Horrobin, 2001). However, scientific peer reviews have predictive power for scientific quality only if defined as the number of citations (Bornmann, 2010), which probably indicates convergence rather than divergent thinking (cf. Shashok, 2005). To improve acceptance, it is a well-known practice to cite the editors on the board of the journal that someone submits to (Sternberg & Kaufman, 2010, p. 473). Only 8% members of the Scientific Research Society agreed that ‘peer review works well as it is’ (Chubin & Hackett, 1990, p. 192). High-prestige journals unintentionally tend to preserve mediocrity (Starbuck, 2005). “A recent U.S. Supreme Court decision and an analysis of the peer review system substantiate complaints about this fundamental aspect of scientific research” (Horrobin, 2001). Peer review “is a non-validated charade whose processes generate results little better than does chance” (ibid.).

less of a stifling effect (Nickerson, 1999, p. 415). The occurrence of new ideas flourishes under appreciative generosity. Evaluative selection has the intention to enhance creative quality but is applicable only to easy-to-measure, low complexity problems (cf. deterministic settings). My position is that selection should not be done to filter out or dismiss ideas but to stimulate what is preferred while sustaining what is not favored. In the long run, time may decide differently from what you thought was right.

Box 2. The competition tree and the collaboration web

It is quite logical that competition is detrimental to creativity. In Figure 3, the x-s are competing among each other who will challenge the champion of the y-s. Before starting the fight, all have a chance of 100% of being unbeaten. Given that candidates are equally strong, for each pair of x-s, the chance of winning the first battle is 50%. In the quarter finals, the chance of winning is 25%, in the semifinals 12.5%, and the chance of being the top dog of two packs is 6.25%. Likewise for y-s.

In Figure 4, the same competition tree exemplifies a tennis tournament with two leagues, male and female. In this set up, Art and Bill will meet each other with 100% certainty but whether Art will play Eli is a chance of 1 out of 4 and whether he will meet up with Pat is 1 out of 8 (12.5%). This approach may be fine if you are measuring tennis quality and assume that this quality is unequally distributed over the sample so that the strongest will win above chance level. If the selection is on one quality only and the measurement is clear (e.g., ball in or out), a hierarchy works as a proper approximation of reality. Therefore, rules can be strict: Winners never play against losers.

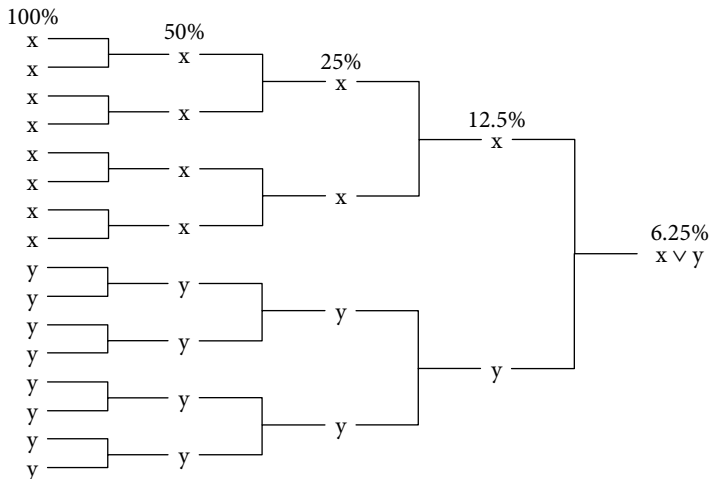


Figure 3. The chance to reach the top halves with every layer inserted

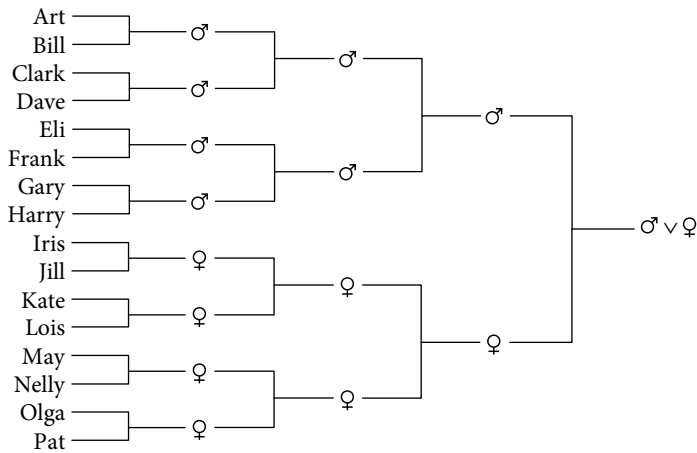


Figure 4. Competition hierarchy only works in a deterministic game setting

However, if Figure 4 was not about tennis but about finding a mating partner ($\text{♂} \wedge \text{♀}$), maintaining the hierarchy is less smart. Fighting for supremacy as a male has a chance of 1 out of 8 to be successful – the same for women. For Art as the alpha male to mate with the best fitting partner also has a probability of 1 out of 8. Pat should beat all the other women first before she can be partners with Art. But in reproduction, there is not just one quality that counts and each fine quality is unequally distributed over the sample in a different way. In other words, you never know whether the one who wins in the other category is the best partner to combine with. In sexual reproduction, measurement becomes blurry, rules crumble, and the hierarchy turns out to be a weak approximation of reality. Art better mates with all women, losers included, to improve overall reproduction quality.

For creativity, the competition tree depicted in Figure 3 represents a collection of missed opportunities. Consider Figure 5, which exhibits a National Idea Challenge, winner takes all, that is, US\$ 100,000 to start up a company. The shortlist counts 16 candidates having ideas about a great variety of topics. Gary found a way to optimize gas combustion; Harry developed a method for mining historic data. A jury decides who is to enter the next round. One candidate of either Lawndale or Fulton River will represent Chicago in the battle of Illinois. In other words, if Art becomes the state representative, Eli's innovation in electro-engineering will never be brought into existence. Yet, the jury of San Diego has an esoteric bias so that Olga and Pat do not stand a chance. The national best idea, then, is the incremental improvement of an echo beam multi-sounder proposed by Art.

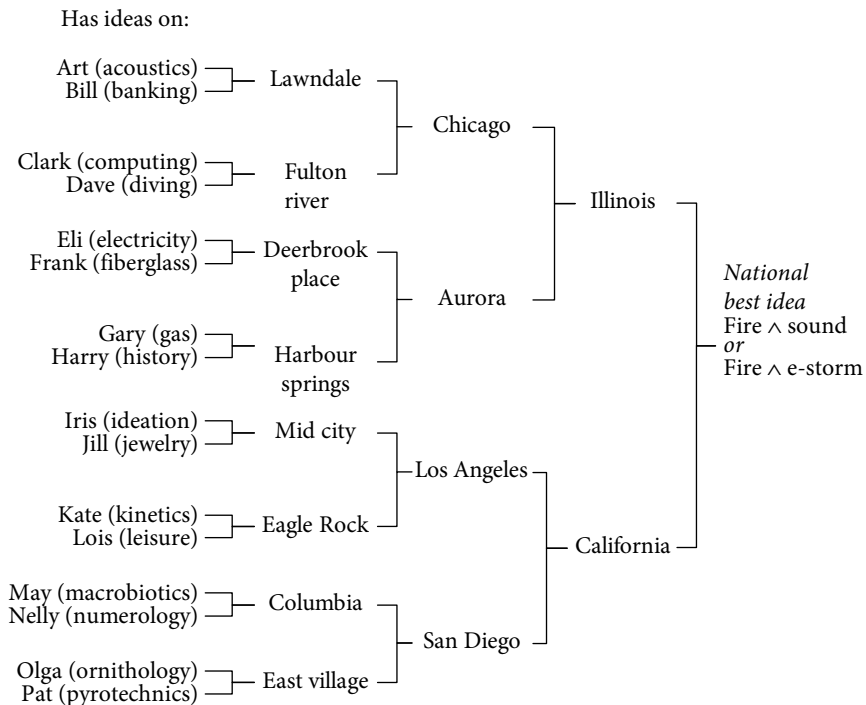


Figure 5. Creative competition: Extinguish fire through sound *or* electrical storms, not both, if at all

What the National Idea Challenge did was imposing a game competition structure onto a creative combination-making effort. What it rendered was the singling out of one incremental improvement within one discipline (acoustics) using biased measurements (i.e. the juries). The hierarchy and strict selection rules (winner stays, losers go home) excluded exposure to all the available information in the structure and reduced the probability that fitting cross-overs occurred. Instead of competing with each other, the true challenge would have been to combine Frank's fiberglass innovation with Clark's new way of computing, to join jewelry with leisure, and even Bill and Nelly may have had something to say to each other about financial forecasting. Art made it to the finals but Eli and Pat were sent home early so that Pat never came to meet Art to make a fire extinguisher using sound blasts. She moreover could never fight fire together with Eli using artificially generated electrical storms.⁴ In creativity, hierarchical competition should be redesigned as web-like collaboration where everyone meets with everybody else and everybody is a winner to begin with. Creativity is not a game, but play.

4. Sound blast and electrical storm inventions were done within DARPA's Instant Fire Suppression (IFS) program (<http://www.darpa.mil/NewsEvents/Releases/2011/01/20.aspx>)

2.6 Families

In an analysis of the family situation of the shapers of the modern world, Gardner (2001, p. 132) comes to the conclusion that people as diverse as Picasso, Einstein, Gandhi, Freud, and Stravinsky had bourgeois backgrounds, living in the periphery of big cities, in families where hard work and high moral standards were prevalent. Love and warmth in moderate quantities were mainly directed toward doing work, taking responsibility as a person for discipline and work ethics (*ibid.*).

According to Csíkszentmihályi (1996, p. 156), the level of curiosity in early childhood seems to predict creativity at later age while curiosity is stimulated by talent for a domain and by the level of positive reinforcement by the parents (*ibid.*, p. 159). Creative people do not always live up to the standards of formal education but genius seldom emerges out of nothing (Simonton, 2009, p. 141). Due to the availability of mentors and role models, density of genius in previous generations predicts density of genius in the next (*ibid.*). Formal and deterministic environments ask for repetitive behavior (i.e. learning through imitation); probabilistic circumstances require creativity (i.e. talent) and taking multiple perspectives (i.e. learning through mentors and role models) (cf. Simonton, 2009, p. 95). With this in mind, the observation by Davids may be worthwhile that innovation is stimulated best by mixing formal education with learning-by-doing and vice versa (Davids, 2008, p. 527).

Csíkszentmihályi (1996, p. 8) states that creative work should be relieved from simple daily tasks that are directed at existential survival such as household jobs, insurance, or keeping a calendar. Not too much attention should be drawn away by everyday mundane tasks. Care, concern, and support of the entire community increases creative quality (Csíkszentmihályi, 1996, p. 36).

2.7 Personality

Davids (2008, p. 8) acknowledges that technology push and thus technological change has a dynamics of its own, which is related to an individual drive for creativity and intrinsic motivations. There is a balance between synthetic, analytic, and persuasive tendencies in creative people (Sternberg & Lubart, 1999, p. 11), drawing on intelligence, knowledge, and environment as well as personality, motivation, and thinking style. Self-confidence, attraction to complexity, aesthetics, and risk taking are mentioned (*ibid.*, p. 8) as typical aspects of a creative personality. By contrast, psychological inertia, aversion of risk and failure, knowledge deficits, bad memory, taboos, and not asking questions feed resistance to change and keep people from creating novelty (Savransky, 2000, p. 6, p. 63).

Box 3. Dionysus and Apollo

In his *Birth of Tragedy*, Nietzsche (1872/1972, p. 21) explains the inner workings of the creative mind. He envisions a role for Dionysus, the Greek god of wine, intoxication, and drunkenness (cf. Romanticism) as well as for Apollo, the god of beauty and harmony, a being of complete reason (cf. Classicism) (Figure 6). Dionysian in Nietzsche's view stands for the spiritual that emerges from lust. This is in contrast to the Apollonian, representing order and structure. In Nietzsche's view, the two passions are completely entwined and explain the decline of high culture as well as its possible rebirth. The Dionysian entails chaos and despair, a world of pain and confusion, but has regenerative power for Apollonian clarity and rationality, the world of appearances and pure aesthetic contemplation.

In much the same way as Nietzsche thought that the Apollonian ('reason') should be revitalized by the Dionysian ('lust'), Freud posits that accepted creative curiosity is a replacement of forbidden sexual curiosity about the parents. Every now and then, the creator needs to subconsciously get into touch with this sexual lust (e.g., through dreams, idle time, association) to refresh the conscious lines of thought (Csíkszentmihályi, 1996, p. 100).

Figure 6. Apollo (left) and Dionysus (far right)

Csíkszentmihályi (1996, p. 52) observes that how creative someone becomes in later life bears little relationship to how talented they were as children (also Howe, 1999, p. 445). Creative personality has some genetic disposition but it has to come to expression through a genuine interest in the domain, curiosity, wonder, openness to experience, involvement, and devotion (Csíkszentmihályi, 1996, pp. 52–53). Creative people have high levels of sensitivity (ibid., p. 73): They suffer extremely and enjoy tremendously.⁵

Csíkszentmihályi (1996, pp. 57–68) posits that creative personalities can play with the extremes of their character if the situation so asks and have no inner conflict with opposite traits in them: aggressive and cooperative, smart and naive, playful and disciplined, extrovert and introvert, humble and proud, they acknowledge the dark side of their character (cf. the Dionysian versus Apollonian, Box 3).

Savransky (2000, pp. 60–61) proposes a dialectic that makes resolving contradictions the core of innovation. Creative people would turn recurring design trade-offs into win-win situations. Creators are capable of changing perspectives, have many ideas and answers, flexible minds, original and unusual associations (Csíkszentmihályi, 1996, pp. 57–68; also Martindale, 1999, pp. 141–142).

Creative people alternate between imagination and reality (Csíkszentmihályi, 1996, p. 63). Convergent and divergent. Without contrasting personality traits,

5. Reminiscent of Goethe's *Egmont*, Act III: "Himmelhoch jauchzend, zum Tode betrübt."



Box 4. Transunfriendly bureaucracy

Coming from Germany, living in America and having studied in the Netherlands, Justus Eisfeld was a woman still when he graduated, and his diploma carried his old name and gender. While living in the United States, he experienced quite some difficulties during job applications. Therefore, he requested a corrected diploma at the University of Amsterdam, which was denied based on a law barring universities from issuing replacement diplomas (*The Washington Post*, Nov. 30, 2010). Justus played this through the Equal Opportunities Commission and even the Education Minister had to step in to announce that the university administrators ‘interpreted the law too strictly.’ Gender change was a reason to replace a certificate. Left without a legal basis, the University of Amsterdam had to yield to the request (*ibid.*). My question would be: If normal legislation is already interpreted too strictly then how can academic freedom ever blossom? Justus: “When you give people the ability to be themselves in more than two defined categories you open up ways for people to live, which sparks diversity. Diversity sparks creativity and I think it is important to look at what we contribute to society in terms of our views and our experiences.” (Retrieved Aug. 29, 2012 from <http://www.wewhofeel differently.info/interview.php?interview=104>)

new ideas are not recognized (*ibid.*, p. 76). It is the ability to be in two states simultaneously, sensitive and rigid, dominant and submissive so that creative people can double their repertoire (*ibid.*, p. 71). Regarding this, psychological androgyny seems to be beneficial to creativity (*ibid.*, p. 70) (Box 4). It also appears that creative girls are more aggressive than other girls and creative boys more sensitive than other boys (*ibid.*).

