The Creative Process and Reality

An analysis of search and cognition in the creative process and a call for an ecological cognitive framework for creativity research

by

Bo T. Christensen

Psykologisk Studieskriftserie kan bestilles skriftligt eller pr. telefon (89424900).

UDGIVET PÅ PSYKOLOGISK INSTITUT
AARHUS UNIVERSITET, ASYLVEJ 4, 8240 RISSKOV

RISSKOV, 2002

Tryk: Institut for Statskundskab

FOREWORD

The present dissertation is not only interesting in its analysis of the creative process. It is also itself a substantial and creative contribution to psychological theory and the development of fundamental scientific concepts. There are apparent paradoxes in the traditional understanding of creativity, as there seems to be an insurmountable gap between the objective reality of existing objects and qualities and the subjective creation of the new and surprising. Bo Christensen suggests a convincing solution to these paradoxes by expanding the reduced and often implicit ontology of most psychological theory. The objective category of the factually existing is supplemented with the possible and the impossible. And the category of objects' qualitative identity is supplemented with their numerical identity. This extends the field of reality as object for subjective activity, and thus makes room for a process of creative activity, including a "creative cycle", which demystifies creativity and prepares it for theoretical and empirical investigation. However, the method and the fundamental concepts developed have implications beyond the study of creativity in the narrow sense. They imply consequences for psychological domains such as developmental, clinical, and educational psychology. Thus it is to be hoped that the dissertation will be read by a wide range of psychologists and psychology students.

Jens Mammen

Professor, dr.phil.

PREFACE

The present book was originally written in partial fulfillment of the requirement for the degree of Candidate of Psychology at the University of Aarhus, Denmark. Aside from a few spelling corrections and a few more endnotes and references, the basic structure and content of this book is identical with that thesis. My interest in creativity started when I was preparing to write my bachelors thesis on the topic of intelligence in Activity Theory. I wanted to incorporate creativity into the explanation of intelligence, but needed a theoretical framework for creativity that was compatible with the materialistic theory of Leontjev. I set aside three pages in my bachelors thesis to develop such a theoretical framework, which quickly became the entire project, and ended up being the main topic. It turned out that I had stubled across a research question very few cognitive researchers had taken seriously, and where American and Russian approaches to cognition appeared in conflict, along with constructivist and realist explanatory frameworks. This triggered my interest and imagination, and I kept on working on the problem. The present book is basically a much more developed and extended theoretical explanation of creativity in the real-world. It functions as a kind of broad theoretical framework for my present Ph.D. research project entitled: 'Creative Cognition in the Real-World: Examining activity and cognition in the creative process, in an in vivo - in vitro study'. So what was intended to be a three page explanation of creativity in Activity Theory has now become my dominant line of research, at least in the foreseeable future.

I have been questioned about my extensive use of endnotes, so much so, that I thought I would use this preface to explain their content and usage. Basically the endnotes in this book consists of two things: primarily they consist of ideas and comments of relevance to creativity research in general that diverge from what is of critical importance to what is the present line of argumentation. This means that the text can easily be read without referring to these endnotes. Should the reader be interested in diverging into broader issues (apart from a narrow line of argumentation) in creativity research, he or she may refer to the endnotes for what I consider interesting points, ideas and comments. The other function of the endnotes is simply that some of them contain definitions of terms left unexplained in the text, or the original language wording of quotes translated into English in the main text

I would like to dedicate this thesis to the creative works of Karl Popper and Michael Polanyi for both being so intuitively, conflictingly and confusingly right. I hope the influence of both these great philosophers of science is evident in the present work.

Finally, I would like to extend a warm thanks to the real-world for always being there for me. You are my continued source of inspiration - please forgive me for always wanting to change you.

Bo T. Christensen,
Aarhus, 2002

TABLE OF CONTENTS

1 INTRODUCTION – THE PROBLEM UNDERTAKEN. 3

2 SETTING THE STAGE 9

2.1 CREATIVITY – A DEFINITION 9
2.1.1 Novelty 10
2.1.2 Usefulness and adaptability 12
2.1.3 Levels of creativity 16
2.2 LIMITATIONS OF THE PRESENT ANALYSIS - THE CREATIVITY FIELD NARROWED DOWN 18
2.2.1 The creative process – a description 21

3 CREATIVITY AS SEARCH – INFORMATION PROCESSING APPROACHES 31

3.1 INTRODUCTION TO THE SEARCH CONCEPT – EVOLUTION AND ELEMENTS 31
3.1.1 Search in its most elementary form 32
3.2 PROBLEM SOLVING AS SEARCH 35
3.3 CREATIVITY AS SEARCH 41
3.3.1 Perkins and Klondike spaces 41
3.3.2 Boden and impossible creativity 44
3.4 PROBLEMS WITH THE INFORMATION PROCESSING VIEW OF CREATIVITY AS SEARCH 47
3.4.1 Boden 47
3.4.2 Perkins 51
3.4.3 Limitations of the information processing approach to creativity as search 52
3.5 REALISM AND CONSTRUCTIVISM IN CREATIVITY 54
3.6 SUMMARY 58

4 STEPS TO AN ECOLOGICAL APPRACH TO CREATIVITY 61

4.1 THE ONTOLOGICAL DILEMMA: HOW CAN SOMETHING BE NOVEL, AND AT THE SAME TIME COME FROM SOMEWHERE? 61
4.2 THE SEARCH DILEMMA: HOW CAN YOU SEARCH FOR SOMETHING YOU DON'T KNOW WHAT IS, AND WHICH DOESN'T EVEN EXIST? 70
4.3 THE CREATIVE CYCLE INTRODUCED 76
4.3.1 The perceptual cycle 77
4.3.2 The creative cycle 80
4.4 SUMMARY 86

5 COGNITIVE ASPECTS OF THE CREATIVE CYCLE 91

5.1 WHAT IS THE DIFFERENCE BETWEEN PHYSICAL CREATIVE ACTION AND CREATIVE THINKING? 94
5.2 WHAT KINDS OF PROCESSES ARE INCLUDED IN CREATIVE COGNITION? 98
5.3 HOW IS KNOWLEDGE STRUCTURED IN A WAY THAT MAKES IT POSSIBLE TO SIMULATE VARIATIONS AND ANTICIPATE NOVELTY? 102

5.3.1 Variations in creativity *104*
5.3.2 Explanations from cognitive science *106*
5.3.3 The inadequacy of cognitive explanations *107*
5.3.4 Mammen, and the category of choice *111*
5.3.5 Barsalou, and perceptual symbols *115*
5.3.6 Conclusions concerning the structuring of typicalities and possibilities . *121*
5.3.7 Anticipatory knowledge structures *123*
5.4 WHAT CONSTRAINS THE SIMULATION OF VARIATIONS? 129
5.4.1 Purpose constraints *133*
5.4.2 Availability constraints *133*
5.4.3 'Uncertainty directed' constraints *136*
5.4.4 Search strategy constraints *136*
5.4.5 Situation constraints *137*
5.5 SUMMARY 139

6 THE CREATIVE CYCLE AND STAGES IN THE CREATIVE PROCESS 143

6.1 PREPARATION 144
6.1.1 ... a note on expert vs. novice creativity *146*
6.2 INCUBATION 146
6.2.1 ... a note on (inner vs. outer) cuing *147*
6.3 ILLUMINATION / INSIGHT 148
6.3.1 ... a note on 'sudden and surprising affect' in creativity *148*
6.4 VERIFICATION / ELABORATION / EVALUATION 149
6.5 SUMMARY 150

7 CONCLUSIONS AND FUTURE RESEARCH 153

ABSTRACT

This thesis argues for the need for a synthesis of so called realist and constructivist approaches to the study of the creative process. Such a synthesis is attempted resulting in an ecological cognitive framework called ‘the creative cycle’. It is argued that this framework is capable of explaining the creative process as it occurs in reality. Existing literature on creativity (notably the Information Processing approach) is reviewed. Central issues in creativity, such as ontology, search, and cognition, are analyzed and discussed.

PART I: INTRODUCTION – THE PROBLEM UNDERTAKEN

”It is precisely *the alteration of nature by men*, not nature as such, which is the most essential and immediate basis of human thought.”
- Friedrich Engels

1 INTRODUCTION – THE PROBLEM UNDERTAKEN.

A central concern in the scientific study of creativity is the question of where creative ideas and products come from. Metaphorically it is a question seeking to locate a spatial place of origin for the products and ideas generated through the creative process. It is a question that seeks to explain the miraculous process whereby novelty comes into being. The seemingly miraculous nature of the process has led philosophers to point to divine beings or platonic worlds of ideas as the place of origin of creative products. However, when psychologists have attempted to answer the same question, most frequently the location has been set inside the mind of the individual creator. In many psychological explanations of creativity, the creative idea or product arise in a sudden flash of 'insight', seemingly arriving from nowhere. In the creativity literature this has been termed the 'ex nihilo' problem (e.g., Perkins, 1988; Boden, 1991), meaning 'out of nothing'. Although most theories would agree that creative ideas and products cannot come out of nothing, not many theories take seriously the challenges posed by the 'ex nihilo' problem, and actually try to formulate a theory that can make up an alternative.

In the present thesis, I will try to take seriously the 'ex nihilo' problem, and take a different approach to the study of creativity. I will point to the overwhelming neglect of the inclusion of the real-world – of an ecological perspective – in the study of the creative process.

Put to the extreme, the difference can be seen as two apparently opposing approaches to the study of the creative process.

One approach (which could be called a 'constructivist' one) focuses on the constructive force of subjective processes, and has a tendency to limit the end product of the creative process to 'a changed mind'. Novel ideas have arisen, and that marks the end of the process. Creativity is a 'mental feat' occurring in the head of the creator. A narrow focus on concepts such as 'insight' can lead to such a view. Ideas arise seemingly from nowhere in a sudden flash of insight.