2.8 Brain

Putting up a fiction is not only inborn to the human brain, the non-human world shows plenty of examples of transmissible fiction-making as well (e.g., plants that imitate insects) for which a brain is not even a prerequisite (Hoorn, 2012, pp. 3–5; pp. 83–85). The same is valid for creativity and novelty-seeking, which also are not exclusive to humans. Kaufman et al. (2011) studied non-primate animals such as birds and dolphins and connected their curiosity and exploratory behavior to neurological processing areas. Kaufman et al. refer, for example, to the work of Finn, Tregenza, and Norman (2009), who report on the Veined octopus (*Amphioctopus marginatus*), moving over the sea floor with coconut-shell halves pulled to their bottoms, then reassembling the halves and slipping inside as an instant hide-out.⁶ Non-human animals have the cognitive ability to recognize novelty, which is a function of the hippocampus (Kaufman et al., 2011). They seek out novelty,

6. Watch them do this at <http://www.youtube.com/watch?v=r9UM65Ha40Q>

sometimes at high risks, which stimulates their dopamine systems. Non-human animals are capable of imitation and can pass on creative behaviors. Such learning by observation relies on the cerebellum and certain cortical regions. Creating a tool and realizing that it is a novelty may pertain to the prefrontal cortex and interactions between the left and right hemisphere (Kaufman et al., 2011).

Where in the (human) brain creativity takes place usually stirs quite some debate. The typical divide is between cerebral locations that regulate more rational skills versus locations where ideation takes place. As we shall see, however, these specialized areas are continuously interacting while the creative process unfolds (cf. convergence vs. divergence).

For instance, Heilman, Nadeau, and Beversdorf (2003) propose an interaction between mid and side locations of the brain, containing specialized knowledge, which is integrated by the frontal cortex. They explain that the frontal cortex is strongly connected with polymodal and supramodal regions of the temporo-parietal cortex where specialized knowledge and concepts are stored. To be creative, extensive specialized knowledge in the temporal and parietal lobes is accessed by the frontal cortex. Through intrinsic neuronal co-activation across modular networks, the frontal lobes increase the availability of distributed concepts so that divergent thinking and developing alternative solutions can take place (Heilman, Nadeau, & Beversdorf, 2003).

According to Kaufman et al. (2010, p. 220), the divide is more classic – between the right (associative) and the left (rational) hemisphere. These authors proclaim that the left hemisphere would be dominant for sequential and analytical thinking (e.g., logic reasoning and task planning) whereas the right hemisphere deals more with holistic, parallel, and global processes. These authors suggest that in creativity, there is a combinatorial interaction between the hemispheres (ibid., p. 221): Novel ideas would be born right-hemispheric but rely on left-hemispheric knowledge, skills, and task execution to become manifest.

Brain plasticity is well equipped for reshaping (cf. recombining) known mental representations (Damasio, 2001, p. 59). The neural circuitry of creative brains shows overall greater interconnectivity between all major associative regions than in less creative brains (Feist, 2010, p. 119). However, brain plasticity and the formation of new connections can be impeded by severe stress.

The frontal brain areas regulate the norepinephrine system in the locus coeruleus of the brain stem (Heilman, Nadeau, & Beversdorf, 2003). When stress activates the frontal cortex, high rates of locus coeruleus firing stimulates the secretion of neurotransmitters such as norepinephrine, exciting the survival response of “fight or flight.” Accordingly, high levels of norepinephrine increase the signal-to-noise ratio, resulting into focused attention and clear detection (cf. Chapter 4,

Section 7.1). At the same time, however, the number of available conceptual representations decreases, which lowers the chances of thinking divergently and hence, inhibits creative invention (Heilman, Nadeau, & Beversdorf, 2003).

Schweizer (2006) and Schweizer et al. (2006) confirm that people with chronic stress become inflexible, do not change positions during an argument, and reject alternative thoughts. They stay with known behavior patterns, even if they know these behaviors are ineffective. The more stress reactions are activated, the harder stereotypical behavior can be stopped because the brain reinforces these pathways at the cost of alternative routes (i.e. reduction of brain plasticity). Trying something new becomes more complicated. Stress also stimulates the growth of the amygdala, a nucleus of neurons or the 'almond of fear' in the old brain, which connects (particularly negative) emotions to events. People become overly irritated and have no room for 'mind wandering,' which is beneficial for creative thought (Schweizer, 2006; Schweizer et al., 2006).

This position is confirmed by Martindale (1999) and reconfirmed by Kaufman et al. (2010, pp. 222–223) and Berns (2010, p. 61). Martindale cites ranges of studies, demonstrating that motivation through external rewards (money, honor), or pressure to achieve goals induce stress and increase arousal, which reduce originality and decrease variability of behavior (Martindale, 1999, p. 140). Arousal and alertness are reality-oriented mind settings and result into stereotypical behaviors. Reverie has low levels of arousal, increasing the likelihood for creative inspiration (ibid.). High arousal reduces creative solutions to problems. Low arousal relates to more creative solutions but only during inspiration, not during insight. Creative association happens with unfocussed attention, not in a control mode (ibid., p. 142). Control processes such as evaluation and focused attention tend to restrain creativity. Founded on Martindale's terminology (p. 143, p. 149), creativity flows from 'defocused disinhibition.' Coming from a completely different angle, Tolle (1997/1999, p. 19) confirms that creativity is derived from oscillations between thinking and a conscious absence of thought, which he calls "stillness."

Insight or creative problems are solved in a better way when people are in a positive mood than under conditions of anxiety (Subramaniam, et al., 2009). In a meta-analysis of 102 effect sizes of the mood-creativity relationship, Baas, De Dreu, and Nijstad (2008) found that positive active moods (e.g., happiness) enhance creativity more than negative active moods (e.g., fear, anxiety). Deactivating and avoiding moods evoke even less to no creativity irrespective of positivity (e.g., feeling relaxed) or negativity (e.g., sadness) of the affect.

3. Negative world view, positive world view

In doubting the Romantic myth of the poor tormented artist, Csíkszentmihályi (1996, p. 19) affirms that creativity basically is positive and optimistic, thriving under prosperous conditions (also Zander & Zander, 2002, p. 4). And although the previous sections indeed indicated that everything positive, stimulating, and coming from intrinsic motivation improves creative productivity, whereas negative, restraining, stressful, external motivations do less so or not at all, the literature also continuously underlines that, on the positive end as well, there may be too much of a good thing (e.g., Kozbelt, Beghetto, & Runco, 2010, p. 20).

3.1 Moderation or balance?

Dauids (2008, p. 479–480) asserts that innovations are stimulated if innovators are rewarded in a moderate way (money, attention) and have moderate protection (e.g., a patent system but lenient). Simonton (2009, p. 92) also emphasizes moderation in money and points out the negative repercussions of fame and glory (*ibid.*, p. 127): The enhancement of self-consciousness decreases creativity. Csíkszentmihályi (1996, p. 65–66) indicates that on the one hand creative people need social interaction and exchanging ideas but on the other they need solitude to muse on all those impressions. The acquisition of domain knowledge and experience is important but creativity is hampered by overspecialization (Martinsen, 1995; Weisberg, 1999, p. 226; Nickerson, 1999, p. 409–410). For creativity to happen there is an optimum level in the amount of challenge and emotion (Heinzen, 1989) and in the number of constraints and rigidity of structure (Runco & Sacamoto, 1999, p. 86). There is but a partial relation between creativity and intelligence. Moderate IQ scores seem to suffice (Sternberg & O'Hara, 1999, p. 262; Nickerson, 1999, p. 396; also Heilman, Nadeau, & Beversdorf, 2003) but some argue that there is no relationship at all (e.g., Park, Lubinski, & Benbow, 2007).

In all, creativity deteriorates when personal characteristics run into the extreme: When self-confidence becomes arrogance, risk-taking becomes irresponsible, non-conformism is merely recalcitrant, inquisitiveness becomes out-of-control impulsiveness, and freedom becomes anarchy (Nickerson, 1999, p. 414, p. 418). Sheer suffering does not help creativity but neither does ultimate bliss. Constraints may be detrimental to exploratory and original endeavors but reckless risk-taking does not lead to innovation either. Generally, an optimum level is assumed in traits and circumstances for creativity to transpire.

The issue is probably this. Going into one extreme downplays the perspective of the contrasting tendency and thus mitigates the likelihood to come up with an atypical response. I guess that going into the extreme of one mode while neglecting

the other shrinks the options to deal with the whole spread of challenges one might come across. For example, Sternberg and O'Hara (1999, p. 266) cite ample evidence that high intelligence performs better on goal directed tasks in well-defined problem spaces whereas high creativity is better at open-ended questions, playful solutions, comprehending humor, or dealing with the unexpected (cf. Chapter 3). Therefore, moderation may not be the issue here but rather tolerating or better inviting the other perspective to simultaneously come into play and exert a *balancing* effect on the other tendency. This balancing act may set the best stage possible for being creative. The balance does not have to be equal, however. It may well be that the positive and involving circumstances should be plentiful while the negative and distancing aspects are not absent (cf. Hoorn & Konijn, 2003). A positive situation that contains a certain level of discomfort provokes a creative tension because without some dissatisfaction or something to wish for, there is no reason to change, solve, or design (Chapter 3, Section 3). Too much discomfort and people become discouraged (i.e. apathy, despair) or fixated on survival (e.g., anger). No discomfort and people become conservative rentiers, exploiting and protecting all that is considered beneficial (cf. the decline of the Dutch Republic, Davids, 2008, p. 515).

3.2 Old brain survival; young brain opportunities

The old brain such as the diencephalon, the brain stem, the amygdala, and the locus coeruleus are responsible for the survival of the organic system. Detection of prey and threat asks for clear signal detection, fight or flight behaviors that can be simply executed based on reflexes and routine solutions exerted from the temporo-parietal cortex where specialized knowledge and concepts are stored, exactly fit for a particular and frequently encountered situation. It is the dinosaur inside (cf. Figure 5). Stress and arousal enhance that state of mind and make it even more prepared to execute the stereotypical behaviors that are apt for the situation at hand. External motivations such as money and punishment impinge upon that survival system in a world that is reduced to simple and clear deterministic rules of eat or be eaten, targets to achieve, deadlines to make, goals to be scored, to publish or perish. The survival system that is biased to detecting danger and, hence, survival thinking is surrounded by fear, monitoring and controlling a negatively-laden environment to which it reacts rather than in which it acts.

Figure 7. Four weeks: human embryo in reptile stage



The creative act, on the other hand, is a shift in emphasis towards the new brain functions while postponing (not banishing) the functionality of the old brain

systems. You could also read this as the functionality the human organism has developed (i.e. creativity) in dealing with highly probabilistic challenges in addition to solving problems of a nearly deterministic nature (i.e. autonomous control).

Dependent on the deterministic or probabilistic nature of the situation, we have the choice between *reacting or creating*, between survival and freedom of choice, between necessity and opportunity, between a quantity of hours and the quality of life. When we assume to be in a world of survival, we put forth solutions of a deterministic nature; when we assume abundance, we breed opportunities (cf. Zander & Zander, 2002, p. 19).

Perhaps we should teach people rules only when survival is at stake and teach them to forget all rules when they should exercise their creative abilities. Rules become less important the more our activities evade the reign of the basic autonomous control system and the more we escape from basic physiology into the sphere of higher brain functions.

4. Openness and universal access

Openness is “the relative degree of freedom given to the dissemination of information and knowledge” (Pamela Long cited in Davids, 2008, p. 388). Zander and Zander (2002, p. 19) point out that a personality of openness and imagination that is looking for possibilities leads to a leadership culture (ibid., p. 31) that welcomes making mistakes and treats them as “fascinating” rather than “faulty.” Tidy managerial approaches force copying behavior (do it my way), which squelches innovation and creativity (ibid., p. 34): “Standards can wreak havoc” (Zander & Zander, 2002, p. 36).

It seems then that the most important moderator of creativity is openness or, put differently, the absence of constraints. Davids (2008, p. 374) shows that during the rise of the Dutch Republic, non-market factors were the most important for innovation, particularly in the absence of institutional limitations or regulations. Davids argues that innovation thrives if there is no resistance against novelty (ibid., p. 376) and no protectionism (ibid., p. 377) (cf. labor unions). Preconditions for creativity are interconnections between disciplines (e.g., science and craftsmanship), free flow of information and goals, and knowledge representation in various media such as text, visuals, and artifacts (e.g., models) (ibid., p. 453).

Davids (2008, p. 4) contends that import and export of ideas (e.g., technology transfer) is a measure of creative leadership: When more ideas go out than in, leadership grows. Protectionism, thresholds, settled concerns, and ideologies disturb the flow of information (ibid., p. 4, p. 7) whereas a creative hub has a high throughput of ideas and serves as a distribution center of novelties (ibid., p. 4). Innovation

leadership flourishes under heavy investment, political diversity, and a context of openness (*ibid.*, p. 7). Csikszentmihályi (1996, pp. 32–33) claims that creativity is sensitive to available information, state-of-the-art technology, and wealth.

Dauids (2008, p. 7, p. 534) states that the preconditions of leadership are to occupy key positions in the most extensive, wide-ranging trade networks, where capital, goods, technology, and energy accumulate, while attracting talented immigrants. Immigration of knowledge workers and skilled artisans boosts innovation (*ibid.*, p. 266) because the newly introduced knowledge and technology undergo homemade improvements and optimizations directed at the local situation (*ibid.*, p. 268).

Dauids (2008, p. 533) also points out that leadership in innovation as measured by the import-export balance of innovations does not predict economic growth as such but does give an indication of the income level, where leading countries have higher incomes than followers.

4.1 Increasing serendipity: Influx of diverse information

Openness facilitates access to the big mediator of creativity, namely to acquire the largest possible perspective on the information universe. The largest possible access to free floating information of the most diverse kind raises the highest chances that serendipity may strike.

Creativity is likely to happen in environments that are in the middle of exchanging a diversity of information, coming from different people, different cultures, and different viewpoints with the least restrictions possible. If creativity is in the combination of seemingly unrelated domains (Chapter 4), bringing as many of those domains together increases the statistical chance that one or more elements will connect and that novelty transpires.

While bringing together a rich diversity of people and information and applying rules as leniently as possible or not at all, the variability of behaviors increases. In utter chaos, combinatorial explosion provides the best chances for serendipity to happen. Average behavior among a group of individuals deteriorates chances for creativity. Serendipity assumes sheer coincidence (*cf.* physical creativity) but human agency that has a hunch for similarities increases its chances: People can make an educated guess of relatedness.

4.2 Determinism and rules, probabilism and creativity

The tenet of determinism is the dominance of fixed rules. However, the previous sections converged to the point that rules and especially strict rules are the main limitation of being creative. The more probabilistic the problem space, the less rule-based approaches are effective. The tenet of probabilism is the absence of

certainty and it is this freedom that allows creativity to mix and synthesize beyond all boundaries and come to genesis.

From assuming a probabilistic universe and in the absence of guidance by a set of rules it follows that whoever wants to be innovative, original, and creative simply *has* to be tolerant, accept diversity, invite multiple views, be non-exclusive, and non-elitist, if only for strategic reasons (cf. Chua, 2007). That brain, that person, that family, that school, that organization, that society, that economy, that culture simply *has* to be inclusive, feed the need for cognition, stir curiosity, welcome diversity, stimulate traveling, be outgoing, and do anything that increases the chances for new combinations to happen.

Inclusive is the socially oriented generalist who lives in a universe of probability and opportunity, is risk-taking, extravert, directed at diversity, is imprecise, has recreational knowledge but is an exciting personality. Exclusive is the elitist specialist in a universe of deterministic rules, regulations, and (natural) laws, who is risk-avoiding and cautious, biased to rejection, introvert, directed at identity and prestige (Box 5), precise, has expert knowledge but is boring.

Box 5. Identity vs. openness: About tunnel vision and the owl's neck

Because little is stable in the world, identity is a feeble concept (Hoorn, 2012, pp. 91–94) but many people are attached to the idea of having one. With globalization, Internet, the urgent call for creativity, and openness as its facilitator, many feel their traditional 'identity' is watered down by outside influences. It is the 'old originality' feeling overrun by new originality. There is a tension between diversity (i.e. individualistic deviance) and a feeling of identity or belonging (i.e. collective conformation). Growing diversity breeds less identity and more detachment while allowing for more disruption and novelty (cf. Romanticism) whereas tradition breeds more identity and more involvement while allowing for continuity and familiarity (cf. Classicism).

Some time ago, we were invited to the birthday party of the daughter of one of our friends. She turned 18 and it was fun watching the kids socialize and interact. In a way, nothing had changed since the days that I as an adolescent visited the birthday parties of my friends. Or did something change? I was already amazed that we were invited by her at all but this could have been the pressure of her parents. Further, we brought our nine-year old twin daughters and they were welcomed and entertained by all the friends with certain eagerness I must say, boys included! Moreover, neither boys nor girls did shy away from the grown-ups. They liked to chat with us; they appreciated our music, mingled, and around 5 AM, started to bake some eggs for us to soak up the alcohol of that night. Were we so cool? I guess not. We were wearing nice suits and evening dresses, talked about our children rather than the latest rock concerts – more bourgeois than we could imagine at their age. Were they so boring? I guess not, because they were dressed according to the latest trends, with jeans hanging below the buttocks, t-shirts with graffiti, iPods, and untidy hair. The only thing I could conclude was that something had changed and that these kids were far more sociable than we allowed ourselves to be at their age.

I also noticed something else and this puzzled me already for a long time, being an inhabitant of always-push-it-to-the-limit Amsterdam. It occurred to me that, in the past ten years, hardly anything new happened in youth culture, not in fashion and not in music. What they did over the last years was mixing the styles of the older generations without much ingenuity or creativity. That's probably why they also appreciated our taste and played music from the 60s, 70s, and 80s on their iPods. When I was young, we were much opposed to the hippy culture of our older brothers and sisters. We were into punk rock and new wave and denounced aficionados of disco music or people with right-wing preferences, sometimes even violently. I cannot imagine me bringing two nine-year old girls to bed while my friends were watching or worse, cracking jokes at their parents! We formed a strong in-group with a strictly defined identity, looking for the greatest possible distinction with other groups: We delighted in our tunnel vision. The youngsters at today's parties were curious about the out-groups, mixing in different cultures with their own and allowing multiple views. They were looking around for all there was to choose from: They explored the world with an owl's neck.

Then I saw the connection with the effects of globalization on local culture. People who are socially or geographically isolated develop their unique ways, their own words and languages, special forms, amazing rites, and specialist skills. Such distinctive and 'pure' cultures may be found in isolated tribes in the Amazon rainforests but also in religious sects, hard-boiled squatters and punk rockers, or monodisciplines in the arts and sciences. Because they are so specialized and convinced of their own beliefs and approaches, they are not equipped to deal with anything different than what they are used to and, therefore, strong in-group cultures are vulnerable to change. Yet, strong in-group cultures also develop unique forms of expression, something which is definitive for creativity. Outside their own conventions, their poetics so to speak, they do not compromise their designs by listening to critique or insights of others. They are idealists who burn for their 'own way of life.' Or they are very afraid.

Generalists, who know a little bit about everything but nothing in particular, easily adopt the insights and views of other cultures. They are open-minded, tolerant, cross the borders of other disciplines unwearyingly, integrate new ideas into their own solutions, have a holistic and pragmatic view on any problematic; they are children of a globalized world, well adapted to absorb change. Their strength is that they have multiple views available and are therefore better problem-solvers. Tolerance also is an aspect of creativity because it enlarges the options and 'materials' from which someone can make and build things. Including more people is including more talent and thus chances increase that something creative comes out of it. Whereas accepting the ways of multiple out-groups may be politically correct these days, it also may have a serious drawback. We are creating an egalitarian world, everything starts to look alike, and we are running out of unique selling-points while suffering from a loss of identity. Whether in Mali or Guatemala, they all wear the same boring jeans, t-shirts with graffiti print, listen to iPods, and drink diet coke from plastic cups at parties.

Both openness and authenticity are conducive to creativity. After all, cultural crossovers unlock options for making novel combinations but, pushed to the limit, they produce homogenization. But crossovers need to be made between disparate entities, so that diversification ("authenticity") of information is important just as well. One can only combine traditions in an unexpected way if those traditions are different ("authentic") in the first place. In other wor(l)ds, we should create and design from an in-group attitude so to accomplish uniqueness, distinctiveness, and identity combined with a position of multiple out-groups (or invite them) to improve our solutions. This leads to optimization or redesign of the creation based on that input under the condition that uniqueness will prevail. In creating and designing, let us first be autistic and then be versatile. At the end of the tunnel, let's put on the owl's neck!

5. I-shaped people, hyphens, and T-shaped people

In trying to overcome survival issues by establishing a well-organized and harmonious, almost self-contained, system, a deterministic-mechanistic outlook on life functions reasonably well. Complex tasks can be decomposed into smaller, less-complex tasks and specialist employees (from machine operators to university professors) provide the best possible means of efficient task execution. Organizations are structured according to strict hierarchies, processes, and procedures while responsibilities are taken away from the work force to be accumulated in higher nodes of the hierarchy, who are “supervisors by profession,” the scientific managers. The mechanistic view creates a world of specialists, concentrating on what they are good at (cf. Csíkszentmihályi, 1996, p. 48).

However, specialization entails repetition and great skills but not necessarily a lot of creativity (Davids, 2008, p. 435). Development will only be incremental. Although specialization leads to diversity (many trades co-exist), specialists usually can adapt badly (Weisberg, 1999, p. 230; also Chapter 3, Section 10.3). They die out in environments that have changed for good. Gell-Mann (1997, p. 20) stated that “it is vitally important that we supplement our specialized studies with serious attempts to take a crude look at the whole.” Today’s open post-industrial information society with its WikiLeaks,⁷ Living Labs (Chesbrough, 2003), The Long Tale (Anderson, 2006), and (almost) free world trade and travel, brings about a general state of human intellectual creativity instead of comfortable material consumption (Masuda, 1983, p. 3). Such a world needs a different type of person and a different kind of leadership.

I-shaped people are the pure specialists who are working in a self-centered, self-possessed way and can hardly adapt to change. They feed on one particular type of grass and if that grass is displaced by another type, they die out. The hyphens are the true generalists: Jack of all trades, master of none. They connect the letters but are not part of the alphabet. They are brokers and matchmakers and important as they are, they are lost without the expertise of others. The most creative ones are the T-shaped people, who have:

... a principal skill that describes the vertical leg of the T – they’re mechanical engineers or industrial designers. But they are so empathetic that they can branch out into other skills, such as anthropology, and do them as well. They are able to explore insights from many different perspectives and recognize patterns of behavior that point to a universal human need. (Brown, 2005)

7. <http://wikileaks.info/>

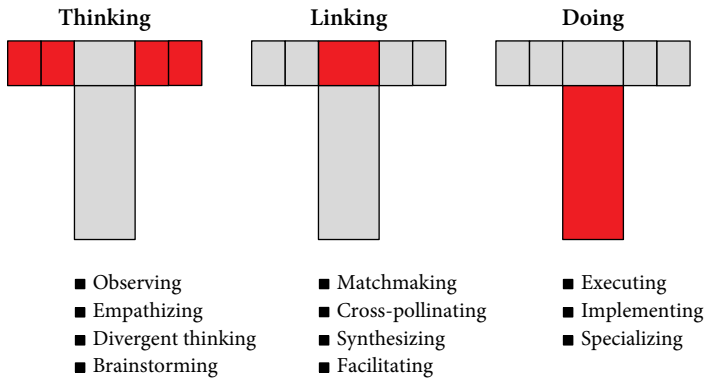


Figure 8. A combination of focused attention with a helicopter view makes one fit to deal with most challenges. Image courtesy Vincent Rump

There is no either-or anymore in being an expert or a novice problem solver (Figure 8). In the ill-defined situations that an open information society flushes forward, we have to stay novices to a certain extent, with some naiveté, open like children if you want but with the expert knowledge of a master. With Savransky (2000, p. 17), we should become a “specialist-universalist centaur.”

When challenges are ill-defined and need vision rather than procedures, the generalist part of the T-shaped person should take the lead. While working, problems become clearer so that the specialist part can take care of implementation of the solution and do the diagnostics, troubleshooting, checks, tests, etc. In other words, creative problem solvers start with plenty appreciative generosity (divergent, empathic) and postpone evaluative selection (convergent, logic) until the effectiveness of a solution is beyond chance level. Rules come far behind and in second place.

6. Leadership styles

The divide between generalist and specialist is visible in leadership styles as well. Managers are foremost specialists, precise on their tasks and targets, whereas leaders usually sketch the broad perspective. *Creative* leaders combine both and play the “specialist-universalist centaur” (Savransky, 2000, p. 17) to generate opportunities for all.

6.1 Management is valuable; leadership priceless

Although management and leadership are both part of the same continuum, they are intrinsically distinct activities. Management is focused on maintaining and

exploiting a *status quo*. It is activated by problems that need to be contained in terms of risk management. Its focus is not generally conducive to generating the type of creative energy that is needed to ultimately design an entirely new product, service, or world. Leadership, on the contrary, is far more exploratory. It prefers to perceive problems as dilemmas for which no perfect solutions exist. It searches out entirely new and unexpected solutions. The creative state of mind, then, turns from exploitation towards exploration. *Homo economicus* becomes *homo ludens*. The messy leaders should come in first, tidy management comes thereafter.

6.2 Tidy management

The striving for clarity and order can be recognized in the design of Western governance, laws, cities, homes, technologies, cultural behaviors, and the assumption that progress is possible, leading to an ideal state of a “reasonable society.” Fed by the notion of improvement (Friedel, 2007), this idea is visible from marketing campaigns to social security programs in which symbols, stories, and environments are created that sell happiness and comfort (Figure 9) and in which growth and wealth are values and even rights of their own.

The way to lead well-organized societies in which well-defined goals are shared by most of its members is managerial, focusing on practical control rather than visionary inspiration. With a society in a state of order, strategy, forecasting, planning, and placing smart bets create the power sources (Horth & Buchner, 2009, p. 3) to fit the future of a business or a career into an established framework or system. “If managed well, success will follow” (ibid.).



Figure 9. Happiness for sale

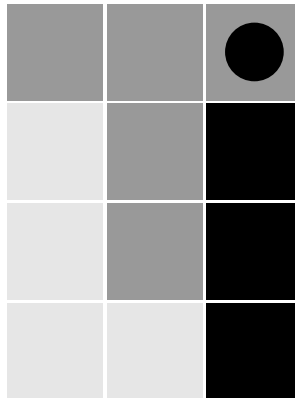
In a managerial approach, creativity and initiative are not a prerequisite. On the contrary, rules and regulations are necessary to limit behaviors such that the expected outputs are delivered. Internal motivations and human agency are surplus to requirements so that motivation has to be stimulated from outside: By rank, reputation, tenure, wages, punishment, social security, insurance, holidays, labor unions, and the Hay Group Guide Chart-Profile Method of Job Evaluation (see Armstrong & Murlis, 2004). Within a closed framework that functions by known rules and procedures, managers are important regulators that have valuable ideas, theories or information, and process-control skills (Horth & Buchner, 2009, p.3) to maintain the *status quo* or to invoke incremental steps in a continuous line of predictable evolution. In an orderly situation, deep research, performance

measurement, formulas, logical facts, deductive and inductive reasoning, proof and precedent successfully inform decision making (Horth & Buchner, 2009, p. 8). Under the assumption that hypotheses and parameters provide the proper descriptors of a situation, decision makers can propose quick and accurate measures, sift right from wrong answers, resolve ambiguity and drive towards results that can be logically expected (ibid.) – in a stable system, that is (Box 6).

In an ever-changing world, past performance does not predict future performance. Repeating earlier successes may negatively impact the functioning of an organization (D. Miller, 1990; Holling & Gunderson, 2002). The common reaction to decline is protectionism instead of innovation (Davids, 2008, p. 201).

Box 6. The mathematical gardener

Creativity is not for everyone. The director of Larx Technology Inc. hired a gardener to redo his backyard – a rectangle. One third he wanted to be a lawn, a quarter should make up a flower bed, and the remainder would become a terrace. The gardener started calculating and divided the area into 12 blocks, 3 of which he filled with flowers, 4 of which he made of grass, and 5 blocks formed the terrace. The result looked like this.



When the director came to look, he said: "I never told you to make such a layout and what is that big flower pot doing up there on my terrace?" The gardener said: "Larx Technology's garden incorporated with the twelve months of the year: LTi flourishes the year around! The big flower pot is the dot over the i." "Rubbish," said the director and the gardener had to put everything back to normal. At his own expense.

As a client, the director did not appreciate transgressive behavior and getting more than was asked for. He felt LTi, and therefore, he was mocked by this playful artisan. Little did he know that the gardener did not abbreviate the name of the company but the name of the Linear Time-invariant system theory to test the response of a linear and time-invariant blockhead to an arbitrary input signal.