The other approach (which could be called a 'realist' one) would instead focus on where the creative product came from, and how something came to be something else. In such an approach objective structures are the main

unit of analysis, and the creative product is seen as (often physical and tangible) products existing in a society and domain. Here focus is on the fact that creativity primarily changes the world, rather than merely the mind of the creator.

Modern creativity research has all but ignored the second approach that points to the inclusion of the real-world in the study of creativity. The present thesis is an attempt to *highlight the need for a synthesis of the realist and the constructivist approaches to the study of creativity, as well as an attempt to actually generate a framework for such a theoretical synthesis capable explaining the creative process in reality.* The road to such a synthesis will go through an analysis of the central notions of 'creative cognition' and 'creative search'. The synthesis will be formulated with inspiration from ecological cognitive psychology and Activity Theory. A plethora of subproblems to this overarching project will be treated in this thesis.

The basic structure of this thesis will be to first analyze an approach to creativity that views creativity as a process occurring in the mind of the creator. The approach chosen is the Information Processing approach. Having reviewed the strengths and especially the limitations of this approach, the need for a synthesis between so called constructivist and realist approaches to creativity is discussed and recommended. After having overcome some obstacles facing such a synthesis, a framework for an ecological cognitive approach to creativity is created. And finally, this framework is viewed in the light of existing research on the creative process.

Part by part, the thesis will progress as follows:

In part two, I will discuss and define the concept of creativity, along with other concepts used in this thesis. Further I will provide a brief overview of the creativity research domain in order to explain the limits to the present analysis.

Part three is an analysis of so called Information Processing approaches to creativity. I will highlight their strengths and limitations, and criticize them on a number of counts. Because the Information Processing (IP) approach to creativity views creativity as a search for a solution to a problem in a problem space, the concept of *search* is analyzed in relation to creativity. I will ask what it is the IP theories seek to explain by placing such a heavy emphasis on 'creativity as search'. Based on the limitations of the IP theo-

ries I will carry out a discussion on the need for a synthesis between so called 'realist' and 'constructivist' approaches to creativity.

Part four will discuss some initial dilemmas concerning ontology and search facing any theory of creativity that seeks to incorporate a realistic aspect (i.e., an ecological approach) into the theoretical framework. I will ask how an ontological framework for the creative process in reality can be viewed, and how the search for novelty is possible.
After an attempt to overcome these dilemmas, an ecological cognitive framework for the creative process is generated.

Part five will further specify and clarify the ecological cognitive framework by analyzing *cognitive* aspects of creativity. In particular, it will deal with the distinction between 'internal' and 'external' creativity; the types of processes in play in creativity; the structure of knowledge; and constraints on creative generation.

Part six will finally relate existing research on stages, elements and characteristics of the creative process to the ecological cognitive framework created in earlier sections, in order to estimate the degree of fit between them.

Finally ideas for future research are provided.

But before embarking on this quest for a synthesis between realist and constructivist approaches to creativity, we first need to define the phenomenon we are dealing with…

PART II: SETTING THE STAGE

"New forms do not come from nothing, not for us humans at any rate; they come from prior forms, through mutations, whether unsought or invited. In a fundamental sense, there are no theories of creation; there are only accounts of the development of new forms from earlier forms."

- Frank Barron

2 SETTING THE STAGE

In this section I will define creativity and other central concepts to be used in this thesis, along with outline the domain of creativity research and pinpoint where the problems undertaken in the present thesis fit in.

2.1 Creativity – a definition

One would think that consensus on the definition of an evasive phenomenon like creativity would be scarce. But surprisingly there does seem to be some consensus as to at least two necessary components[1] of creativity. As Mayer (1999a) writes:

> "In summary, there is some consensus in the creativity research community concerning what to study: Creativity occurs when someone creates an original and useful product." (Mayer, 1999a, p. 451)

This definition allows creativity a special place among constructs in psychology. No other psychological construct I can think of is defined by qualities (originality and usefulness) of *products* in the world (even though the definition also points to the subjects creating the products). Compare for example with definitions of intelligence, extraversion, or learning.

Various phrases for the same underlying constructs have been used: The *originality* component has also been called novelty or variability, and the *usefulness* component has also been called adaptive, appropriate or valuable, depending on what the individual theory seeks to focus on. But novelty (originality) is always considered the most important necessary criteria for creativity.

However, these two concepts (novel and useful) are somewhat vague and unspecific. Simply stating that a product needs to be 'novel' and 'useful' really does not help us much in understanding what creativity is. I believe that the two concepts, although pointing in the right direction at a very general level, need to be made more specific. Not all products labeled 'novel' and 'useful' are necessarily creative. A person making his 105th counterfeit ten-dollar bill is, for example, creating something novel and useful in a broad sense, although most people would certainly not term that a creative act.

The specified definition of creativity used here is this: c*reativity occurs when someone brings a product with generalizable originality and with the potential for adaptive spread into being.*

In the definition, the term 'product' is to be understood in a broad sense - to imply anything ranging over theories, literature, paintings, inventions, discoveries, dances etc. The concept of 'novelty' is specified by pointing out that it needs to be 'generalizable originality', and 'usefulness' is specified to mean 'potential for adaptive spread'. In the following two sections I will clarify why this specification is necessary.

2.1.1 Novelty

Novelty, although being the single most important criteria in the definition of creativity, is also one of the most philosophically debated subjects. What does it mean that something new is brought into existence[2]? How is it even possible? The dictionary explanation[3] of creativity seems to hold that creativity has to come into being out of nothing. Perkins (1988) called this seeming paradox the 'ex nihilo' problem. It probably derives from the observation that prototypical creativity brings into being some 'thing' never before seen by mankind. How can this be? – that a product suddenly appears seemingly coming from nowhere. This seeming paradox can, however, be resolved by studying creativity in its process; by studying how the development of novelty occurs, and how it actually comes about. The problem with focussing on the end product is, as Ghiselin says:

> "All finished productions have the simplicity of order, which reveals itself rather than its origins" (Ghiselin, 1952, p. 18)[4].

The *end product* view analyses the question to be one of two states ('not here before, now here') - with the link between the two being the inexplicable part. However, the approach taken here is that of *process* analysis. This focus on *process*, rather than *product* presents an answerable question to the creativity researcher: what are the mechanisms and processes that enable the production of novelty to occur? It is analyzing how one state came to be another and what actually happened in the coming into being of the novel product. Where did it come from? How was it created? What was joined and taken apart?
Below follows some notions and specifications on the kinds of novelty needed in creativity.

2.1.1.1 Kinds of novelty; novelty of kind

Depending on frame of reference and definition, novelty can be seen as a rare feat or a commonplace occurrence. It is certain that the kind of novelty we see in novel recombinations, novel connections and creation of novel singular objects is very common. We create this kind of novelty all the time every day in action. Most action performed bring together or take apart, move, connect and combine etc. Such common creation of novel connections between objects and subjects are not novel in the sense needed in creative products. As Hausman argues:

> "[…] it seems that a necessary condition of the novelty is the presence in an object of irreducible and unprecedented or unpredictable difference. However, it is obvious that if novelty were nothing more than irreducible, unprecedented difference between an individual thing and its antecedents, then novelty could be ascribed to every discriminable thing. Each event or object in the world can be considered new with respect to its singularity" (Hausman, 1984, p. 20).

Singularity is thus not the right kind of novelty required for creativity. And indeed it may come as a surprise to some that singularity of a product is not that important for creativity. I will now try to explain why. As described above, novelty and originality are used to describe the same essential construct for creativity. 'Original' has two meanings. It can be a noun ('an original'), implying singularity and object permanence or a verb ('to posses originality'), implying being the *first of a kind*. And this is a very important point. When judging creativity, THE original is virtually unimportant, as singularity is not the kind of novelty needed in creativity.

The kind of novelty needed in creativity is *novelty of kind*. The creative product needs to be a *first instance* of a category or tradition, in short, 'of a novel kind'. In virtually all creative fields (theories, inventions, discoveries, literature, prose, and so on) there is no difference between the original and exact copies thereof, in terms of their level of creativity. Think for example of a first manuscript for a book as opposed to subsequent copies. (A special case are arts and crafts, where the original is important due to the craftsmanship). Thus creativity is not attributable to some single, numerical identical, object. The creativity refers to the 'over-singular generalizability' of the product, to the 'kind' it is the first exemplar of.

Something is not creative because it is a novel singularity, but because it somehow stretches *beyond* a particular object. Thus, *'an original'* does not imply creativity, but 'a product *with originality'* does. 'Originality' refers

to the beginning of a tradition or kind, and stretches forward in time, implying that later exemplars of this novel structure can be made. This means that the originality in creative products is generalizable. Not only in terms of exact copies, but also in terms of mutations thereof. Mutations are further developments of this first exemplar that can still be fitted under the umbrella of the 'kind' implied in the first exemplar (the original). A creative product must be an exemplification of a (generalizable and original) kind. Besides being generalizable (i.e., having a structure and properties that are transferable across products), the originality of kind must be sufficiently distinct (different and separable) from other kinds of products. Indeed, this is what it means for a kind to be 'original'.

To summarize: The novelty in creativity is a novelty of *kind* (of which the particular creative product is an exemplification). Novelty of kind implies that there is a structure in the creation that stretches beyond the particular product. This structure is generalizable and potentially applies to other products. Novelty of kind needs to be distinctly clear from other kinds (otherwise, it is, of course, not novel). The novelty in creative products needs to be 'generalizable originality'. For the remaining part of this thesis the use of the concept 'novelty' will be used in this sense.

2.1.2 Usefulness and adaptability

The criterion of usefulness in creativity seems straightforward, as the criterion of novelty has to be qualified by some kind of evaluation. Novelty alone does not cut it – simply producing random novelty without purpose or value is not creative. Consider for example schizophrenic ramblings - although novel recombinations, they can hardly be considered creative. However, the criterion of usefulness becomes complex when one asks 'useful to whom?' Perhaps because of this complexity some authors use the term adaptability in stead. By using adaptability, the qualifying criterion is directed towards human development *in context.* We, as humans, can increase our knowledge of the world, and adapt our world to us or us to our world.