6.3 Creative leadership

To break away from crisis, there is an urgent need for creativity. It is the job of a leader to set the conditions right and provide access to that universe of diverse information. However, most leaders in our organizations, institutions, and nations are not leaders at all but rather managers, governors, bureaucratic administrators, let alone that they could be called *creative* leaders (Box 7).

As much as the search for mechanisms and the rationalization of work and society led the West to prosperity and expansion, an opposite tendency was never afar although not much appreciated in official institutions such as the church, the state, corporate business, and universities. In arts, design, and activist sub cultures, living in a more chaotic universe assumes intuition, affect, deviation from the rule, and ensues a taste for the brilliant outlier who tries to escape the stifling effects of each and every system (cf. Nietzsche's critique of Darwinian survival). Many of the original thinkers whose most radical work was hardly appreciated or misunderstood at first broke through the ceiling of familiarity and shaped our present day (e.g., Picasso, Einstein, Stravinsky, Gandhi). These people did not stay with the questions already asked but showed that we could ask different questions, where imagination and opening up new opportunities lead the way to innovation and inspiration rather than profit maximization, tenured positions, and monthly reports.

"Today, uncertainty is palpable" (Horth & Buchner, 2009, p. 3; also Williams & Yang, 1999, p. 373–374). The very concept of capitalism is changing (Hall and Soskice, 2001, pp. 2–4). "Planning for next quarter is a challenge. Even more difficult is to commit to decisions that will play out in one to five years. What is the new process, the innovative product, the game-changing service or the compelling vision?" (Horth & Buchner, 2009, p. 3). Emerging technologies, massive urbanization, cultural diversity, and global ecology have come into play and force societies through multiple transitions that cannot be ignored for the sake of logic,

Box 7. The state of the Western mind

If you want to know the state of mind that definitely destroys creativity, you should read *The Way of the Rat* by management guru Schrijvers (2004, originally 2003). Entirely written from survival thinking, it is a self-help manual for becoming a jerk at work. Leaving motivation and involvement, the way to success is paved by conspiracy, power games, jealousy, and being nasty. This recommendation to selfishness, privateering, being phony, and unbridled greed was an international bestseller, translated into 17 languages, and awarded best management book of the year 2003. That makes one think about the state of mind the Western world is in, given that creativity will be the only way out of Western industrial and cultural crisis. So what is your style of leadership? The way of the rat or *The Art of Possibility* (Zander & Zander, 2000)?

harmony, and order (Horth & Buchner, 2009, p. 6). Even if these systems were near-deterministic when studied in isolation, their interactions are chaotic and unpredictable. As problems and circumstances gain complexity, they lose their fit to accepted patterns.

The usual response to such an analysis is one of cultural pessimism, apathy, or indifference. A creative leader, however, should hold the turmoil for just great! It forces her or him to open up and put all possible information and interpretations on the table. It does not even force them; they happily greet all the collective creativity required to make sense of ambiguity and develop and deploy solutions that do justice to their intentions to create a meaningful and sustainable world (Horth & Buchner, 2009, p. 9; cf. Puccio & Cabra, 2010, p. 164). Ambiguity is not wrong in any sense: *Ambiguity breeds opportunity whereas clarity breeds closure*. A creative leader slows down, reflects, and tries the unconventional (Horth & Buchner, 2009, p. 9).

A creative leader thinks in dilemmas as well as solutions. Creative leadership celebrates imagination and inventiveness, combining the capacity to create on the one hand and making a meaningful difference on the other. While it focuses on completing tasks, it additionally emphasizes enabling others to reach their full potential (cf. Puccio & Cabra, 2010, p. 164). Creative leadership is not 'the management of creative people' but applies creativity to managerial problems (Box 8). Creative leadership is not inventing a creative product and making good money with it (cf. Charles Branson or Steve Jobs). Creative leadership is viral in that it teaches others to be creative leaders of their own lives. This is what makes leadership truly creative, entrepreneurial, and constructive.

Creative leadership explicitly distinguishes itself by a sense of authorship and authenticity. Authorship has been disappearing from management: Everything is linked to anything, resulting in a general lack of vision, which leads to a lack of authenticity in managers. In creativity, however, dispositional personality traits are more crucial than general circumstances whereas the reverse seems to be valid for exceptional leadership (Simonton, 2009, p. 185). Creative leadership is about developing an authentic signature and a vision, guiding and enabling people by sharing this vision. Creative leaders respectfully take a stand and vent an opinion, not shying away for accountability. Rather than a role, leadership is an activity and a pro-active attitude. Creative leaders are not interchangeable.

Creative leaders make a highly self-conscious effort to surpass analysis that is based on past experiences, known facts, and assumptions. Instead, they work backwards in an attempt to be prescriptive by using scenarios – not in the sense of being implied predictions of the future but rather as a way of looking at multiple alternatives for the present state.

Box 8. Cartoon coloring

At 10:45 hours, the comic album should go to the press but one story consisting of 110 drawings is not yet inked. The inker can colorize 22 images per hour but is entitled to 40 minutes morning break. He earns 60 dollars gross per hour, but overtime costs double. Usually, everyone starts at 9:00 AM. What are the additional costs to meet the deadline? How early should the inker be at work? Can he still take a break? The manager starts calculating:

$$10:45 - 9:00 = 1:45$$

$$1:45 - 0:40 = 1:05$$

$$1 \text{ hour} = 22 \text{ images}$$

$$110 - 22 = 88$$

$$88 / 22 = 4 \text{ hours}$$

$$110 \text{ images} = 1:00 + 4:00 = 5:00 \text{ hours}$$

$$5:00 - 1:05 = 3:55 \text{ hours overtime}$$

$$1 \text{ hour overtime} = 2 * 60 = \$120$$

$$3:55 * 120 = \$470 \text{ extra costs}$$

Without a morning break, the inker starts at $10:45 - 5:00 = 5:45$ o'clock in the morning, else at 5:05

The creative director looks at the cartoon and sees that the story is about a racial conflict between two boys. The only thing he does is put a title to the cartoon: "A black-and-white history of today."

Duration of the implementation of the solution: 5 minutes

Additional costs: 0

Bad tempered worker: no

Deadline: made

Saved time: 1 hour

What was the creative director doing differently from the manager with the black and white problem? The manager looked at the correct execution of the process regardless of the content. The creative director saw similarity between cartoon content and the apparent process error of uncolored images and made it meaningful.

Creative leadership knows that nobody knows as much as everybody. They foster togetherness through collective intelligence. Creative leaders favor joint and trans-disciplinary approaches in which co-creative networks are mobilized to optimally generate collective intelligence (e.g., Surowiecki, 2004/2005). Understanding the problem and formulating a solution are not distinct phases but are interwoven. Instead of looking for the "right answer," creative leaders design both the problem as well its solutions. Shared understanding requires a continuous dialogue with all possible stakeholders of the relevant communities.

Creative leaders acknowledge they are certain of being uncertain. They subscribe the idea that uncertainty leads to opportunities (Palmer, 2005). They playfully embrace uncertainty by engaging complexity with a divergent mind, openly

Box 9. Where to draw the line?

Certain views advocate the position that “creativity flourishes when our minds are allowed to work without artificial restraints” (Half, 1994). Others, however, point at the strict work procedures that certain artists follow to arrive at the desired level of artistic production (e.g., Sullivan, & Harper, 2009). Both visions are correct but depend on the stage the creative development is in (Chapter 5). In its infancy, the creative process should proceed without constraints; during acceleration and beyond, strict procedures guarantee continuous output. It is originality versus production and the question is where management should take over from leadership. In my own experience of working with academia and industry and in doing artistic productions, the turning point is when the first working prototype is ready. By that time, proof of concept is delivered and industrial production should take the experimental set-up to a more sophisticated level. Until that time, managers, business people, politicians, and administrators should stay away as far as possible because they will prematurely kill ideas with demands of ‘feasibility’ (read: they cannot imagine things being different). This does not count for technological development alone: A theater piece or music production can be approached in quite the same way where the creators should be given the time to make a working prototype before professional production takes place.

dealing with living systems that are extremely dynamic. The goal is not to make them static, but rather to take optimal advantage of their dynamics to facilitate multi-faceted solutions. And once a new principle does catch on the contours of an orderly state, creative leaders call for tidy management to co-create the logics, rules, and regulations that guarantee the continuity of the new principle (Box 9). For the time being. And for as long as it lasts...

6.4 Creative leadership at the sigmoid

At each stage of creative development, leadership gradually changes. In Chapter 5, the Creative Sigmoid of cumulative growth of creative combinations was introduced. It was discussed how right before stagnation, at the shoulder of the sigmoid, people should crossover to a new domain. That picture is reiterated in Figure 10. Moreover, the organizational pyramid explained in that same chapter is placed over the sigmoid to see which layer is in the lead at what stage of creative development.

At the early stages of the Creative Sigmoid, you can see leadership penetrating chaos through creativity (Figure 10). This stage takes an almost Buddhist mindset, with a calm awareness, living in the here and now, mindful, not being judgmental. Highly vigilant, the creative leader in this stage jumps to the occasion whenever serendipity strikes and takes authorship for *what* is to be done. This is her ‘strategy.’ S/he can improvise with ease and create novelty from what went wrong.

Once creativity has brought some unexpected order into chaos, acceleration commences, which requires a more tactical approach. Although there is some system, blind variation occurs plentiful so that it is really important *how* things are achieved. Standard procedures do not apply yet; the manager is 'Darwinian' in the sense that s/he thinks of new ways to keep mutations and chaos effects (e.g., fluctuation of stock potential) in check and establish some form of continuous evolution.

Close to the shoulder of the sigmoid, just before Cardwell's law of stagnation sets in, operations management designs the way productions should be executed and standardized, fine-tuned to diverse markets. These managers are Darwinian in that they continuously apply selective retention, concerning evaluation and selection of employees, processes, goods, services, and the resources needed. Critical factors of success and failure are defined for the niche of choice. This way, incremental improvements guarantee the best possible quality of a product or in commercial settings, the highest return on investment.

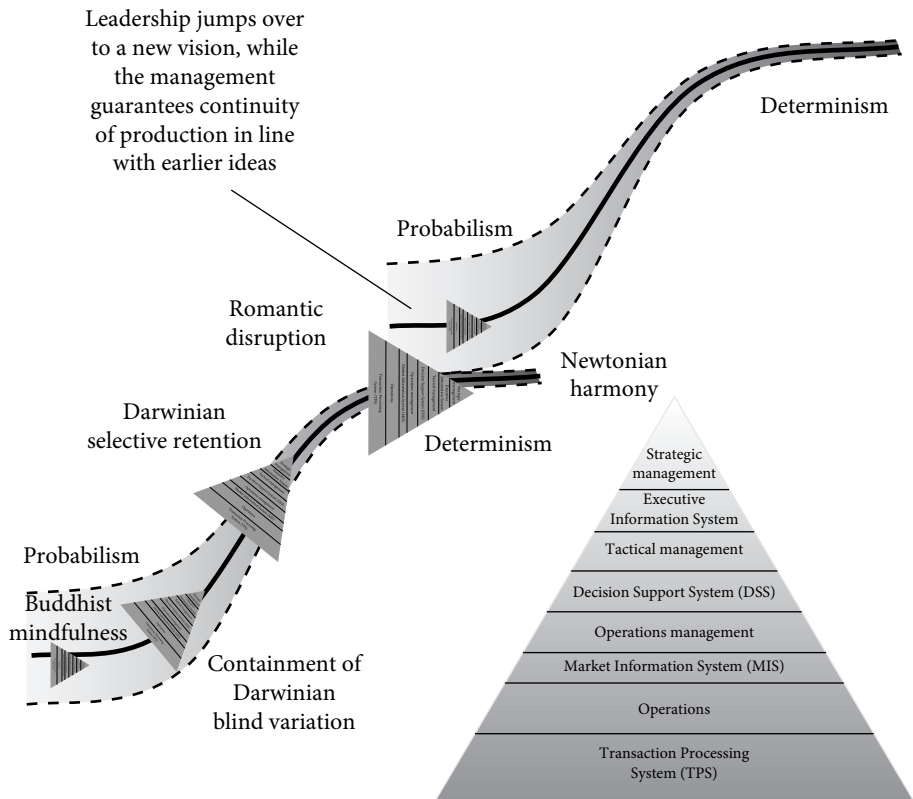


Figure 10. Creative leadership and organizational growth at different stages

Operational employees work in a fully regulated environment so that development of the Creative Sigmoid stays on plateau. Operations are ‘Newtonian’ in that they can be mechanically evaluated on measurable variables such as effectiveness, efficiency, and effort (Hoorn, 2013). The work force strives for harmonization of work procedures, wages, and work ethics. The masses of professionals and artisans are rather Classical in their orientation. They are optimizers at best. If they want to break away from standardization, they have to step out of the “world of measurement” (Zander & Zander, 2002, p. 17) for a while. They should not care too much about the “assessments, scales, standards, grades, and comparisons” (ibid.) that middle management created for them to regulate their behaviors. By alleviating or sidestepping the rules a little, they find the freedom to do micro-inventions and incremental improvements to known techniques, artifacts, and methods (cf. Homans, 1974). If they are successful at allowing more probability to their near-deterministic world, their innovation can “surf up the sigmoids” (Chapter 5, Figure 6). This means that their innovation diffuses up the rankings, being interpreted more freely while progressing, for the leadership to change the vision.

In Figure 10, you can see why organizational growth occurs while the sigmoid develops. You can only handle more people if the environment becomes more regulated. That is why start-ups need to be small – that keeps them flexible – and why corporate organizations are large and inert. Adding more people increases rule pressure (cf. Chapter 5, Section 5.3). If we are a few, freedom will be plenty. If we are many, there’s little room for each of us.

For the visionary, the stifling effect of the masses has already begun at the rising flank of the Creative Sigmoid. Too crowded on plateau, s/he deliberately seeks a Romantic disruption of the system s/he first initiated. Then she becomes the mindful Buddhist again to enjoy the chaos s/he just created.

During epochs of maturity or high culture, the vision behind the execution of operations is lost. People habitually perform behaviors because tradition so demands. If the top of the pyramid is occupied by a manager rather than a leader (cf. Nietzsche, 1989/2008, p. 242) the asymptote of the big growth curve remains at plateau for a long time due to maintenance rehearsal, perhaps even declining after some time. A visionary at the top is most likely to liberate the problem space from rationalization and conservation to dive into that “universe of possibility” again (Zander & Zander, 2002, p. 19). From there, the creative leader has to persuade others into accepting change (Csíkszentmihályi, 1996, pp. 27–28).

7. Changing conditions of creativity

Owing to its increased determinism, the Creative Sigmoid asks for leadership adapted to changing conditions. How conditions change at each phase of the sigmoid

and what it does to leadership is discussed next, while digesting almost every aspect of the literature that was reviewed in this chapter, from infancy to decay.