Adaptability for humans can have to do with directing our activities towards the tension between what we can presently explain about the world, and the actual world (an sich). The standard example of this has become the fact that according to our theories of flight the bumblebee should not be able to fly (although allegedly that quantum physicists have indeed found a way of explaining this now). Such a tension between ontology and epistemology is a constant source of creative problems in need of discovery and

solution (e.g., Perkins, 1988). Similarly, human motives and needs opposed to the demands and strains of the environment are a constant source of inventive problems and solutions that can be considered useful or adaptive. For example, finding ways to find time for both work and family life *can be* a creative problem for the individual. These are two general (but not the only) sources for creative problems, and they operate on all levels of human activity (individual, societal, species).

Many theories focus exclusively on adaptability of the *single person* to an environment. Recently, though, there has been an increased awareness of the fact that prototypical creativity involves introducing adaptive novelty that is useful to the entire society or species. Csikszentmyhalyi (1988; 1990) has created a systems approach to creativity, where a creative product is evaluated in relation to the entire domain within which it is created. The evaluation is done by gatekeepers (called 'the field') of the domain. Creativity, in such a model, is not evaluated in isolated objects, but must be evaluated against the traditions, history and evaluative functions of the entire system.

These findings implies that usefulness (adaptability) can not be evaluated on the basis of human universals but must be seen in context. The usefulness of a product can thus be seen as adaptability to the current domain or context.

There is a problem with this, however. Viewing adaptation is this way can be problematic in that it seems to be evaluating a novel product in relation to the past. It seems to imply that the usefulness of a product is best measured in relation to the prior history of a domain. But maybe usefulness should instead be measured as it's *potential impact* on the domain? If we consider inventions such as the TV or the laser, then it does not make much sense to measure usefulness in terms of what (needs and motives) was before, and what context was at the time of conception of these products. It is surely a stretch to say that society *needed* TV, and hence it was a useful invention. Measuring in this manner will necessarily underestimate usefulness in radically new and different products, as they may not seem to be filling an adaptive hole or need!

Fortunately there is another way of conceptualizing usefulness. Usefulness must be seen in relation to the future. As we saw above in the novelty section, novelty of kind implies that a product is generalizable. By measuring usefulness in relation to the future, we are actually measuring a product's

potential for generalizable spread in the present context or domain! We are estimating how far this new product will go – the number of copies sold, the number of quotes made, the number of times used, the number of people using it, the number of mutations made of it, the length of time it is used and so on[5].

Thus evaluation of usefulness, rather than being an evaluation of what needs it seems to be filling, is an evaluation of the potential of how far this adaptation can spread in the present context or domain.

The concept of 'spread' is inspired by Richards Dawkins' (1976/1989) 'meme' concept. Memes are an equivalent of genes, operating by the same basic principles, but at a cultural level.

> "Examples of memes are tunes, ideas, catch-phrases, clothes fashions, ways of making pots or of building arches. Just as genes leap from body to body via sperm or eggs, so memes propagate themselves in the meme pool by leaping from brain to brain via a process which, is a broad sense, can be called imitation. […]. If the idea catches on, it can be said to propagate itself, speading from brain to brain." (Dawkins, 1976/1989, p. 192).

Dawkins argued that the same three qualities that ensure gene survival (fecundity, longevity and copying-fidelity) could ensure meme survival (however, in the present argument these qualities should not be taken as more than a metaphor).

An issue that should be addressed by a theory arguing that usefulness in creativity is really 'potential for adaptive spread', is the existence of destructive inventions, such as instruments of war, or ways of exploiting other people, or other inventions that can harm humans and human society. We do not usually refer to such products as 'creative' although they do seem to have the ability to spread in society. This points towards the normative aspect of creativity, i.e., that creativity is generally considered good. However, as argued here, products are evaluated as being more or less *adaptive to a particular context or domain*. A domain, as argued by Csikszentmihalyi (1988; 1990), can be synchronized swimming, backgammon, Mormon religion, the scientific discipline of psychology, gun making, or any other symbolic system that has a set of rules for representing thought and action. Viewed in this manner, the invention of a novel kind of weapon may have the potential for adaptive spread in the domain of weaponry production. Similarly, the invention of a destructive computer virus may be creative from the perspective of the domain of computer programming, just as ways

of bookkeeping can be creative, although they are also deceitful. When usefulness is defined as the potential for adaptive spread in a context or domain, then of course, what the domain (or context) is, partly decides what is deemed useful. But in general (i.e., in most domains), creative products are synonymous with constructive (rather than destructive) products.

How can the 'potential for adaptive spread' be measured? Any evaluation can only be an estimation of '*potential* spread' because at the time of conception of the product, we do not yet *know* how far this novel kind of product will go and what the impact on the domain is going to be. We can only try to estimate. 'Spread' can be defined as the extent to which a kind is generalized in time (persistence, durability over time) and space (spread in number of copies and mutations at any given time). One can find similar views in e.g., Simonton's (e.g., 1999c) historiometric method (e.g., by using number of citations to evaluate the creativity of scientific literature).
One *can* objectively measure how far a product actually spreads in this manner – but only post hoc. Any person attempting to evaluate the creativity of a novel product right after it's conception can only do so through a complex evaluation of 'potential for spread' in a given domain based on the persons im- and explicit knowledge of the particular domain and field. But although such an evaluation is quite uncertain, it is not to be discarded, as it is more inclusive than the objective post hoc measure. Some products having had the potential to spread, may not actually spread (for example due to lack of communication), and thus will be underestimated by a method estimating objective spread post hoc. An estimate of 'potential for adaptive spread' is exactly what we are looking for when evaluating the usefulness of a product. This is due to the fact that 'objective spread post hoc' may devaluate the usefulness of the products that *did not* spread, however great their potential was. But choosing a strategy for measuring usefulness (either the objective 'spread post hoc' or the subjective 'potential for spread') is always a compromise[6].

To summarize: usefulness in creativity is *potential for adaptive spread*, and it will be used in this sense for the remaining part of this thesis. This brings us to the entire definition of creativity: c*reativity occurs when someone brings a product with generalizable originality and with the potential for adaptive spread into being.*

We can now see why a person making his 105th counterfeit ten-dollar bill is not creative. The particular product he is currently making (his 105th ten-dollar bill) is not an exemplification of a kind with generalizable original-

ity. Creating a product that is novel only with respect to its singularity is not novel in the right way for creativity. If the person, on the other hand, was the inventor of a novel production method for the bill, it could be another matter. The usefulness of the ten-dollar bill may also be in question depending on which domain the product is believed to be an adaptive contribution to (society vs. organized crime).

2.1.3 Levels of creativity

The above definition of creativity still leaves open to discussion what *level* of 'generalizable originality, with potential for adaptive spread' should be considered creative.

Both elements in the definition can occur at various levels. Novelty can be novel for a particular person, for a group of people, for a society, or for the entire population of the world (e.g., Johannesen, Olsen, & Lumpkin, 2001). Similarly, the product can spread simply in the frequency of use of the product by the creator (within the future action of a single person), spread between individuals in a group of peers, or spread between individuals in entire societies or domains.

So what are we to call creative? Is it the toddlers discovery (and continued use) of how his hands can be used to grasp things? Or is it Einstein's theory of relativity we are talking about? Many creativity researchers have given thought to this subject, and taken sides, or tried to describe the levels of creativity.

On the one hand, there are theories such as Creative Cognition, that argue for creativity being ascribed to all levels, including so-called 'mundane' creativity (e.g., Ward, Smith & Vaid, 1997). Here we also find Boden (1991), who argues that psychology should concern itself only with mundane creativity that is novel to the individual (she calls it P-creativity, for 'psychological'), rather than creativity that is novel for the entire world (called H-creativity, for 'historical'). Anything H-creative will also always be P-creative, and, argues Boden, studying historical creativity is beyond the scope of a psychological theory. On the other hand, we have Dean Keith Simonton arguing for creativity being ascribed to people making products that change societies or domains (e.g., Simonton, 1999c). Finally, some researchers have tried to classify the levels between the two extremes (see e.g., Cohen, 1989; Cohen & Ambrose, 1999, and her 7 levels of adaptive creative behaviors, ranging from 'learning something new' to 'transforming a field').

Below I have provided my own interpretation of the levels of creativity. The reason for the distinction is only to pinpoint which level I am referring to as 'creative' in the present thesis. In my distinctions below, I have included 'level of competence of the creator' to accommodate a developmental aspect - what Vygotsky (1978) calls the Zone of Proximal Development[7]. I believe the levels of creativity should be categorized according to two criteria:
(1) Who is making the judgement about creativity (the creator, a more competent person, or experts (i.e., what Csikscentmyhalyi, 1988; 1990, calls 'the field'))
(2) Whether the product is *novel* to the creator, to peers, or to the entire domain – along with whether the product will *potentially spread* to the creator's own actions, to peers, or to the entire domain.

Level of creativity	1	2	3	4
(1)Who is making the judgement?	Creator	More competent person	More competent person	Experts (field)
(2)To whom is the product novel, and to whom will it potentially spread adaptively?	Creator	Creator	Peers	Domain

Fig. 1. Levels of creativity

As figure 1 illustrates, there are clearly distinctions to be made. Most prototypically creative is of course level 4, with revolutionary scientific discoveries, and groundbreaking inventions. I believe it is a matter of vocabulary what you call the different levels. Should they all be called 'more or less creative', or should the word 'creative' be restricted to only some levels?

In the present thesis, I use 'creative' in the sense of level 4 (evaluated by experts, novel and useful to the domain). By doing so, I am disregarding developmental aspects of creativity (i.e., I am not including the level of competence of the creator in the evaluation of creativity). Novelty and usefulness at this level concerns everybody (the creator, the domain, and the evaluators alike). At lower levels of creativity, a debate about whether *learning* can be considered a creative process is inevitable. After all, in learning, a person gains a skill that is novel and useful to the individual. It is, however, not novel beyond the individual, which is the point made here. Learning is reproducing (or recreating), whereas my focus is on first time

production beyond the individual level. This distinction enables me to disregard what could be called a 'level of competence' debate (i.e., whether the creativeness of a certain product should be evaluated according to the level of competence of the creator). Note, however, that I am not for that reason discounting that creativity *can be* viewed from such a perspective, but it is simply not the focus of the present thesis. By making this distinction I am pointing out that the kind of creativity I am after lies *beyond* the Zone of Proximal Development, that is, beyond what more capable peers can help you achieve. Hence, in the present thesis, I am dealing with products that are novel to the entire domain (including the creator and evaluator), and which possesses the potential for adaptive spread across individuals in the domain, as evaluated by experts.

After having reviewed the concept of creativity and its definition, I will now try to outline the creativity domain, and focus in on the problems undertaken in the present thesis.

2.2 Limitations of the present analysis - The creativity field narrowed down

The purpose of this section is to pinpoint the focus of this thesis by providing a sketch of the creativity field, and then highlight what is included and excluded from the present analysis. To provide us with the overall sketch, I have made the obvious choice to use a classic model in the creativity literature. It is the four P's model of creativity.
The model simply separates the creativity domain into four[8] mutually dependent areas: the creative **Product**, the creative **Process**, the creative **Person**, and creative **Press**.
Rhodes (1961) and Mooney (1963) were the first to use this model. Rhodes used it to divide the domain into subareas after having failed to find a single unifying definition of creativity, and Mooney used it to provide an overview of the domain, by separating concepts and theories into their main area of focus. The four areas are obviously closely related, and a complete theory of creativity must deal with all of them. Here I will briefly review these areas mainly to highlight the limitations of the current analysis of the creative process and reality.

Theories focussing on the creative **person** focus on individual differences in creative endeavors. This is definitely a main area of focus in the creativity literature, attempting to find the defining characteristics of creative people, compared to less creative people, or even uncreative people. Creativity is for example seen as personality traits, abilities, types of motivation,

styles of thinking, and related to IQ and psychopathology. I will not touch upon this major area of focus in this thesis, as my aim is a general psychological one. I am assuming that all people exhibit creativity to a greater or lesser extent. At the general psychological level of analysis used here, I assume that the processes involved in creative endeavors are similar for all people. This is not a dismissal of the fact that people vary in their *specific* creative processes, or that creative geniuses do exist, however that is simply not the focus of the present analysis. This does not necessarily contradict the limitation that only products that are novel and useful to the domain (as evaluated by experts) are termed creative in the present thesis, as I am *not* assuming that such products can only be brought about by creative geniuses. The present thesis deals with the creation of products that are novel and useful to a domain, but it does not deal with individual differences among the persons making such products.

Theories focussing on the creative **product**, tend to highlight the characteristics of the results of creativity. I briefly hinted towards this area of focus in the section on novelty above. Historically a focus on the sudden appearance of a product, not before seen in the world, can easily lead one into the 'ex nihilo' problem. Focussing on the result of the process (the final product) can make creation seem impossible, as the creation can seem to come into being out of nothing. The solution lies in focussing on the historical making of the product – the creative process - instead. I will proceed in my analysis without further reference to the exact nature of the creative product. I will leave it at the few remarks made in the 'definitions' section above.

Theories focussing on creative **press** focus on the impact of the environment on the creative individual. However, usually 'the environment' is understood as being merely the social and psychological climate and sometimes the negative effects of the immediate physical setting the individual in placed in to do his or her creative work (see Davis, 1999). This focus on creative climate (e.g. in organizations) can be seen in theories by Amabile (e.g., Amabile et al., 1996), Ekvall (1996) or in Carl Rogers' (1954/1970) focus on psychological safety. In the present analysis, with its focus on the creative process in reality, it would seem obvious to include discussions of press. And indeed environmental influence on the creative process is part of the basic underlying discussion carried all the way through the thesis. But the environment is understood much more broadly than the 'social and psychological climate and sometimes the negative effects of the immediate physical setting'. The concept of environment as used here goes beyond the

climate concept, and includes e.g., any setting or object ever experienced. We will see in part 4 how the concept goes even further, when creative ontology is discussed.

A note should be made on individual vs. social creation. The present analysis takes as its focus the single individual in the creative process in his or her environment. This has been a traditional way of studying the creative process, and it is the one used here as well. However, taking such a standpoint can easily lead in a straight line to an image of the individual as the Grand Creator, while forgetting the social nature of the process and the origins of the elements and the nature of the processes that brought the final product about. The present thesis will thus be ill equipped to explain e.g., creativity in groups. But the present thesis does not ignore social aspects, as culture, society, and other individuals are also included under the heading of the environment. So even though the individual in the creative process is the focus, social processes are not completely excluded.

A further note should be made on the concept of domains. As briefly touched upon in the section on usefulness, some theories evaluate creativity in a systems model, with reference to a given domain. This has recently (re-)sparked the discussion on the domain specificity or domain-generality of creativity (both in terms of whether intra-psychological processes are domain general or -specific, and in terms of whether the necessary and sufficient criteria for evaluating creative products are domain general or specific). It is clear that different domains do have different specific criteria for evaluating a product as being creative. A scientific model, besides being novel in the right way, also has to be useful in the right way (what I above describes as 'potential for adaptive spread'). But the criteria constituting 'the right way' in science is not the same as the criteria in art etc. Spread often occurs only within a very particular domain. Therefore it is necessary to mention that the examples of creativity used in the present thesis are from the domains of discovery and invention[9]. At least to some quantitative degree this focus will make a difference if attempts to transfer the present analysis to other domains will be made. Whether there are qualitative differences as well, I will leave open for further investigation.

Finally we have arrived at the creative **process**, which is the main focus of the current thesis. Theories focussing on the creative process usually divide the creative process into a number of stages, and analyze the cognitive (and sometimes conative and affective) components and mechanisms operating in the different stages. I believe this is the best scientific approach when

one wants to study the historical emergence of new phenomena, and is hence preferable in an analysis like the present, where the mystical historical coming into being of novelty is in focus. However, there are several points to be made in relation to the exact nature of the present analysis. For one thing it is essential to differentiate between the creative process and creative problem solving; it is necessary to point out which mechanisms will be dealt with etc. Therefore an extended view of what characterizes the creative process, and what will and will not be discussed in this thesis, will follow in the next section.

2.2.1 The creative process – a description

Before delving into the characteristics of the creative process, a few discriminatory definitions have to be made. Many people find it difficult to distinguish between 'creativity', 'the creative process', 'problem solving' and 'creative problem solving'. This difficulty is partly caused by shifting uses of terminology (Treffinger, 1996). As indicated in the above section, 'creativity' is a broad concept, referring to process, person, press and product. The creative process is the focus of what goes on in creation (mechanisms, stages, etc.). However, one often sees reference to 'problem solving', and 'creative problem solving' in creativity literature. How are these concepts to be understood in relation to the creative process?
Problem solving is a research tradition distinct from the creativity field, and the creative process. It is defined as "[…] cognitive processing directed at transforming a given situation into a goal situation when no obvious solution method is available to the problem solver" (Mayer, 1999b, p. 437).

This means that, although the terms 'creative process' and 'problem solving' do have an overlapping set, they are also distinct phenomena (see fig. 2).

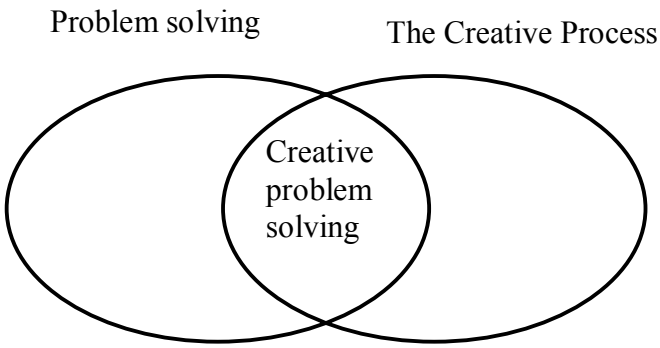


Fig. 2. The relationship between problem solving and creative problem solving.

The part of 'problem solving' involving creativity is called '*creative problem solving'*. Compared to problem solving in general, creative problem solving is characterized by including what could be called 'creative aspects' in one or more of the elements of problem solving (i.e., the initial state, the goal state, and the solution method or operations). Insofar as one or more of these elements are missing or unclear, we are dealing with a *creative* problem to be solved (Cropley, 1999, p. 517). As such, the type of problem at hand seems to demarcate problem solving from creative problem solving[10]. For example, well-defined problems (i.e., initial state) with clear structure would involve ordinary problem solving, while a fuzzy, ill-defined or ambiguous problem would involve the specific case of creative problem solving (Treffinger, 1996, p. 18; Reitmam, 1965). The same is true of both solution method and goal state[11]. A typical example of a well-defined problem is a position in the game of chess, whereas an ill-defined problem could be a problem like 'Tell me all the different ways you could use a hat rack?' As the above model (fig. 2) indicates, the creative process includes more than 'creative problem solving'. While creative problem solving is particularly directed at problem *solving,* it largely ignores the research area of *problem finding* (e.g., Getzels & Csikszentmyhalyi, 1976; see Jay & Perkins, 1997 for an overview). Problem finding directs attention towards the fact that the creative process far from always involves a clear, rational and directed search towards a goal. Often the thing to be found is not a goal, but a clarification of the problem. Indeed redefining the problem one undertakes can be a creative endeavor in itself. What the area of problem finding is indicating is the circular nature of the creative process. Finding problems will spark off solution attempts, while solutions will create novel problems and opportunities to be found. This is pointing towards the dialectic tension between invention and discovery, where developments in one create opportunities for the other. There is no true start and finish in the creative process. Besides the focus on problem finding, a number of other differences exist between creative problem solving and the broader research area on the creative process (e.g., focus on the affective aspects in the creative process). In conclusion: 'Problem solving' and 'the creative process' are somewhat distinct research phenomena although they have an overlapping set in 'creative problem solving'.