7.1 At infancy

If something completely new should be created and there is no plan or not even an understanding of the situation, it is important to create the conditions to which ideas can emerge. Requirement number one is to have freedom. To be amidst a free flow of information, be that of goals, interests, ideas, materials. This freedom allows for diversification as authenticity is not limited by any constraint. Shaken and stirred in a dynamic, turbulent, unstable, random, and probabilistic environment, heterogeneity, diversity, and pluralism increase the chances that disparate entities collide or become available simultaneously. To the observer, dilemmas, paradoxes, and challenges surface that seem insoluble at face value.

Certain personalities are attracted to such enigmas. They are attracted to the complexity of the question, to things that are awkward, unfashionable even, attracted to its incomprehensible aesthetics. Their maxim of life is that ambiguity is opportunity and that clarity breeds closure. It is their mission to seek out those opportunities, provoke novel ideas, to resolve those contradictions, and create win-win solutions.

It is a necessity to have free and open access to information diversity, which should be available in various forms (e.g., text, image, sound, models, maps). After all, representation of the problem primes its solution and as many angles as possible should be tried. To become acquainted with that universe of diverse information, creative pioneers simply have to be intrinsically motivated and fire up that individual drive to venture into the unknown. That is why they cannot be anything else than curious people, inquisitive, wondering, exploratory, experimenters, entrepreneurial, experience seekers, intelligent. To acquire as much diverse information as possible, they should have an insatiable need for cognition and genuine interest in numerous domains because in this phase, there is no way telling what the right direction is or what should be achieved.

Ways to acquire information diversity is to be extravert, outgoing. Traveling, living in multicultural settings, knowledge transfer, learning through mentors and role models, cutting across disparate domains, encountering the state-of-the-art, trying the cutting edge, mixing formal education with learning-by-doing are all ways to obtain a rich palette of options to draw from. Impulsiveness is not necessarily conducive to creativity because there is not enough patience to become acquainted with an area and it might give rise to recklessness. Living in the periphery of a distribution center of novelty is quite optimal. The source of information diversity is near but at the same time there is a quiet place to mull over all impressions (see below).

To gain as much impressions as possible, creators should be highly sensitive. This should not lead to sheer suffering (cf. “Weltschmerz”), because that takes away energy from creating to use it for survival purposes. Yet, due to high sensitivity, creators are affective people and play with the whole range of their emotions.

On the one hand it is very important to find many materials to work with and be accustomed to many domains. A wide vista on this landscape should be maintained so that the knowledge of the creator has to be recreational. On the other hand, creators should not become Jacks of all trades and master of none. They should be experts in one domain but to avoid tunnel vision, they should maintain general skills as well. To keep asking questions and stay ‘fresh,’ creators should keep some naiveté, stay a novice to a certain extent. Being a specialist *and* a universalist is the optimal balance a creator can establish.

From this need for information diversity so to have as many options as possible to solve an issue, creators will attempt to take away barriers to that information. Thus, non-conformism, tolerance, accepting differences, being non-elitist, being non-exclusive, no resistance against novelty, no protectionism, and being empathic guarantee the openness that is needed for continuous input of information diversity. Therefore, creators are necessarily unruly. They have to escape social pressures and oppose tradition. To them, rules come far behind and in second place. Deviation from the rule, escaping the system, reduction of rules, changing the rules are necessary to open up new options. Therefore, no rigidity, no fixity, no standards, no limitations, restrictions, or regulations. Creators acknowledge their dark side so to double their repertoire of behaviors. This may even go so far that aggressive violation of rules, revolt, rebellion, recalcitrance, and anarchy open up the way to previously inaccessible areas of information and behavior. This tendency may only be kept in check by ethical boundaries but in itself creativity is independent of moral judgment.

With creativity in its infancy, still wondering through the diversity of the information universe, evaluation and selection are premature limitations on open access to all possible options. Judgment has to be postponed. One should be generous, welcome mistakes because they show new ways of conduct. Creators should grant themselves and others plenty of second chances, welcoming uncertainty. One cannot ask to be precise because nothing is decided yet in a world of probabilities.

The only thing they do in this stage is to contemplate multiple views and alternatives, ask different questions, change perspectives, engage into divergent thinking and increase the chances that a lucky finding will strike. To see chances and not merely chaos, to believe that opportunities can be really materialized, someone has to be optimistic, be in a positive mood, feel happy, self-confident, and have faith in talent of self and others. This is not ultimate bliss or the absence

of discomfort. There should be something that needs to be changed. Self-confidence is not being arrogant. When everything is uncertain, one should be able to rely on oneself. Arrogance, however, is non-inclusive. You resist the view of others in favor of your own. Faith in talent is not talent competition. Competition means that certain talents are more important, downplaying the views of others.

To digest all impressions and come to a synthesis, the creator then seeks solitude. This is not the lone individual who leaves the world in renunciation – care, concern, and support by the entire community helps not to be distracted by mundane tasks. The atmosphere should be peaceful; the surroundings should show their goodwill.

To process and link together the disparities in the enormous bulk of information that has been sampled, creative people have greater interconnectivity of brain regions, which help them make novel crossovers. To make the new connections, the brain needs stillness, no distractions, mindful unfocused attention, or defocused disinhibition. This is not holiday relaxation but conscious absence of thought that allows associations to pop up spontaneously and float away again, not holding on to anything in particular.

At this stage, one can be in two states simultaneously (e.g., sensitive and rigid), allowing disruptions in style, balancing opposite traits and states (e.g., imagination and reality, convergent and divergent thinking). Perhaps we could call this the superposition of mental states? It is the holistic, parallel, and global processing of information diversity, which requires an extreme flexibility of mind to let imagination and reverie play scenarios of possible pathways to take. A playful state that has no task direction, doing anything for new combinations to arrive. Allowing all perspectives and finding balance in all contrasts and oppositions, personal growth and self-improvement are likely to occur.

Then the breakthrough ideas happen. The brain actually grows neurons into areas previously unconnected. One could call this inspiration. Associatively, this leads to novel combinations of apparently disparate entities, evolving into the design of the problem as well as its solution. Because such solutions are not the result of reasoning from the givens, they are ‘intuitive.’ The interpretation of insight may come in hindsight. The occurrence of insight is accompanied by the joy of discovery, its internal reward, the delight of the new perspective, different, original, signified by personal authorship and authenticity. These are the conditions that lead to visionary solutions.

To make the new idea concrete, the creator must use the energy that was freed during insight to undertake action, develop a pro-active attitude. Conceptual innovators also plan for action, take responsibility for their idea and are accountable for its outcomes. To endure the resistance against the novelty, they should bring plenty of involvement and devotion, not being scared of taking risks without

becoming reckless or irresponsible. It is the moment where people are not only creators but become leaders as well.

If you want to frame the creative personality in Lifo terms (Atkins, Katcher, & Porter, 1967), then during the infancy of creation the creator has an adapting, dealing-away orientation: Open to new experiences, enthusiastic, inclined to experiment, and flexible.⁸ During early acceleration (next section), people need to be gathered around the new idea. Here, leadership becomes more pronounced and in Lifo terms, the supporting, giving-in orientation will be prominent. The creative leader turns into a helper, a social leader with values to prove worthy, be modest, principled, cooperative, dedicated, and in pursuit of excellence.⁹

7.2 Early acceleration

After the birth of an idea, it is important to bring together other people who will help realizing the concept, invest in it, or who will be your audience. This may be mechanics or musicians, construction workers or spectators, readers or followers. Moreover, with the knowledge and skills these early adopters bring to bear, the rough idea is optimized, redesigned, and gradually improved.

In this stage, creative leadership is social and directed at mutual exchange. Therefore, social interactions and interactive communities are set up around the idea; networks that provide fresh information are used for optimization. To provide an open invitation and to welcome all, the creative leader maintains multiple goals, takes care of organizational flexibility, of open networks with loose ties and integrative structures that extend sectors and communities with long distance connections, making available widely distributed concepts. Linking up with intersecting domains inside and outside disciplinary boundaries, looking for joint and transdisciplinary approaches, the aim is to aggregate collective intelligence, stimulate co-creation, collective invention, and attracting talent (immigrants included) to improve and materialize the central idea.

To establish trust in the leadership and in the group members, high moral standards are to be maintained. Not in a rigid way because rigidity is stifling. As said, there is a delicate balance between ethics and creativity as the first limits the latter. The (moral) values that need to be celebrated are togetherness, belonging, trust, collective pride, and respect. Positive reinforcement comes in the form of love and warmth in moderate quantities. Financial rewards or status are subordinate at this stage. Creative leaders enable others to reach their full potential and help others to be creative in leading their lives. With appreciative generosity, they

8. <http://www.lifo.com.au/index.php?module=pagesetter&func=viewpub&tid=2&pid=24>

9. <http://www.lifo.com.au/index.php?module=pagesetter&func=viewpub&tid=2&pid=22>

make the collective more creative. At this point, more ideas and innovations are exported than imported.

Certain people who are more creators than leaders will stop at this point, looking for the next challenge. They 'bought low and sold high' (Sternberg & Lubart, 1999, p. 10) in the realm of ideas. They lose interest and want to jump to another domain. Others, however, who are leaders rather than creative, want to upscale the work, improve the quality, attracting more customers, admirers, gather more disciples.

They start a continuous dialogue in a networked society, sharing reliable information throughout the collective. They focus on (mass) collaboration, cooperation, teamwork, user-generated content, and on the communication of diverse ideas. Together with their core group, they settle in extensive wide-ranging trade networks where capital, goods, technology, and energy accumulate, and where there is a high throughput of ideas. Oriented at the outside world, exchanging ideas, information, materials, and passing on designs across various domains, disclosing inventions to competitors (not patenting), and making technologies open-source help the adoption of novelty. Copying is free and reciprocal.

7.3 Halfway acceleration

Somewhere halfway the acceleration phase of the Creative Sigmoid, a focus switch takes place. Here is where leadership becomes less important and management takes over. Innovation management looks for implementation of innovations and growth potential. If they want incremental innovation to continue with a chance that sometimes new in-category crossovers happen, they should take measures to share risks collectively, boost the investment rate, and reward initiative. Licensing should be compulsory and potential free-riders should pay for use.

Although creativity thrives in wealth and under prosperous conditions, the management should assure fixed wages at a moderate level, collectively negotiated, about equally distributed, and guaranteed. Wages should be fixed to provide a basis; they should be moderate to avoid indolence.

If innovation is to continue, work is neither about personal gain nor competition. The focus of development should still lie on non-market factors, servicing many niches, not competing on price but quality. Management should be concerned with brokerage in social networks and stimulate job mobility, rewarding employees with moderate attention (not: fame and glory, not: prizes and awards). In Lifo terms, the type of management in this stage has a controlling, taking-over orientation: entrepreneurial, competent, result-oriented, persistent, initiating, urgent, and directing.¹⁰

10. <http://www.lifo.com.au/index.php?module=pagesetter&func=viewpub&tid=2&pid=4>

7.4 Just before stagnation

Just before the Creative Sigmoid curves into asymptote, certain measures can be taken to create a cash cow – a product, work, service, performance, work of art that yields money, merchandize, attention, and glory of its own (cf. Van Gogh's *Sunflowers*). This is the moment where what was once creativity definitely has become industry.

Management should gain control over resources, information, social networks, and funding, forming official consortia with universities, high-tech companies, and publishing houses. They should gain access to gatekeepers and referees. Collaboration is done within companies or within the sector to dispense knowledge through the organization while coordination with non-market stakeholders takes place. Networks are a mix of cohesion and brokerage; occasionally, outside influences are absorbed. For the sake of continuity, an average high income level is more important than (exponential) economic growth. With hard work and plenty of time, perfection can be achieved.

7.5 At maturity

Maturity is the realm of the bureaucrat and governance resembles bookkeeping. The focus is on maintaining the *status quo* of settled concerns. It expresses itself in a hierarchy of offices with responsibilities residing in the higher nodes, a caste of supervisors by profession, taking impersonal decisions based on formalities, monthly reports, belief in official methods and sacred approaches. At maturity, management is nearly effortless because rules and regulations have been installed that make the organization or the nation run almost automatically. Managerial control concerns every aspect of work processes, behaviors, and practicalities and is not interested in contents. Leadership is a role and one qualifies only with official certificates. There is a fixed division of labor between specialists, with specific domain knowledge, trained in trade-specific skills. Selection at the gate and continuous evaluation are preeminent and concern value, use, significance, appropriateness, impact, aptness, and the like. Improvement only comes with age following a path-dependent career. Tenured positions bring status and reputation.

To consolidate this system, conditions should be as stable and deterministic as possible. What at infancy was one big dilemma is now reduced to a set of low-complexity problems, which can be solved through convergent, logic, sequential, and analytic thinking. Starting from a given category and through deductive reasoning, formulas, deep research, and jurisdiction disambiguate meaning, resulting into strict definitions, proof and precedent, precision, and exemplary results. Official and quasi-official institutions are established to formulate standards of

performance, define pre-set criteria and thresholds, issue strict instructions, and do performance measurement. There is a high pressure to achieve goals, deadlines to be made, tasks to complete, and producing the expected outputs.

The bureaucrat is cautious, risk-averse, and manages risk by installing formal rules and regulations, routine processes, legal measures, and demanding compliance. Central values are quality and safety. One needs the conserving, holding-on orientation (cf. Lifo), being careful not to lose what was gained, to get things right, to be systematic, analytical, maintaining, and tenacious.¹¹

At this point, creativity is superfluous and must be managed. Mass production of mainstream products ensures profit maximization for the *homo economicus*. Cash cow consolidation without innovation. This strategy allows for short term planning and precise target setting to exploit resources most efficiently. Immediate need-satisfaction is the driving force and motivation to undertake action is mainly extrinsic, through external rewards, financial remuneration, market shares, or external demands (e.g., politics, military, social) or financial/economic constraints. The organization learns through imitation, copying known behavior, following stereotypes. It lives on fashions and fads; repeating earlier successes is highly appreciated (e.g., iPhone 5). Main effort goes into marketing, personal PR, and persuasion.

The organization is large and directed at identity. It shows a strong cohesion within tight social networks. It has a lot of followers. Dense reciprocal ties lead to consensus seeking, groupthink, and negotiating collectivistic agreements. Bourgeois backgrounds are preferred. Work ethics, discipline, and social control assure continuity.

7.6 Decline

Fresh insights are not stimulated at maturity but accidental if they happen. And it might be argued that maintaining the cash cows has a function to heavily invest the returns into creative novelties that are still in their infancy. However, there also is a range of attitudes and behaviors that is deliberately countering creativity, which eventually bends asymptotic growth into decline.

Decline sets in where alternative thoughts are rejected upfront, where there is explicit resistance against novelty, and where change is suspect; where bad adaptation, tunnel vision, and not changing positions restrict possibilities, and limitations and constraints rule supreme (prevention over pro-action). A society of social exclusion, exclusiveness, of closed networks, with people biased to rejection weakens itself. The overspecialization of experts, of formal education, of

11. <http://www.lifo.com.au/index.php?module=pagesetter&func=viewpub&tid=2&pid=23>

elitist connoisseurs causes knowledge deficits in foreign domains, which makes community members unprepared once resources are depleted and are to be found elsewhere.