Having made these discriminatory distinctions between the creative process, problem solving, creative problem solving, and problem finding, I now define the area of focus in the present thesis to the creative process in general. It will thus not concern problem solving in general, although *creative*

problem solving will be included as a natural, but somewhat limited, view on the creative process. Where appropriate, the terms *creative process* and *creative problem solving* will be used.

Even though creativity cannot be said to posses a true start and finish, the creative process does indeed, at least descriptively, seem to go through a number of stages.
We will now look at what characterizes the creative process, and its various stages.

2.2.1.1 Preparation–incubation–illumination–verification

Wallas (1926) devised a model of four stages of the creative process. The model has stood the test of time, as the model today is widely accepted, and is (at least descriptively) virtually unchanged since its conception. Later research (e.g., Ghiselin, 1952; Koestler, 1964; Shaw, 1994; Seifert et al. 1995; Cskikszentmihalyi & Sawyer, 1995) on the creative process have often made use of the same, or very similar, concepts to describe the developmental stages of the creative process. The model is strengthened by the fact that Wallas, in his original presentation, underlined that the model was not to be perceived as fixed in its progression through stages (one can indeed go back and forth, as the task demands it). Furthermore he underlined that several different tasks could be carried out at different points in the process, at the very same time. And he also underlined that the process could last from minutes to years. These and other precautions have allowed Wallas' model to live, while other stage theories in psychology have suffered. The four stages of the model are presented below, with particular focus on discriminatory aspects and recent punctuations of particular elements in the model.

2.2.1.1.1 Preparation

The creative process, as explained by Wallas' (1926) stage model starts off with a preparation stage. Thereby it is highlighted that creativity is not simply a sudden moment of insight, but actually requires the acquisition of knowledge of the domain, as well as conscious work on the problem at hand. In the preparation stage the subject learns about the domain, acquires skills and knowledge, and explores and clarifies the situation. Thinking about requirements for a good solution occurs, and relevant information is gathered. In short, it is hard work, immersing the person into the domain. The work is mostly of a conscious and deliberate nature, according to Wallas (1926). An important aspect of the preparation stage is that at some

point, after having narrowed the problem down, and worked on it, the subject reaches an impasse. The problem cannot be solved by means of his or her present (structuring of) knowledge of the situation. The subject recognizes that an impasse has been reached, and that ends the preparation stage.

2.2.1.1.2 Incubation

Descriptively, the incubation stage can be thought of as temporarily setting a problem aside after a period of initial work, and it usually occurs after an impasse has been reached that blocks (awareness of) the solution (Smith & Dodds, 1999, p. 39). In short, not much seems to be going on. The subject goes about his or her daily business, and does apparently not work consciously any further on the problem. Wallas believed that incubation should be explained by unconscious processes:

> ”The Incubation stage covers two different things, of which the first is the negative fact that during Incubation we do not voluntarily or consciously think on a particular problem, and the second is the positive fact that a series of unconscious and involuntary (or foreconscious and forevoluntary) mental events may take place during the period.” (Wallas, 1926, p. 86)

The time away from the problem may be spent on conscious work on other problems, or in relaxation from all mental work, according to Wallas. The theory that unconscious mental processes are involved, or even explains, the need for an incubation stage has been repeated many times in the creativity literature. Ghiselin (1952) argued similarly in his classic review of how a large number of creative individuals explained their own creative process, and it was also a central point in Koestler’s (1964) classic work ‘The Act of Creation’. However, alternative explanations have been developed. Smith & Dodds (1999) list the various theories about the function of incubation. At least six different propositions have been offered, ranging from 1) simply time to do further conscious work, 2) recovering from fatigue, 3) forgetting inappropriate mental sets, 4) remote association, 5) unconscious work, and 6) opportunistic assimilation. After having put the problem aside for a while, an ‘incubation effect’ can result in an illumination (i.e., a sudden realization of a solution), which occurs either during the time away from the problem, or when one returns to the problem after the incubation period. Illumination is the next stage.

2.2.1.1.3 Illumination

The illumination stage is more frequently referred to as 'insight'[12]. It refers to the well known phenomenon in the creativity literature of a sudden and surprising feeling of arousal, linked with a feeling of knowing the answer, or a method for reaching the answer. In the literature it has also been called the AHA! experience or the Eureka phenomenon, and the literature is full of anecdotal evidence for its existence. Kekulé, Archimedies, Alexander Flemming and Sultan have become household names in this respect, and everybody in the creativity domain knows of their sudden discoveries of everything from the ringlike structure of benzene molecules, the theory of displacement of water, penicillin, and the connection of two sticks used to reach for a banana.

Depending on frame of reference, various insight theories usually highlight either the *affective* aspects of suddenness, spontaneity, unexpectedness and satisfaction (e.g., Gick & Lockhart, 1995; Seifert et al., 1995); or the *cognitive* problem solving aspects of a movement from not knowing how to solve a problem, to suddenly knowing how to solve it (often involving restructuring) (e.g., Weisberg, 1995; Mayer, 1999b; Ohlsson, 1992). Correctness and completeness of the solution is often implicitly assumed in the latter frame of reference.

Sternberg & Davidson defines insight as:

> " […] a distinctive and apparently sudden realization of a strategy that aids in solving a problem, which is usually preceded by a great deal of prior thought or hard work; often involves reconceptualizing a problem or a strategy for its solution in a totally new way; frequently emerges by detecting and combining relevant old and new information to gain a novel view of the problem or of its solution; often associated with finding solutions to ill-structured problems." (Sternberg & Davidson, 1999b, p. 58).

The definition is quite loose due to the many 'neither necessary, nor sufficient, but nonetheless often present' aspects of insight that is included. Thus it seems that insight in essentially 'an apparently sudden realization of a strategy that aids in solving a problem', with the rest of the definition being merely frequently occurring qualifiers. The essential first part seems to highlight the problem solving nature of insight, with the sole additional necessary criteria being suddenness. Remembering the distinctions from the previous section, one could argue that this definition deals more with 'problem solving' than with the creative process (i.e., the focus on a

movement from 'not knowing how to solve' to suddenly 'knowing how to solve' - see Mayer, 1999b). However, the definition is saved by the long list of qualifiers, which point in various directions in the history of theoretical dealings with creative insight. Some of them will be briefly touched upon below.

First of all, the definition is qualified by the adding of the concept of *work*. Insight is linked to the previous stages of incubation and preparation, and requires the additional stage of verification in order to constitute a creative process. Insight out of this framework is not creative, although a number of theories would have us believe this. Second, the definition points towards ill-structured problems as the source of insight, rather than well-structured problems, thereby moving focus from problem solving in general, towards creative problem solving. Third, the concept of problem *finding* is implicitly included in that one can '…gain a novel view of the problem…'. Forth, the concept of combinatory processes is included, thereby pointing towards theories of idea generation and recombination and analogy, and their central role in producing novelty. Fifth, insight only have to *appear* sudden, thereby finding a common ground between theories arguing for the incremental nature of the creative process, and theories arguing for sudden changes in the process (this point will be elaborated in the following section). Sixth, some insights are reconceptualizing, i.e., altering the conceptual space. This directs towards the Gestalt notion of restructuring, which in Gestalt psychology is necessitated by fixation[13]. Restructuring was believed by the gestalt psychologists to be the *sine qua none* of insight. Classic types of Gestalt fixation are 'mental sets'[14] and 'functional fixedness'[15].

Although these six (and other) concepts qualify the definition made by Sternberg & Davidson, the definition seems to be lacking most of the affective components that are so characteristic of having the AHA! experience. Insight is not only sudden, but also surprising (unexpected), and followed by an increase in arousal. Perhaps this lack of focus on affective elements is due to the 'problem solving' nature of the present definition. As mentioned above, such cognitively focussed definitions often implicitly assume that insights are correct, or at least a step in the right direction. However, focussing on the affective aspects can highlight the fact that insights can be, and indeed often are, wrong!

Another point to be made on the insight phenomenon is that insights seem to imply giant leaps in knowledge. From one second to the next new knowledge appear. However, as Gruber (1995) argues, 'leaps' need to be seen in context. When one is immersed in an insight, emotions are running high, and often the experience is remembered long after seemingly with

'flash-bulb like' clarity. But what seems like a gigantic leap from the perspective of the person having the insight, is perhaps nothing but a small step, viewed in the historical development of the entire idea, product or concept[16]. Similarly, viewed in retrospect the insight is usually easily incorporated into the continuity of the creative process, however discontinuous it feels at the exciting moment.
This difference in how continuous (or 'big') an insight is perceived to be (depending on where and when it is viewed from) has been called 'telescoping' by Gruber (1995). One needs to take this effect into account when discussing whether insights are really leaps of knowledge, or part of a strictly continuous process. There is no reason they cannot be both, depending on perspective.

2.2.1.1.4 Verification

After an insight has occurred, the subject needs to verify that the results are correct. In later models of the creative process, this stage is often referred to as 'elaboration' or 'evaluation', implying that an insight usually is not 'the whole story', but normally just a clarification in need of further work. So in this stage one evaluates the insight, develops and refines it further, and tests the validity of the insight. Insights are merely preliminary solutions or solution aspects, and need not concern the whole problem undertaken. The stage of verification may not seem as interesting as the other stages, but it is vital to ensure the validity of the insight; to test whether what one thinks will work, actually will work.

Having reviewed the definition of creativity, and narrowed down the aspects of the creativity domain that the present thesis will embark on examining, it is now time to start looking at the creative process, and its relation to reality. We will start by looking at the Information Processing theories, and their explanation of creativity.

PART III: CREATIVITY AS SEARCH – INFORMATION PROCESSING APPROACHES

"The creative act is not an act of creation in the sense of the Old Testament. It does not create something out of nothing: it uncovers, selects, re-shuffles, combines, synthesizes already existing facts, ideas, faculties, skills. The more familiar the parts, the more striking the new whole."
- Arthur Koestler

3 CREATIVITY AS SEARCH – INFORMATION PROCESSING APPROACHES

When one wishes to examine how the creative process takes place in reality, a natural place to start is to view creativity as a search process. The creative process, as briefly reviewed in the previous section, proceeds through several stages, producing a novel and useful product. As such, the creative process can be described as a directed activity, as a searching process taking place in the world. The clearest proponent of this approach to creativity (i.e., viewing it as a kind of 'search') in the literature, is the information processing (IP) approach to creativity. I will start out by examining closely IP theories of creativity.

A search can be described as conative because it involves a subject being actively directed towards an object. As such, search is inherently a relationship between a subject and an object. Any search theory must necessarily include a subject, action, an object, and a space within which the search takes place. In a search the subject moves around the space to bring him or her into contact with the desired object. Furthermore, the space includes constraints of various kinds, and the subject's actions can be described as entailing search strategies. There are of course many kinds and levels of search, not all of which are creative, and theories of creativity as search focus on a very specific kind of search. The majority of this section will center around an attempt to characterize what the IP theories mean by the different elements (subject, object, activity, space) of search in creativity. The discussion will then center on the strengths and limitations of the IP approach. Finally I will argue that the IP theories constitute an inherently constructivist approach. Further I will argue that a synthesis between constructivist and realist approaches to creativity is needed for a complete explanation of creativity.
As it will become clear, in the IP approach to creativity, a search is inherently a search for a *solution* to a *problem* in a '*problem space'*.

But before I proceed with the analysis of the IP approach to creativity, I will first take a look at what characterizes 'search' in its most elementary form. This is done to highlight the limitations of the IP search concept.

3.1 Introduction to the search concept – evolution and elements

The search concept, as indicated above, implies a directed activity. It necessarily entails a subject in a directed activity towards an object in a space.

In this section I will attempt to separate these elements to better compare how the various approaches to 'creativity as search' differ and are similar. Analyzing the search process down to these extremely basic elements obviously highlights the fact that a search is not a specific human activity, but is a process originating far back along the evolutionary line. Furthermore there are obviously many kinds and levels of search that do not entail creativity.

To inform the IP approach to creativity, I will begin by first viewing search in it's most elementary form. This is done by going back along the evolutionary line to the very first searches conducted by subjects (here referring to animals). This method is classically an Activity Theory approach (e.g., Engelsted, 1989; Leontjev, 1977). Activity Theory researchers have attempted to classify the different evolutionary levels of activity (such as search). I will use this research to inform the IP approach to creativity as search, in terms of limitations and strengths, in later discussions.

3.1.1 Search in its most elementary form

Humans are, of course, not the only animals to carry out searches. Indeed, some theories place activities such as search, at the very core of what it means to 'have a psyche'. Below I will briefly review a line of argumentation about the nature of search carried out in an Activity Theory[17] tradition, by Engelsted (1989).

Engelsted (1989) seeks to explain the essence of what it means to 'have a psyche' by looking at the psyche in its most elementary and general form. He seeks such a form very far back in evolution; all the way back to where simple organisms were just developing self-initiated movement. Before self-initiated movement organisms did of course still move. But such a movement was always the result of homeostasis. As Cannon stated , homeostasis "refers to any process that alters a given condition, and as a result initiates other reactions that tend to reestablish the initial condition" (Cannon in Engelsted, 1989, II, p. 47). In other words movement was seeking to regain a state of optimum – a strictly reactive state. But however smart this optimum guided kinesis is, it cannot explain spontaneous activity. Many organisms only display such reactive movement - fit to regain optimum. But at some point in the evolution, self-initiated movement was developed. As Engelsted argues, in the activity of self-initiated movement the process of homeostasis is reversed. In homeostasis we have a function that could be described as 'stop-go-stop' and where optimum is the norm and movement the exception. On the other hand spontaneous activity re-

quires what could be called a 'go-stop-go' function, where motion becomes the norm rather than the exception. Spontaneous activity is a quality of organisms as far back in evolution as the protozoan.

As Engelsted (1989, II, p. 54, own translation[18]) writes: "The new relationship that comes into being with spontaneous activity is exactly the opposite of the reactive O→S. Instead it is S→O which means that the organism by way of it's spontaneous or self-initiated […] activity brings itself into contact with feed". This new relationship is exactly the opposite of the servo guided reactive kinesis that drives the organism out of contact with negative stimuli. Where the servo guided kinesis (O→S) is constantly related to the *physically present* stimulus, the spontaneous kinesis (S→O) precedes the stimulus, and is in that sense related to the *absent* (ibid., p. 54). Self-initiated movement *implies* that there is an object to search for in the space.

This new relationship of spontaneous activity is teleological. That, however, is not to be confused with the subject *possessing* or *having* a will or intention. Rather, the subject with spontaneous activity *is* striving[19]. Engelsted goes on to define 'activity[20]' as this new spontaneous kinesis with it's inherent teleological quality (ibid., p. 55).

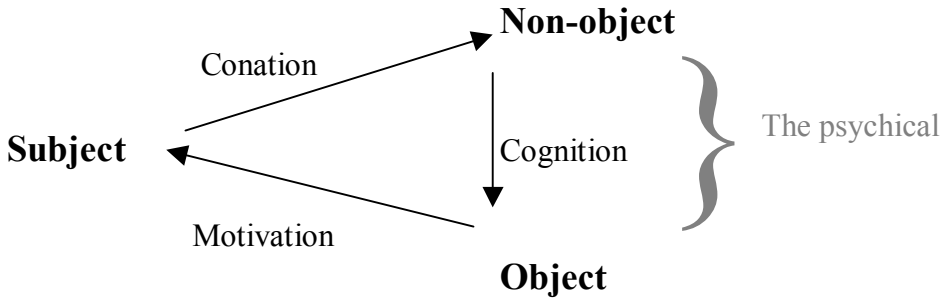


Fig. 3. The category of the non-object, and it's relationship to the psychical (Engelsted, 1989, II, p. 69, own translation).

The concept of '*the absent*' implies a new category in evolution. It is the category of the 'non-object' (see fig. 3). By this, Engelsted means that self-initiated movement *implies a search for an object that is not yet present*! Again, this does not mean that the subject has an *idea* of the object – simply that the self-initiated movement by the subject *implies* that there is an object out there to be found. "It is the spontaneous kinesis in itself that 'im-

plies' the absent object as a logical category" (ibid., p. 67, own translation[21]). In that sense the object exists in the activity of the subject *before* it is concretely and physically present.

Engelsted argues that the dimension from the non-object to the object is the dimension of 'the psychical'[22], which, thus, is a function of active movement. So, rather than talking about 'having a psyche', Engelsted talks about 'being psychical'.

An important thing in this connection is that performing a 'search' is a very general ability that all psychical subjects are capable of. What is required is self-initiated movement in a space. This general characterization is valid for all psychical subjects, although it does not mean that the psychical remains in the same form as the protozoan. Indeed, in evolution later forms of psychical activity develop many new qualities. It is the evolutionary development of this S→O relationship that the writings of Leontjev (e.g., 1977) focus on. All the levels of search, between the protozoan and the human, are, however, not important in this thesis.

There are a couple of important points to take away from this short presentation of the elements of search: The search elements can be analyzed down to a *subject* actively being directed towards an *object* in a space. This means that a search is fundamentally a teleological activity, implying a non-object that the search is directed towards. It is an activity directed towards something outside the subject, a something that is implied in the activity. Furthermore, this characterization implies that a search is fundamentally directed at something in the world (outside the subject). A search is always a search for *something* regardless of whether or not the animal or human has any *idea* or *concept* of this something (i.e., the non-object). This makes any search '*object directed'*, and *'object driven'*. This places a heavy emphasis on the real world existing prior to the search. Thereby I am implying that the search concept should fundamentally be explained in realist terms (with it's emphasis on objects of search). Having argued that a search in its most elementary form is fundamentally a realist concept implying an object out there to be searched for, it obviously needs to be stated that searches, in the highly advanced human form, takes many different and more advanced forms that that of the protozoan.

Humans, for example, search for lost car-keys and other objects. But we also separate goals from motives (what is called an 'Action'[23]) and search for jobs if we are poor and hungry. We are puzzled by facts, and search for

answers to questions. We search for non-objects we are not even sure are out there, such as water on the moon and the meaning of life. And we search our memory for lost and forgotten episodes in our childhood. We search for the perfect husband or wife, the ultimate high, or reasons and motives for other people's actions. And we search for solutions to inventive problems, the laws of nature and meaning in text. We now have strategies for search; collaborate searches in groups and societies; we have both simple and advanced methods of telling us if we are getting closer to or further away from the goal; and so on and so on. Yes, we have come a long way since the only way to perform a search was self-initiated movement in a physical space[24].
But essentially the search concept still remains realistic in implying the non-object and object.

Creativity is a very special kind of search. We cannot simply move around a physical space and expect to bump into a creative product. Indeed, if we could, such an activity would not even be considered creative! In that case we would simply have 'found' a creative object. Remembering the definition of creativity, the subject needs to '...bring into being...' and hence cannot simply 'find'. What this difference implies we will look at later in this section.

But after these introductory remarks on what it means to search in creativity, we will now look at the IP theories focussing on creativity as search. For each theory we will attempt to outline what constitutes the subject, the object (and non-object), the space and the activity.

3.2 Problem solving as search

In 1972 Newell and Simon published their monumental 'Human Problem Solving', where they attempt to develop a theory of humans as Information Processing Systems (IPS), with problem solving being viewed as a search for a solution to a problem in a problem space. This theory is historically the first IP theory we will look at, but it focuses on problem solving, rather than creativity. As outlined in part 2, problem solving is to be distinguished from the creative process, although they have an overlapping set[25]. But the theory is included here because it is with reference to this first instance that later IP theories developed their theories of 'creativity as search'.