A culture decays once it is driven by privileges and duties, when labor unions and social security replace personal responsibility, when greed is the main motivation for action, when civic duty dictates moral, and obedience to authority is unquestionable. The power issue is germane in this respect. Power sets free an addictive mix of testosterone and dopamine – and someone who is in power needs plenty of higher cognitive regulations to keep an open mind to dissident opinions. The seat of power is the lion's den for creativity. Power hides itself in secrecy, exerts ideological pressures, defines taboos, and is exercised through punishment and penalty. Opposition to policies inevitably leads to being locked out. Resistance needs to be broken. The main motivator is the fear of force, threat, and avoiding punishment (cf. *argumentum ad baculum*).¹² Prestige and rank are the main grounds for accepting conclusions. Therefore, apportioning blame and pointing out failure are acknowledged instruments to weaken the position of others whereas self-occupied and self-centered aggrandizement reinforces one's own. In such a culture, growth and wealth are inalienable rights of the self-possessed, permitting the defense of individual property, of maintaining monopolies, and effecting mercantilism and protectionism. Of being rentiers.

Those who live under such reign will start to think of themselves as 'uncreative,' mainly because they are not allowed to, and develop a sense of cultural pessimism, sadness, apathy, psychological inertia, and a negative public mood. This situation can go two ways, both of which kill creativity. One is the path of decadence, bowing one's head to the powers that be and indulging in comfortable material consumption that comes in reward (*panem et circenses*). Instant happiness and indifference to anything else produce homogenization and conservatism. The other is the path of orthodoxy, of moral supremacy, a flight into social isolation as a kind of introvert resistance. It may come about as political manipulation and obstruction, and then soon develops into rigid radicalism, aggression, and a feeling of existential survival. Arousal and alertness, to fight or flight, stress, fear, and anxiety install the urge to destroy, while forgetting how to create.

8. A hard reset

What should leaders do to invite the world to creativity? It is the job of a leader to set the conditions right and provide access to that universe of diverse information

12. For example: "If you think we are going the wrong way, find yourself another job."

with the best possible opportunities for serendipity to happen. The research literature on creativity provides overwhelming evidence that creativity happens when formats are as open as possible, mixing a large diversity of people and types of information, which should be freely accessible. Therefore, a creative society should deliberately abandon the traditional formats and formalities. They should not want to give specific assignments to creators. What such a society does want is a free exchange of information, leniently guided by a number of topics they want to touch upon. That may not be governmental tradition but it certainly will lead to creative innovation.

Create a culture with a shared understanding of the knowledge, customs, values, rules, symbols, and ways of interaction with the social and natural environment. Maintain the rules that support creativity. Abandon rules that stifle it even if they are brought under the heading of 'but you said anything goes, so my proposal of exclusion should be included.' There is no straightforward answer to how inclusive creativity should be. Are criminals welcome to join in? What if someone is merely interested in brain picking? What if he or she continuously dominates the discussion, has an overblown ego, shows a negative attitude, engages in power play, or is blatantly commercial? My personal approach is to exclude those who are driven by survival issues from the initial stages of creation and to exclude those who are scatterbrained from the implementation phase (as well as from tackling existential problems). There should be some regulation but as little as possible and only to rule out dishonest behavior or to contain health risks.

We should stimulate individual breakthrough thinking that has a societal follow-up in optimization of ideas. Therefore, education of general skills should be a collective responsibility, whereas teaching trade-specific skills should be an obligation of companies and organizations. We should have tight (Internet) networks in accordance with job fluidity and collectively negotiated wages of a moderate height. Collaboration should take place within and between companies, within and between sectors, while involving non-market stakeholders such as governments and end-users. Reliable information should be shared collectively, while individual freedom is guaranteed, organization is flat, and competition is absent or merely of a friendly kind.

Then look for the person who is most segregated from the mean (group) development but has the largest access to the most differentiated information (which may be provided by others). That is the one to come up with the next breakthrough idea. This radius of action may be widened when people most separated from the current developments do this in co-creation.

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Creation

The virtuality of epistemics

“No single man can make a distinction between the realm
of his perceptions and the realm of things that cause it ...”

(Schrödinger, 1944/2010, p. 145)

The ACASIA process accounted for the way combinatory creativity unfolds and the ensuing Creative Sigmoid explained the accumulation of creations, both being nourished or impeded by a host of factors, most importantly, having access to the largest possible diversity in the information universe. How much of that information universe is available to the creator or audience is a matter of openness of perception and the level of tolerance to deviation. The current chapter discusses the relation between perception and creation: After all, all creators start out as creators of fiction because, previous to execution, their vision lingers in imagination. Creators deliberately seek to make fiction to expand the problem space and increase the opportunities for finding alternative solutions at the cost of ‘truth telling.’ Additionally, the creator is the first perceiver of his or her work while the audience serves as co-creator in delivering their interpretations. Epistemics of the Virtual is a theory explaining how a perceiver deals with fiction and the attribution of truth. It also shows how a perceiver becomes a creator once the understanding of novel comparisons turns into making novel combinations. Taken in unison, the output of ACASIA contributes to the development of the Creative Sigmoid, which in turn is inputted to Epistemics of the Virtual again, and so the cycle continues.

1. Epistemics of the virtual

The current chapter is an attempt to bring the creative process in line with the way in which people perceive reality and how they attribute truth to an insight or a solution. After all, “nothing has ever been created without being imagined first” (K. Kelly, 2010, p. 210), while creators typically show ample confidence that their insights are correct (Topolinski & Reber, 2010).

In *Epistemics of the Virtual* (Hoorn, 2012), I drafted a framework for the way in which people deal with fiction from a perception point of view. Perception is

strongly related to imagination and imagination is nothing but to put up a fiction mentally. It is an internal response to signals arriving from sensory cells but all perception is 'inner' imagery to which meaning is attached (Berns, 2010, p. 57). New experiences unleash the imagination because they force the perceptual system out of the easy shortcut of standard categorizations (ibid., p. 58).

In the present book, *Creative Confluence*, I drafted a framework for the creation of a fiction (i.e. a vision, a possible solution) that later might be materialized as a poem, a business innovation, a new states form, an invention, or a scientific discovery. Creators relate to and add to what conventionally is understood as reality, they change the perceptions of our reality, including their own. They are not only the bringers of new insight; they are also the first judges of that novelty and evaluate its consequences for the world view(s) they, their peers, and society hold.

Fungi and algae form lichen on a tree trunk. This is creative confluence. The *Geometrid moth* from Borneo imitates the lichen in color, jagged contours, and disrupted patterns. That is epistemics of the virtual. As a book, *Epistemics of the Virtual* offers an account of the mental processes and cognitive systems that lead to what people regard as knowledge of the world or beliefs about reality (cf. Goldman, 1978). The book discusses how people differentiate fiction from reality, the role of perceived realism and the attribution of truth. Moreover, the book discusses the way novel comparisons are understood (e.g., metaphors), which can be connected to the way people establish novel out-of-category combinations. Finally, the model links up with the way in which people become attached to or stay aloof from virtual others, whether they are fictional characters, mediated figures, or historical personalities such as great inventors, illustrious musicians, or other unrivaled luminaries. It turns out that, to be regarded a genius, it does not matter too much that creators make incorrect assertions about reality, convey 'false' hypotheses (Livio, 2013),¹ or that they are represented unrealistically (cf. Hollywood movies).

Next I will try to compare and combine the ACASIA process on creativity with the cognitive mechanisms of reality perception. This is to figure out what creators do differently from people who are in a more analytical or logical mode of thinking and how that affects their and our world view.

A world view is a construction of the mind (Chapter 2). It works with a system of beliefs or an ontology that tells us how the world is classified and which entities belong together in what way and which do not. For example, a train is an exemplar of the category of vehicles and a horse belongs to the animals. Such an ontological classification may have a more deterministic nature when people think in terms of

1. For instance, Newton formulated his laws on motion through *vacuum* merely because he did not have the mathematics to calculate action through a medium (Miller, 2000, p. 21).

either true or false, either correct or incorrect, exclusively right or wrong. With strict category boundaries in place, a horse can never be classified as a vehicle. The classification may be of a more probabilistic nature when multiple valued logics are accepted, allowing for intermediate values such as maybe, perhaps, and probably (i.e. a horse may perhaps be seen as ‘a kind of vehicle’).

Entities or features of entities that run counter to the ontological classification go through a process of epistemic appraisal, mainly checking whether features “look realistic” rather than “are real.” A bionic leg on a horse immediately draws attention to itself and people will scrutinize whether that thing truly is a prosthesis or not. Because they do not exactly know how bionic horse legs work and how people look like, they will want to know whether its features look realistically (e.g., does it have metal plates, wiring, pneumatics?). Things should look how people *imagine* that they should look like (cf. Shapiro & Chock, 2003). In an analytical mode, stimulus discrimination is strong and the seemingly unrealistic features will almost always lead to rejection whether this is correct or not: Although the horse has a mechanical leg, it is still not regarded a vehicle. In a more associative mode, more features can be qualified as unrealistic and yet make changes to the ontological classification, accepting that there may be peripheral members to a class (“We just don’t know”).

When a category mismatch occurs and certain features seem quite unrealistic, the perceiver has one option left. In *I like to see it lap the Miles*, Emily Dickinson (1891) visualizes a railroad train as an iron horse that ‘licks itself up the valley,’ ‘feeds itself,’ and ‘stops at its stable doors.’ The perceiver of such a novel combination can compare the entities that the combination is composed of (here, train and horse) to find out whether such combination is literally meant (no), metaphorically (yes!), or can be rejected as sheer nonsense (perhaps...). The creator does the same, except that s/he has a number of extra tools (e.g., abstraction and adaptation) to deliberately *make* all kinds of details mismatch a given category, yielding a novel combination that can be seen as literal, metaphoric (i.e. Dickinson’s poem), or anomalous. Whereas the perceiver processes novel comparisons that are made by others, the creator has ACASIA in place to create novel comparisons to present to others.

In both cases, changes to the belief system may lead to adapted or different ontologies, which are fictional at first: Perhaps trains can be envisioned as mechanical animals of some kind and perhaps horses are some sort of organic machines... It is only after repetitive confirmation (e.g., bionic horses, monorail trains with biochips) that such classifications are taken for real. This process of iterative verification of the new ontology produces incremental changes and develops according to the Creative Sigmoid, because increasingly more rules and empirical limitations bring order to an initially chaotic view.

2. Creation, fiction, and truth

The same set of data can be covered by multiple theories. The same observation can be claimed to support a different ontology. Poincaré coined this the underdetermination thesis (Miller, 2000, p. 35), indicating that in principle there are various explanations of the same phenomena, in physics and philosophy alike. For instance, if a literary scholar follows a Marxist perspective, the behavior of the protagonist in the novel may be explained from her economic background (cf. Brizee & Case Tompkins, 2012). If another scholar would interpret the same story with post-colonial theories, the character's behavior would be explained from colonial power relationships (*ibid.*).

Every set of data is open to numerous hypotheses (Miller, 2000, p. 79). Basically, this comes down to the dilemma that on the one hand we do not know whether our assumptions are true and, on the other, we cannot trust our sense perceptions, our 'measurements' of the world. No matter how sophisticated our measurement devices are, also natural sciences in the end depend on sense perceptions (Schrödinger, 1944/2010, p. 163).

In Chapter 3, we observed that problem spaces that are ill-defined, underspecified, or "underdetermined" are probabilistic by definition with the qualification that probability can approach a near-deterministic state. While (near) deterministic problems require logics and analysis, probabilistic challenges demand more creativity. Albeit in smaller quantities, near-deterministic problems require creativity as well.

Poincaré's underdetermination thesis provides opportunities for creativity to occur. There has to be an unwarranted jump between theory and observation, a leap from the measurement paradigm to the theoretical paradigm. The theory is abstract and the data are imprecise. There is always an error gap between the perfect model and the imperfect data but that is because the mathematical generality of a theory ignores the empirical detail of the many cases it covers. Yet, the data only seem imperfect because we drew a sample. We never ever measure all the data that are to be measured according to theory.

Because in a Platonic sense, theory has to ignore much of the variance, perfect order is a mental constellation that will only very very seldom happen in the real world. It is the rule of rules (Chapter 1): Underdetermination only ends with a theory that can predict all the variance. Until then, we have to ignore the intricacy of specialist casuistry to generalize over incidents and create a connection, previously unheard of: Trains are horses! Apples can be compared with pears! We can keep on doing this until our imagination runs dry or, indeed, there is a theory that covers all possible exceptions.

World views are built of theories, which are mental constellations and, hence, fiction: Reality-based fiction. Every invention has “real things and a fantastic grain” (Savransky, 2000, p. 181). Error is opportunity for ingenuity (Livio, 2013) and creative discovery. Linguistic error may become a pun and so becomes humor (Attardo, 1962, pp. 141–142) or produces new hybridized words (e.g., saxophone plus cacophony become saxophony).² Data are theory-laden and imprecise data are sometimes beneficial because more exact data confuse issues through interferences (Miller, 2000, p. 85). It sometimes helps to be unfocussed and not see all the differences. Through thought experiments, visualization, and different representations, creators explore the fiction to arrive at new concepts about reality, which may be artistic revelations of Cubism or new discoveries in quantum physics (Miller, 2000, p. 29, pp. 412–417). New ideas do not seem to arise from intellectual deduction (Martindale, 1999, p. 137). “There is no strict rationality in scientific discourse” and “scientists sometimes argue from incorrect premises to correct results” (Miller, 2000, pp. 99–100; cf. Baker-Sennett & Ceci, 1996). Creativity is not logics. It drives the conclusion beyond the premises by side-stepping to a different domain.

3. Creator as first perceiver

In Chapter 4, the ACASIA model started with the Preparation phase, in which the creator fills the ontological databases with up to date knowledge about a domain (familiarization). And although the diversity of entities may increase over time, its availability is limited by the perceiver’s perspective (K. Kelly, 2010, pp. 284–285). Without getting into too much detail, the creator keeps a certain level of vagueness that allows seeking similarity with unrelated domains to bridge the error gap. Details can only reveal distinction with other entities whereas the creator in this stage does not seek the identity of one but rather the unity of many. This is why abstraction is important: It withdraws to the most general and, hence, undifferentiated characteristics that entities might have and that are shared by most other entities, including those out of bound. It is only when all identities are unified and harmonized that creators will destruct the combination of combinations and start anew, combining the broken pieces into different entities.