Basically Newell and Simon's model characterizes problem solving as a constrained and guided search through a space of alternative possibilities. Decision-making is viewed as a rational and logical act, viewing the simi-

larities between human and computer processing as being more than a mere metaphor. Both are viewed as systems that process information over time, proceeding in a more or less logical fashion (Gardner, 1987, p. 150).
The advantage of viewing humans as IPS' searching for solutions to problems is that it allows you to apply the full force of search analysis to problem solving. Human problem solving is viewed as goal-directed search consisting of symbolic manipulation by rule-following systems. The IPS' use heuristics[26] such as means-end analysis to navigate through the space. But before we get into describing the actual activities in the problem solving process, let's look at what characterizes the subject, the object, and the space in problem solving, as described by Newell & Simon.

The subject : As indicated above, Newell and Simon viewed human problem solvers as Information Processing Systems (IPS). An IPS consist of an active processor, input (sensory) and output (motor) systems, and internal Long Term Memory (LTM), Short Term Memory (STM), and External Memory (EM). The problem space, and the processes occurring within it, is limited by the capacity of the cognitive system.
An IPS looks like this (see figure 4):

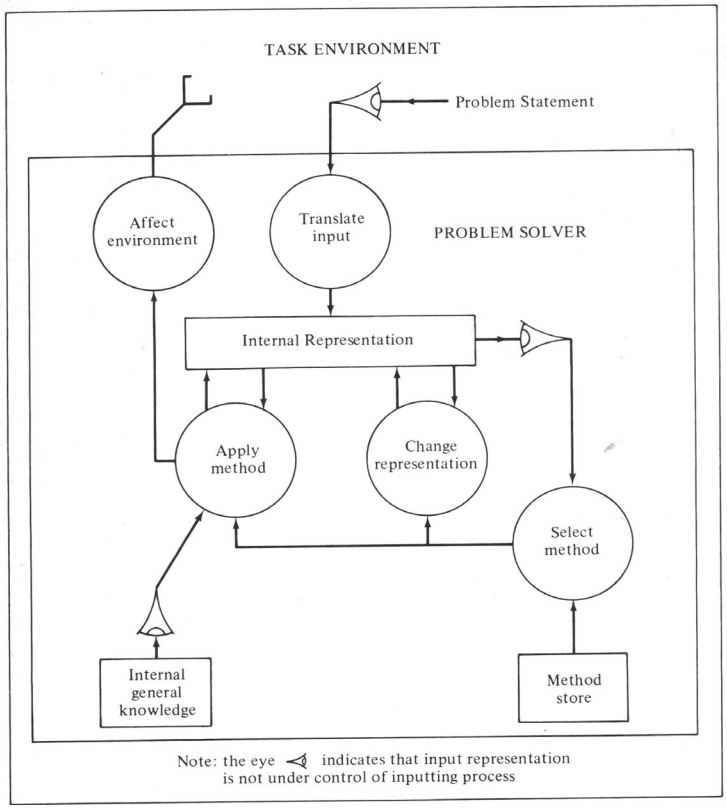


Fig. 4 General organization of a problem solver (from Newell & Simon, 1972, p. 89).

Obviously such a view of the human problem solver places Newell and Simon in the domain of cognitive science in general, and artificial intelligence in particular.

The object and non-object: With Engelsted (1989) it could be argued that at the basic levels of activity (i.e., early in evolution), the non-object and the object basically represents the same thing. The non-object is implicitly found in the self-initiated activity of a subject. For example, for the animal searching for feed, the non-object implied in the activity is feed, and the object, once found, will be some kind of food. As such, one could say that what separates non-object from object for the animal is time and space. In a human problem-solving search the two are distinct in more ways. In the theory of Newell and Simon, problem solving is seen as a search for a solution to a problem. As such the *problem* can be seen as the non-object, with the *solution* being the object.

> "A person is confronted with a problem when he wants something and does not know immediately what series of actions he can perform to get it." (Newell & Simon, 1972, p. 72).

This is not a direct definition, and Newell & Simon go on to explain that problems can be tangible or abstract, specific or general, physical or symbolic.

> "Instead of defining directly what it means most generally for a human to have a problem (or for any organism or device to have one), let us try the following strategy. To have a problem implies (at least) that certain information is given to the problem solver: information about what is desired, by means of what tools and operations, starting with what initial information, and with access to what resources. The problem solver has an interpretation of this information - exactly that interpretation which lets us label some part of it as goal, another part as side conditions, and so on."(Newell & Simon, 1972, pp. 72-73)

Thus a problem is principally seen as *information* about the initial state, goal state, resources and so on. One should think that a solution would simply mean that one reaches the goal state. However, as Newell and Simon (1972) points out, a solution means different things in different situations. One can thus distinguish between solution objects, solution paths, and solution actions. The problems Newell and Simon actually studied were highly structured, complex and formal problems, such as chess and cryptarithmetic[27].

Space: In many respects, the brilliance of Newell and Simons problem solving paradigm can be attributed to their concept of space. They define the space in which problems are solved, as not merely the present layout of the problem and world, but extends it into the possible states. Problem solving is a search in a space of possibilities. As Perkins (1994, p. 140) has expressed it: "We think in terms not just of actualities but possibilities of varying payoff and promise." The space in which problems are solved is a space of all possible (allowable) states, when starting from the initial state.

> "We shall find it necessary to describe not only his actual behaviors, but also the set of possible behaviors from which these are drawn; and not only his overt behaviors, but also the behaviors he considers in his thinking that don't correspond to possible overt behaviors. In sum, we need to describe the space in which his problem solving activities take place. We will call it the problem space." (Newell & Simon, 1972, p. 59).

The problem space is the internal representation of the space used by the subject in his problem solving. But how does this correspond to the real-world? Newell and Simon uses the term 'task environment' to describe this broader space:

> "In talking about the task environment we must maintain clear distinctions among the environment itself (the Kantian Ding an sich, as it were), the internal representation of the task environment used by the subject (the problem space), and the theorist's 'objective' description of that environment. This is the classical problem in psychology of defining the effective stimulus." (Newell & Simon, 1972, p. 58).

The problem space need not correspond completely with realizable external states (ibid, p. 77). Included in the thought processes are also the set of behaviors the IPS considers that prove infeasible, illegal, or in some other way impossible. As such, the subject's wishes and dreams as well as his more realistic thoughts are included in the problem space (ibid., p. 60). An essential feature of the difference between the internal representation (the problem space) and the task environment, is that the distinction contains a *normative theory* of problem solving (Eysenck & Keane, 1995, p. 374). It allows us to assess the best/correct/ideal solution (and solution path and solution action) to a problem.

In later research on problem solving as a search from an initial state, through intermediate states, to the goal state, the broader concept of 'the

task environment' is often ignored, and 'the problem space' is the only unit of analysis.

Activity / search: We have now specified what is meant by a subject, and object (and non-object), and space. The only missing component is the actual activity of search. How is it carried out? By engaging in a search the IPS is looking for a path through the problem space, that will take him or her to the goal. As the number of possible paths are usually very high (just consider the possibility space – the number of possible states – in a game of chess) the IPS uses heuristics. Heuristics are rules of thumb that limits the number of options, and are thus strategies for reducing a large number of possible states to a lower number, hopefully without excluding the path to the goal. One such heuristics is means-end analysis. In means-end analysis the subject creates a subgoal that will reduce the distance to the end goal. And then an operator (action) is selected to solve or achieve this subgoal. Another heuristics is 'notice invariants' (Kaplan & Simon, 1990) where the subject deliberately notices which conditions are being held constant across the (constantly failing) attempts to solve the problem. These conditions are then manipulated. Many different heuristics can be applied in the solution of a single problem. The search stops when a desired goal is achieved. The criteria needs only to be satisfied (rather than optimized) for the IPS to halt the search process.

Evaluation of Newell & Simon's problem-space theory:
Newell & Simon were the first to suggest that problem solving could be seen as a search from an initial state through intermediate states to a goal state. This IP problem-space theory has since been elaborated and tested on many different kinds of problems. Part of the brilliance of the Newell and Simon presentation of the concept of problem space is that they gathered evidence that people indeed think in this exploratory way, navigating through possibilities in search of ones that advance towards a solution, at least on highly structured and formal problems (Perkins, 2000, p. 69). But there are a number of problems with this model, when one wants to explain *creativity* and not just rational problem solving. Newell and Simon concentrated on well-defined, rational, formal and logical problems of a kind where almost no special knowledge (pre-test situation knowledge) was needed to solve the problems. The heuristics used on such problems are usually of a universal (and weak) nature (Eysenck & Keane, 1995). Opposed to these well-defined problems, are problems of the kind used in creativity. Creativity deals with ill-defined problems, where the initial state, the intermediate states, and the goal state are not very well specified. The

problem space in creativity is usually much larger, and with fuzzy boundaries. The heuristics needed to solve ill-defined problems often contains a certain amount of domain specific knowledge, rendering the universal and weak heuristics useless. Metcalfe (1986a; 1986b; Metcalfe & Wiebe, 1987) conducted a famous series of experiments on metacognitive feelings of warmth on the difference between well-defined (such as mathematical) and ill-defined (insight) problems. The subjects were asked to rate (every 10 or 15 s) how close ('warm') they felt to reaching a final solution while solving problems. They were able to do this on well-defined problems, where the ratings showed an incremental 'warmth' pattern. But on the ill-defined problems the subjects were completely unable to judge how close they were to reaching a solution, rendering heuristics such as means-end analysis useless. The solution thus appeared very suddenly, with no apparent forewarning. In fact Metcalfe found that an incremental warmth pattern on the ill-defined problems predicted *wrong* answers. Problem solving of the Newell & Simon kind thus appears only to adequately account for well-defined problems. Simon has later attempted to develop theories of heuristics that would account for problem solving on the 'insight-type' problems used in some creativity research (e.g., Kaplan & Simon, 1990). Here the issue has been extended to one of 'finding the right problem space (representation)' instead of simply working through one. However, as Simonton (1999a) argues, this still does not do justice to the complexity of the creative process.

> "In this tradition, all that is necessary is first to find the most appropriate representation of the problem and then to use the most suitable heuristics to work through the problem space (e.g. Kaplan & Simon, 1990)." (Simonton, 1999a, p. 319).