Because the creator is the first to bridge the error gap and sees a printing press in a wine press (Gutenberg, see Simonton, 2009, p. 123), equals gravity with acceleration (Einstein, see Miller, 2000, p. 314), or submits a urinal to an art show (Duchamp, see Miller, 2000, p. 381), she or he is also the first to evaluate the insight

2. <http://www.meetup.com/Saxophony/>

for its ontological value, in what way the creation changes a known technical procedure, a scientific theory, or our definition of art. The creator is the first perceiver of his creation and, therefore, relies on an epistemics of the virtual to change the initial ontological database. From this changed database, new combinatory concepts can be formed in another round of creativity. For the creator, classifications are only relative (Savransky, 2000, p. 180).

4. Second perceivers and co-creators

Unless the creator never tells anyone else of her creation or destroys it right away, others will get acquainted with the work and have an opinion about it, add to it, change it. In literature, the greater part of reception theory is based on the idea that meaning can only be attributed to a work in interaction with its audience and readership, which dynamically changes through history (cf. Jauss, 1982). Today, admirers of the tango legend Carlos Gardel make sure that his statue always keeps a lit cigarette between his fingers (Figure 1), although the artist never intended this.



Figure 1. Crowd adds cigarette to statue Gardel

As Gilot (2001, p. 176) puts it: ‘The viewer is co-creator’ (also Van Rosmalen, 2011, on listeners). A story, musical piece, art work, or a theory evokes different interpretations in one head or the other. The uses of an invention or business proposition may be different for different people. Over time, the creator self may develop different perspectives on her own work. Sometimes readers provide meanings unseen by the author himself (Eco, 1996). If we take seriously that the receiver co-creates the meaning of a creation, then the discussion on the autonomy of art (e.g., Adorno in Markus, 2006) becomes a non-issue. There would not be art that is non-interactive because that would mean it does not communicate anymore. Those who look become part of the artwork’s history of evolving meanings.

The second and subsequent tranches of perceivers of a creation also evaluate the work for its ontological value and how it changes familiar knowledge and classifications. They rely on their epistemics to decide whether the virtual aspects of the creation are allowed to change certain points in their conception of reality, which may serve as input for another round of creativity by the creator. Group epistemics that decides whether a creation conveys something new about reality or remains a nice but fictitious folly becomes all the more important when people start to collaborate or when designs and solutions are crowd-sourced (e.g., Surowiecki, 2004/2005; Anderson, 2006).

Altered group ontologies are not only possible input, they are also influential for the criteria the creator may use while creating (cf. the field of referees, Csíkszentmihályi, 1996, pp. 27–33). If a psychologist is depreciated for publishing in sociology and anthropology, next time he makes sure to be more mainstream (duly noted: Simonton, 2009, pp. 136–137).

Source credibility and authority of the creator are the main foundations for incorporating a new insight into the perceiver's ontology and the place it occupies (reality, fiction, true, false, literal, metaphor). As a patent clerk 3rd class, nobody bothered about Einstein's proposal for an experiment to test competing electron theories (Miller, 2000, p. 88). Nine years later, after gaining more credibility as a scientist, two extremely expensive expeditions were outfitted to test the clerk's gravitation theory (*ibid.*). When indeed the sun's deflection of starlight was measured as predicted, Einstein became the worldwide recognized genius we know today, making his every thought almost sacred (see, for instance, the book of Einstein quotes collected by Mayer & Holmes, 1996). Yet, as a patent clerk his work was not so implausible whereas as a living legend his unified field theory was not that brilliant (Simonton, 2009, p. 168).

Therefore, Epistemics of the Virtual as a theory has an extension called Perceiving and Experiencing Fictional Characters (PEFiC) (Hoorn & Konijn, 2003). Particularly in creativity, where conclusions cannot be drawn from the premises, its feeble ontological status and the unanswerable epistemic question "How do you know?" are largely compensated by the credibility and trustworthiness of the person who created the work. However, Epistemics of the Virtual makes perfectly clear that most of the people we hold for real, such as politicians, scientists, artists, business people, should be treated as fictional characters because, if we do not know them personally, they are mediated through stories, newspapers, hearsay, pictures, hagiographies, films, or Web pages of others – who probably also do not know the person themselves. Series of experimental studies showed that people build up affective relationships with fictional characters of all sorts (e.g., Konijn & Hoorn, 2005; Konijn & Bushman, 2007; Van Vugt et al., 2006; 2007, 2008, 2009, 2010). With respect to the appreciation of a creative work, whether people like a character or not will affect the status they attach to the work.

5. Epistemics of the Virtual and ACASIA

Figure 2 offers a coarse overview of the Epistemics of the Virtual theory while attempting to place ACASIA within its framework. The framework as elaborated in Hoorn (2012) is extremely intricate and knows many more loops and alternative pathways, checks, classifications, and criteria but for now the simplification of Figure 2 will suffice.

The integration of ACASIA with Epistemics of the Virtual is not merely an academic exercise as it tries to explain how divergent thinking (taking different perspectives on ‘reality’) feeds into the creative process, how beliefs and sense perceptions are related to creativity, where the different problem-solving styles fit in, and what the difference is between scientific and artistic creativity, between engineering and religion. It also shows us how creativity changes ontologies, given an individual’s levels of tolerance and sensitivity. Finally, Figure 2 gives an account of the way people perceive (themselves as) genius and how that affects the qualifications of a creation.

Epistemics of the Virtual (Figure 2) distinguishes two basic processes: ONTOLOGICAL CLASSIFICATION and EPISTEMIC APPRAISAL. The first consists of category verification as an ongoing global check whether the sense perceptions are in line with the belief system (convergence) or put differently, with ‘what we believe the world is about.’ The latter becomes activated more strongly when incoming data mismatch the known categories (divergence, disruption) and on a local plane single features have to be checked for their level of perceived realism. When confronted with an unknown entity, people ask: “Are the features of that weird thing that I have never seen before such that I up to a certain extent could attribute the qualification of being realistic to them?” The unknown entity also could pertain to a different perspective on reality.

The flowchart symbol for stored data in the lower left corner of Figure 2 shows a truth continuum of information that is regarded as ‘true’ according to the perceiver, ‘possible,’ ‘false,’ or degrees thereof. The attribution of what is true or not is subjective, at best inter-subjective, and takes root in the belief system or set of belief systems one adheres to, which may be religious, scientific, cultural, etc.

In *Epistemics of the Virtual*, all that is regarded as the concrete, manifest, empirical and physical world is deemed “Reality” and ranges from things considered true to things considered possible. Although it seems counterintuitive, products of fiction are part of Reality as well because they too have a material side: They have to be carved in stone, expressed in text, in images, or mediated in some way to become accessible to another mind. In other words, the artifacts are part of Reality whereas the mediated content, the things that the artifact refers to and that are partially void of an existing referent (according to belief), is the Fiction. Moreover, we know that fiction in the non-artifact way exists as a phenomenon of its own (we can do “as if”). In other words, fiction is not reserved to a particular genre (e.g., literature or theater), it is part of every message that is mediated one way or the other and that escapes our epistemic possibilities of direct and personal verification. Hence, science, documentary, and journalism are partially fictitious as well.

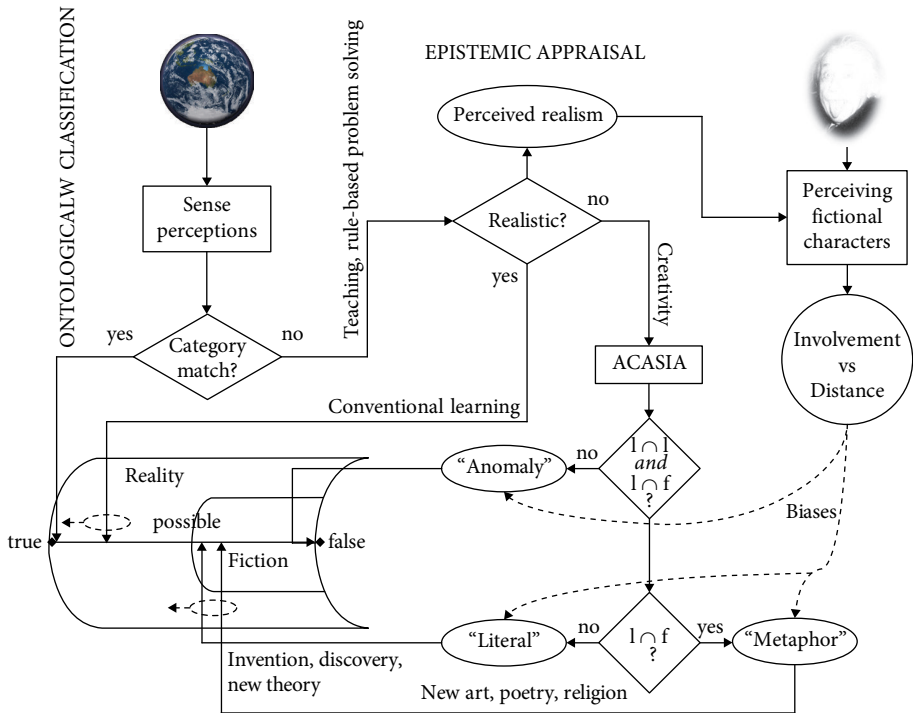


Figure 2. Crude approximation of Epistemics of the Virtual combined with ACASIA.

Funny Einstein: Retrieved Mar. 24, 2011 from <http://www.deism.com/images/einfun.jpg>

Fiction ranges from what is possible to what is regarded as patently false. In other words, the transition from fiction to reality is vague and doubt traverses back and forth through what might be possible but may be impossible. Here we enter the realm where creativity expands what is considered reality into a vision of possibilities and opportunities, whether they are farfetched or not, which is what we call imagination. By and large, the current problem state of a situation will be regarded as part of Reality (according to belief); the desired future state will be regarded as Fiction (according to belief), with an estimate of probability attached to it.

Incoming data that are verified for their membership to familiar categories are stored as 'true' information. The belief system determines what familiar categories are and how crisp or fuzzy their boundaries are allowed to be. In that sense, a theater piece as such may be regarded as 'true' and thus part of Reality but what it refers to may be considered 'possible' or even 'false' (cf. poetic license) and so belong to the Fiction.

When data mismatch the familiar classification of the world or ontology, disruption occurs and, however small, a new perspective on reality has to be taken. The creator may actually seek such disruption by looking into different domains, familiarizing with strange cultures, or welcoming a diversity of views and perspectives. The mismatch causes a 'problem' or 'challenge,' and whether big or small, it can be approached in two ways, intellectually and creatively. Dependent of the more deterministic or more probabilistic problem space and/or the crispness of the personal ontological classifications, the problem-solving strategy may be more rule-based or rather associative (cf. Hélie & Sun, 2010).

When a logical syllogism is encountered (category-match? $\rightarrow$ no), the analyst will deem the proposed solution as plainly false. Figure 2 does not represent this option but in Hoorn (2012, Chapter 6) this is elaborated more decently. Figure 2 focuses on the cases where more doubt and uncertainty are involved. In a conventional teaching situation, for instance, the pupil hears that not only birds lay eggs but frogs do too. The pupil may accept this as Realistic based on sheer authority of the source but yet will verify in imagination what a frog laying eggs would be like. If the category mismatch is not too much out of bound (frog eggs are of a different type), the pupil may decide to extend the category of frogs with a feature called 'laying eggs' and subdivide the category of eggs on the generic feature of 'jelly' and 'blobby.' This is conventional learning and its outcome will be placed on the truth continuum somewhere between possible and true and through empirical verification and repetitive confirmation will shift towards 'true' finally (Figure 2, dashed ellipse). This part is still under the reign of rule-based problem solving with a conversion to more associative styles via analogical reasoning (cf. birds are like frogs, birds lay eggs, therefore frogs may lay eggs as well albeit of a different kind). All the features that are regarded as realistic (i.e. certain animals can lay eggs) together with the features that appear to be unrealistic (jelly eggs?) induce a measure of Perceived realism of the message.

The problem-solving strategy changes when the level of Perceived realism is low as based on an insufficient number of features judged as Realistic as compared to the number of features judged as Unrealistic. For people in an analytical mode or who are rigid and orthodox thinkers (strong stimulus discrimination), this is where processing comes to a halt and where people in a creative mode do something extra. To make sense of an inconsistency with low perceived realism, creators start associating beyond conventional boundaries.

In Epistemics of the Virtual, a high level of deviation tolerance (not depicted in Figure 2) decides that people will enter a process for understanding novel comparisons to see whether they still can attach meaning to something that apparently seems so unrealistic. In ACASIA, this is different because now the creator does not only search for features that match between entities from distant categories but

deliberately constructs those matches through abstraction, selection, adaptation, and integration while diminishing the number of mismatches.

In Chapter 4, the ACASIA process stopped when the observer or creator would call a novel combination a ‘creation’ but we did not specify the type of creation that was established. As explained in Chapter 4, Section 5.2.2, different types of features are elicited that are crucial for the distinction between an original literal thought, a novel metaphor, or utter nonsense (an anomaly). Literal features are descriptors of what someone regards as real about an entity. Literal features can but do not necessarily add to high levels of perceived realism. When small children draw potato people, the denotation is literal but the representation is unrealistic. Figurative features are referential; they are personal or cultural connotations that are established over time. They symbolically stand for something else than what they denote taken literally and have ‘deep’ meaning: For example, green does not only denote the color but also means envy (for a complete dictionary of particularly literary symbols, see Ferber, 2007).

The first test when a creation is established is whether a novel combination of entities from remote categories has a sufficient number of (fuzzy) intersecting features that are literal (l) for all entities included in the comparison (Figure 2: $l \cap l$) AND a sufficient number of (fuzzy) intersecting features that are literal for the one but figurative (f) for the other entity (whether $l \cap f$ or $f \cap l$). If not, if not enough literal overlap AND insufficient literal-figurative overlap is established, the creation is an anomaly. With an anomaly, one neither can make sense out of the category connection in a descriptive way nor in a symbolic, representational, figurative sense. However, although a creation can be nonsense it can yet be fun (cf. absurd humor). Although it is not the discovery of a new natural law or a poetic metaphor, it still is a creation. Hence, a creation that is regarded as an anomaly is classified as ‘false’ in the ontological data base.

Given that both fuzzy intersections are large enough, the second test is to see whether the literal-figurative overlap surpasses criterion. If the connections of literal features of one entity with figurative ones of the other are not numerous or strong enough, the novel connection must be a literal statement about the world. It is the area of scientific discovery and technological invention: Gravity and acceleration are equivalent; a wine press is a model for a printing press. Novel literal creations are about matches between literal features of entities that initially were out of each other’s category. In that case, the invention, discovery, or new theory is first classified in the Fiction domain but on the side of ‘perhaps possible’ (Box 1). Only after repetitive confirmation through the ONTOLOGICAL CLASSIFICATION process may the literal creation slide towards Reality and ‘true’ (Figure 2, dashed ellipse).

Box 1. Floating balloon vegetation and Tulip creatures

Commissioned by National Geographic Channel, the documentary *Extraterrestrial* (2005) invited scientists to envisage what life would look like on other planets with different circumstances. The scientists imagined a moon with low gravity and a thick atmosphere, upholding floating balloon vegetation filled with hot air (Figure 3a).

Figure 3. Floating balloon vegetation (artist impression) (a) and Tulip creatures (artist impression) (b)

Six years later, in 2011, O'Brien and Caron (2012) submitted a paper supporting the theory of the Cambrian explosion – a period of wild form experiments of evolution. They reported on one of the “Problematica,” hard-to-classify species that cannot be readily assigned to known taxonomies (cf. Tuatara, Chapter 2). At first site, one would be inclined to make a wrong category attribution because this underwater life form resembles familiar entities such as flowers but they are colonies of animal life; filter-feeders not related to creatures known today. The researchers called them “Tulip creatures” (*Siphosauctum gregarium*) (Figure 3b), although they are not one creature and gregarious animals rather than plants.

For a lay person reading about Tulip Beds in a Cambrian sea, what is the difference with Floating balloon vegetation on a moon? Which is invertebrate palaeontology and which xenobiological science fiction? It could be the other way around.¹ Science and art converge where the stem and ovoid calyx are reminiscent of a tulip. In science, however, one would control the plant assumption by studying the specimen at the excavation site of Mount Stephen's Burgess Shale in Canada. In art, this is pointless because the associative resemblance makes sense so that an animal can be a tulip, air balloons are floating plants, and Problematica and Cambrian explosions are mere hypotheses.

¹ For virtual reality representations of Cambrian life, watch the PBS documentary *Shape of Life: Explosion of Life* at <http://www.youtube.com/watch?v=Bx53TVZ9tNg>

If the literal matches are sufficient as well as the literal-figurative matches, in other words, if a deeper meaning is attached to a statement about the world, the creation is a metaphor. Note that what is bridging the remote categories may be different for novel literal creations and metaphoric creations. For the novel literal creation, the novelty resides in making new literal connections whereas in a metaphoric creation the literal connection may be conventional or not but the novelty should be in the new connection of literal information to figurative meanings. Either way, the new metaphor, new art form, or novel religious idea will first enter the realm of Fiction, probably closer to the values of ‘impossible’ and ‘false’ and, again, may shift to the mid value of ‘possible’ or perhaps even Reality (Figure 2, dashed ellipse) when the literal-literal overlap of the metaphor becomes repeatedly

confirmed by the ONTOLOGICAL CLASSIFICATION process or when the literal-literal overlap grows because over time the figurative features are gradually taken as literal as well (whether correctly or not).

5.1 Fictional characters and the mystification of genius

This section is not to disqualify great creators but to separate the myth from the merit (cf. Livio, 2013). Geniuses are created in hindsight and their allure usually does not match their actual virtue (Basalla, 1988/1999, pp. 57–59). Modern hero worshipping has given us our geniuses (cf. Simonton, 2009, p. 163) and can sometimes be qualified as pathological or near-religious (e.g., Maltby et al., 2002). “...the contrast between the popular estimate of my powers and achievements and the reality is simply grotesque” (Einstein, 1931/1949). In that sense, the genius Einstein is a fictional character based on the historic Einstein (who we will never know).

Whether a creation is regarded as an anomaly, a new literal statement, or novel metaphor also depends on the bias induced by its source. There are many examples of simultaneous inventions or novel thoughts but the one author became famous and the other did not (e.g., Darwin – Wallace, other examples can be found in Simonton, 2009, p. 149). Particularly when the source is famous, an image is created that hardly refers to the real person anymore such that the actual person slowly gets the feeling she has to live up to that image. Most of the sources we do not know personally; in Epistemics of the Virtual sources that are accessible only indirectly or that are surrounded by image building are by definition fictional characters (also when referring to the self). Fictional characters may be reality-based but are fictitious still.

Figure 2 shows that it makes a difference in the assessment of a creation whether Einstein makes the quote or an unknown (but equally bright) colleague. Perceived realism of the message that the fictional character brings across but also the realism of the representation of the character weighs in on how involved or distant one feels towards the character. The PEFiC theory of Perceiving and Experiencing Fictional Characters (Hoorn & Konijn, 2003) predicts and has evidence to show for (e.g., Konijn & Hoorn, 2005; Konijn & Bushman, 2007; Van Vugt et al., 2006; 2007, 2008, 2009, 2010) that a fixed set of variables is responsible for how we feel about virtual others and in how far we assess and accept, for instance, the quality of their advice.

PEFiC explains that a character is encoded on a number of factors. The perception of the ethical behavior of a character in terms of trustworthiness and credibility strongly determines our attachment to it. For Simonton (2009, pp. 29–30) it is even the question whether evil work can be considered the work of genius.

Perceived aesthetics of the character also contributes to engagement, setting high expectations on performance when characters are beautiful and lower expectations when they look plain. Perceived realism also weighs in but less so than aesthetics and particularly ethics, indicating that as long as a source is regarded as trustworthy (an aspect of ethics), the realism of their statements or appearances is of less importance. For example, Simonton (2009, p. 90) states that landmark people are known for their extreme positions, not because they are correct. I would say that such people linger in collective memory not because their insights are right but because their extreme positions make them salient so that they can serve as the farthest outposts of possibilities (the borders of the bandwidth) in between which more realistic theories can flourish (the average sigmoid). In that sense, characters are also encoded for their affordances, indicating the perceived possibilities they or their work offer for the perceiver to achieve (personal) goals.

After the encoding, a comparison between the character's features and those of the observer (which may be the creator self) takes place to establish a level of similarity ('Is s/he like me?'), relevance to goals and concerns ('Does s/he matter to me?'), and valence ('Should s/he live on or be forgotten?'). Geniuses in that respect are the characters that won fame, reputation, and Nobel prizes whereas the losers are left with obscurity (cf. Simonton, 2009, p. 167, p. 160).

All these factors determine the response to the character, which is expressed as a level of involvement ('I love him/her') *in parallel to and not excluding* a level of distance ('I hate him/her'). The balance between involvement and distance, then, determines how much appreciation or liking the character raises in the observer. Liking the character will place the new literal theory farther down the truth continuum into the direction of 'true,' makes sure that there is a lot of sense and deeper meaning to a urinal in a museum, and that the nonsense of Monty Python is humor instead of a farce.

6. Epistemics of the Virtual, ACASIA, and the Creative Sigmoid

Epistemics of the Virtual assumes that beliefs about the world, whether they are scientific theories or not, can only be approximately true and only within that particular paradigm. Progress in thinking is not that the current theory approximates truth about the universals of nature more than previous ones because that assumes that approximation can be 'better' and that universals exist at all and should be sought after. Epistemics of the Virtual calls such a standpoint 'looking for a unicorn.'

The point is that, empirically, many assumptions may hold for a while but there is a fundamental epistemic gap between what our senses perceive (data) and

what we would like them to perceive (theory). Our senses merely observe what they need in order to achieve certain basic human goals. Basic human goals are different from frog goals, or bee goals, or plant goals. In other words, our ontologies are largely based on indirect observations, indirect measurements, while direct observations cannot be trusted completely (cf. optical illusions) and are limited to what our senses were made for. Thus, what we call Reality is a mental representation of the world that does not have to have a one-to-one correspondence. Gestalt theory even posits that ill-defined problems, those that require creative solutions, come close to having perceptual illusions because a proper representation of the problem space is missing (cf. Hélie & Sun, 2010).

The frog aggregates visual data on a much coarser level than we do because its world is about detecting motion of small things you can eat and large things that can eat you (Zander & Zander, 2000, pp. 10–11). For his theory of life, the frog is well equipped just like Galileo who would never had formulated his theory of acceleration through a vacuum correctly had he had the availability over a digital stopwatch (high resolution data) instead of an unsound pendulum (Miller, 2000, p. 84). Schrödinger (1944/2010, p. 17) states that instruments become useless when they become too sensitive. Not every data point that can be measured supports the pattern that can be detected.

Terms like “rational” and “objective” are feeble and valid only if you adhere to the relevant belief system. Scientific realists such as Miller (2000, pp. 155–157) assume that the structure of the universe is mathematical (ibid., p. 176). Science evolves by extending fictional worlds with causal theory of reference (ibid., p. 238): It is counterfactual but consistent with logic. However, mathematics itself is an abstraction from the details, ignoring piles of data and variances, as well as it is a construction of the mind. “As far as the propositions of mathematics refer to reality, they are not certain; and as far as they are certain they do not refer to reality” (Einstein, 1921). No matter how interesting its results, mathematics itself is not directly observable in nature but only through imperfect sense perceptions. You see it when you believe it. Mathematics is correct only within its own set of rules. This might seem like a sad story but it turns out not to be.

To access the unobservable, we rely on theory (which is a vision on the world), measurement (which is a mediated observation of a sub-set of the world) as well as on metaphor, cultural meaning, and assumptions from cognitive science (cf. Miller, 2000, p. 155; also Gruber & Wallace, 1999, p. 104). The underdetermination of theory is the upperopportunity of creativity. No explanatory or other rule-based system can be so rigid or one can escape from it by combining seemingly unconnected phenomena. And that is because everything we think and observe has a fictitious element to it. That is also where perception theory transfers into a theory of creation. Modern science is the best science fiction story ever told.

6.1 Creative confluence: Creating the “as if”

The perception of a good fiction urges to contribute to that fiction. Certain people do this in an incremental way, selecting certain aspects of the story, adapting them, integrating some other aspects but all within the story line. This is the evolutionary development of an innovation line. Then suddenly someone discovers a new element, a fresh perspective that lies outside the original story line but they see a connection. Such serendipitous findings may be deliberately sought after (e.g., through divergent thinking or free association) or may happen coincidentally (e.g., stumbling upon some new materials). If the story that emerges from the unexpected combination is different enough from the original story line, observers perceive this as disruptive.

Thus, the creative process is put into gear by seeing the fictional element in theory and sense perceptions – how else could you deviate if all classifications, rules, and observations were true? But instead of refuting what is not in line with the long-told story, the creator adds to the “as if” by drawing in more information than originally was covered, creating new representations and new visualizations without bothering too much about their ‘truth’ because their ‘truth’ depends on whether you believe the story in the first place: your epistemics of the virtual. In other words, tolerance to deviation within Epistemics of the Virtual in certain people ignites the creative process of ACASIA, which outputs a contribution to the innovation story line, the Creative Sigmoid, be that in an evolutionary or disruptive manner but that is all a matter of perception. From there, the loop continues (Figure 4).

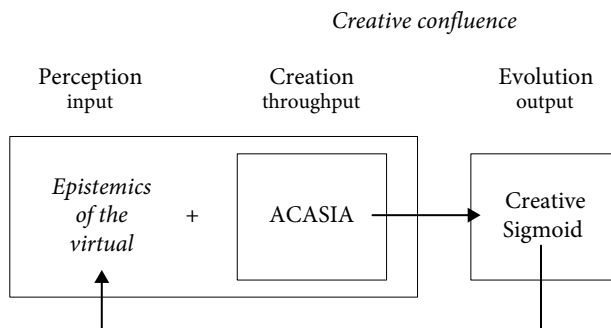


Figure 4. Within Epistemics of the Virtual, ACASIA produces the Creative Sigmoid

7. The Virtuality of Epistemics

The introduction of creativity transitions Epistemics of the Virtual into the Virtuality of Epistemics. Where mere observers try to make sense of deviations and category mismatches that are offered to them (consumption), creators are deliberately seeking and making those mismatches to offer them to others (production). The processes are more-or-less the same but the way they are employed differs while it is also a matter of being first. Reading a novel metaphor means that someone else thought of it before you.

Creation is not asking how do I know? It is all invented (Zander & Zander, 2000, pp. 8–15). Creation is wiring the given to the what if, without knowing whether this is right. Such a daring stance generates a world of possibilities that is virtual to begin with. Creators acknowledge that epistemics is a creation of the human mind that produces a space of virtuality for them to exercise their wit. Seeing is creating, taking is making: Epistemics is the creation of the virtual.

Make – Take

Creativity. Its origin is quantum physics; the optimization is biological. Owing to its 'flawed' perceptual system, the human brain functions as an accelerator of that process because it can create in imagination, checking the various interpretations of an apparent 'error.' Hence, creativity produces an epistemics of the virtual. The trace of accumulated combinations it leaves behind is visible in literature, culture, and the arts, in business, technology, and economy, and has strong organizational consequences. Through playfulness, it comes to expression in education and pedagogy. Its language of description is mathematics (i.e. combinatorics), being stochastic at the particle level, then through fractal emergence present in biology, and in its deterministic end state, via logics and precise calculation. Because of this stochastic-fractal-logics, creativity and the dynamics of it can be modeled in a computer. The full story of these events may be regarded as the texture of Big History.

Confluence. The term was introduced to me by Sternberg and Lubart (1999, p. 4). Confluence of ideas, of information, of people, of theories, of domains, of disciplines, that is what creativity is about. Its natural antagonists are politics, favoritism, intolerance, ego, self-satisfaction, immunity to self-reflection, and performance indicators. More mass! More focus! Monoculture is easy to manage but vulnerable to changes in the environment. If one is infected, all are infected. Letting multiple views coexist is unmanageable but takes all the more vision. Combine without wasting diversity. That is how you turn takers into makers.

The world goes through multiple transitions: Mind boggling technologies enter the private sphere, new media are ubiquitous, global communities replace family bonds, voters are adrift, churches are empty, climate is changing, we created a plastic soup in the oceans, and the financial institutions lost their credit (literally and figuratively). Production work has shifted to other regions around the globe where work is done cheaper, longer, and faster. Work and pension are no longer guaranteed and more ingenuity is needed to switch jobs or to find novel market opportunities. In the West, the industrial age has come to an end and we should be happy about it!

We should love it because these transitions are undesirable only if you believe that life should be predictable from cradle to grave, when you are taken care of by a paternal state, and you have nothing more to do than be an obedient and law

abiding citizen. In that case, you long for restoration of what has been but probably never was. We should love it because great changes rear opportunities seldom seen, exhilarating a type of person that absorbs all change and turns it into something excitingly new. This is the time that the gray and tedious are replaced by the colorful and extraordinary. And I personally jump right smack in the middle of it to provide you with an instrument, this book, to muse on the wonders of creativity.

Each person on the planet should be an open invitation and an inspiration for people to create ideas and craft events that fling the course of a world in transition without knocking off all of its rough edges. That person welcomes infinite expression, development, and proliferation of mirthful possibilities radiating outward, sustaining personal and societal well-being, blended in with a touch of cosmic laughter.

From indolent bystanders gazing at the whims of time to vigorous creators jumping waves of opportunities. If you first grasp the full consequences of *Epistemics of the Virtual* and comprehend how the illusion of reality works, your mind is prepared to let *Creative Confluence* be happening to you. Each maker is a taker at first. Our openness to new knowledge, new experiences, the perceptiveness of our senses and the awareness that what we call reality is an arbitrary choice from a way vaster universe; they are all means to take in the most electrifying information and make something sparkling of our lives: Make, so that others can take!

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