Creativity, Simonton argues, does not begin with the knowledge that a solution to your problem even exists, let alone that there is a right (or good) way to get to it. Simonton gains support from a classic review of the creative process. Ghiselin (1952) reviewed self-reports of creative processes from a large number of famous creators, and concluded that:

> "Production by a process of purely conscious calculation seems never to occur." (Ghiselin, 1952, p. 5)

If clear-cut boundaries, strict rules of logic for changing states, and rational thought processes are necessary ingredients in Newell and Simons problem solving, then creativity must be of a somewhat different kind. Ill-defined

problems cannot fit into such a model, and hence will not let themselves be solved in the same manner.

My concluding remarks on Newell and Simon will be that their main focus is not concerned with creativity (as I have defined it). As such I will not elaborate or discuss the theory any further in this thesis. However, that does not mean that their problem-space theory cannot inform the creativity debate. Indeed, several theories in the IP tradition have elaborated and changed the basic IP search metaphor used by Newell & Simon to try to expand it to include creativity as well. The next section will review two theories that both use the problem-space metaphor in creativity, but with different purposes and outcomes.

3.3 Creativity as search

Several creativity theories have been inspired by Newell and Simon's concept of problem-solving being a search through a problem-space. Here we will review two such IP theories[28], those of Magaret Boden and David Perkins.

3.3.1 Perkins and Klondike spaces

Unlike Newell & Simon (1972), Perkins' (2000) main focus is on creativity. But he is also heavily influenced by Newell & Simon's problem-space theory. He too places a great emphasis on viewing creativity as search, although his theory is not as clearly in the IP tradition as that advocated by Newell & Simon. Perkins argues that the concept of search used in traditional problem solving theories cannot encompass the kind of search needed to explain creativity (e.g., Perkins, 1981; 1994; 2000). Indeed, as seen above, the problem solving literature can explain well-defined problems, but cannot explain the creative search processes in ill-defined problems. As such, Perkins extends the concept of search to include restructuring and ill-defined problems.

Perkins' major contribution is his views on the 'problem space' and 'search activity' concepts. We will thus not deal with his thoughts on the subject and object and non-object here, although it should be mentioned that his views on the subject are not limited to viewing them as information processing systems.

Space: Perkins follows Newell & Simon, and argues that creativity occurs in a space of possibilities. The space for solving creative problems is not limited to actualities – we must include into that space a space of possibilities. Further, we must move away from purely well-defined problems, and include ill-defined problems in the study of creativity.

> "Playing chess has strict rules, but designing a bridge does not. In cryptarithmetic problems the sums have to be right, but who's to say what's right when a poet writes a poem? The origins of the possibility space concept are formal, mathematical, rigorous. However, to adapt the concept to examining problem solving in general, we need to stretch it to accommodate the messiness of informal situations. Informal situations are messy in at least three ways. The space of possibilities to be searched, may be fuzzy, with one state blurring into another rather than being neatly set off as in chess positions. The space of possibilities may appear to change during the course of problem solving, for example, as one gets new information. Finally, one's criteria for success may evolve as one thinks about the problem, rather than staying fixed from the beginning." (Perkins, 2000, pp. 71-72).

Perkins argues that even in these informal conditions (fuzziness, changes in space, and evolving criteria) search occurs in a space of possibilities (ibid., p. 76). I will now briefly review his reply to these three challenges to the search concept in creativity. *Fuzziness* does not change the fact that informal and ill-defined problems can still be described in terms of operators, states, possibilities and promise. Informal and unclear possibilities are still possibilities. Perkins makes a distinction between mental possibility spaces and physical action directed at solving the problem (sketches, models etc.), together making up the entire possibility space (ibid., p. 74). *Changeable possibility* spaces could potentially endanger the idea of a problem space. After all what sense would it make to search a space that changes constantly. Perkins argues that instead of viewing the problem of being one of changing spaces (or representations) one must view it as *jumps within a space*. And finally, *criteria evolve* in open-ended problems as the subject searches for answers. It is hard to conceive how a goal-directed search could occur, if the goal keeps changing. Perkins argues this can be overcome by extending the possibility space once more, to encompass both an original possibility space, and possible changing criteria (ibid., p. 76). The search becomes one of searching both for criteria and goals at the same time.

But what can be said to characterize this space of possibilities that is broader than the 'problem-space' concept used by Newell & Simon? What is the topography of such a space?

Perkins calls the Newell & Simon approach to search, 'reasonable search'. This is the kind of search using heuristics such as means-end analysis (Perkins, 1981, calls it 'hillclimbing') to get progressively closer to a goal state. The kind of space where this is possible, he calls a 'homing space'. Reasonable search in a homing space, can occur in creativity, but it is a very special case. Creativity usually implies a different kind of search in a broader kind of space. This space he calls *Klondike Space* (e.g., Perkins, 1994, 1998, 2000), where 'unreasonable' search occurs. A Klondike space is a metaphor for the inconvenient distribution of gold in the Klondike, where a lot of search can yield no results, and where backtracking to a source may not reveal the mother load etc. This space is quite unfriendly to search, and is challenging in four different ways (after Perkins, 1998; 2000) (see also fig. 5):

A *wilderness trap* has a large number of possible states only a few of which are solution states. Somehow one must cope with this vastness to reach the solution. A *clueless plateau* is a large region of neighboring possible states where the measure of promise does not vary much between states. This makes progressive search impossible. A *narrow canyon of hope* is a solutionless possibility space with many neighboring possible states, but with clear boundaries. The search process tend to get trapped in the canyon even though the solution state may be located outside the boundaries of the canyon. Finally, an *oasis of false promise* is a possibility space where one can, to a point, get progressively closer to what seems like a solution. The measure of promise can get high, but not quite high enough, making the oasis hard to leave behind, in search of solutions elsewhere.

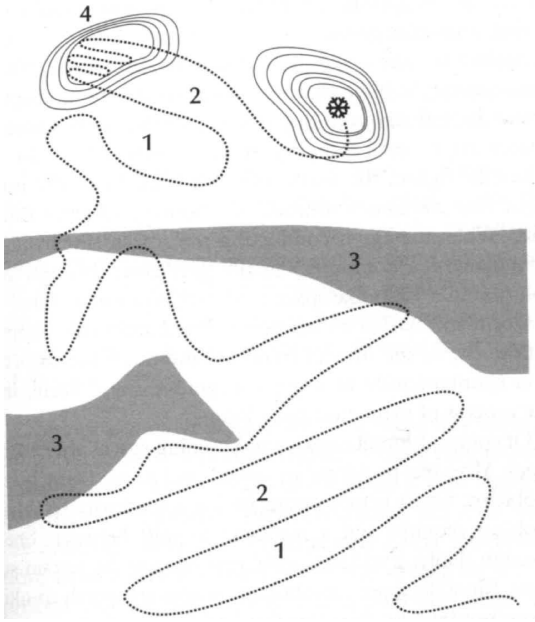


Fig. 5. Seach in a Klondike space: 1. A large space with few solutions (a wilderness trap). 2. Regions with no clues pointing in the right direction (plateau traps). 3. A barrier isolates the solution (creating a canyon trap). 4. An area of high promise but no solution (an oasis trap). (Perkins, 2000, p. 81)

Perkins also deals with the search strategies needed to overcome the difficulties of the Klondike space; the kind of search needed to overcome these creative and unreasonable spaces and get to a solution is of a different kind than the one found in homing spaces. One needs long searches, often with little apparent progress, precipitating events, cognitive snaps and transformations. But this is not to say that means-end analysis and other heuristics don't play a part in search (e.g., when one is in fact relatively close to the solution). As such, Perkins shows us how a search is more than a rational and steady progress in the direction of the goal.

3.3.2 Boden and impossible creativity

Another creativity theory focussing on search is that of Boden (1991; 1994a; 1994b; 1999; 2000). Boden's major argument is that computers can inform us about how creativity is possible; how this magical phenomenon possibly could occur (this is also referred to as weak Artificial Intelligence). Her focus is on which generative processes actually operates during the production of creative ideas, and how computers can be used to imitate what could be going on.

Her argument begins with stating that true creativity is not just improbable (or statistically infrequent), it is in fact *impossible*. It is impossible in the sense that it could not have happened previously, because before the crea-

tive incident there was nothing there to produce it! (Boden, 1991, p. 31). She separates mere first-time novelty from radical originality:

> "A merely novel idea is one which can be described and/or produced by the same set of generative rules as are other, familiar ideas. A genuinely original, or creative, idea, is one that cannot. To justify calling an idea creative, then, one must identify the generative principles with respect to which it is impossible. The more clearly this can be done, the better." (ibid., p. 40)

As such, 'impossible' means that it could not have arisen from the im- and explicit generative rules we have in mind. When evaluating creativity, people recognize this quality (impossible) of creative products from comparing it to the limits and constraints of their mental representation. Boden calls her search space a 'conceptual space' which underlines the fact that it is a wholly internal mental space.

> "A *conceptual space* is an accepted style of thinking in a particular domain – for instance, in mathematics or biology, in various kinds of literature or in the visual or performing arts. A conceptual space is defined by a set of enabling constraints, which make possible the generation of structures lying within the space – for instance, limericks or theories in organic chemistry. If one or more of these constraints is altered (or dropped), the space is transformed. "(Boden, 1999, p. 352).

And further:

> "The dimensions of a conceptual space are the organizing principles that unify and give structure to a given domain of thinking. [...] The limits, contours, pathways and structure of a conceptual space can be mapped by mental representations of it. Such mental maps can be used (not necessarily consciously) to explore - and to change - the spaces concerned." (Boden, 1994a, p. 79)

Creativity is not mere improbable combinatory play in a generative system. It is more than that. Creative ideas are *impossible*, and thus of a exploratory-transformational kind. Such a dimension stretches from 'exploration leading to noticing new instances', to 'completely transforming the conceptual space' (see figure 6).

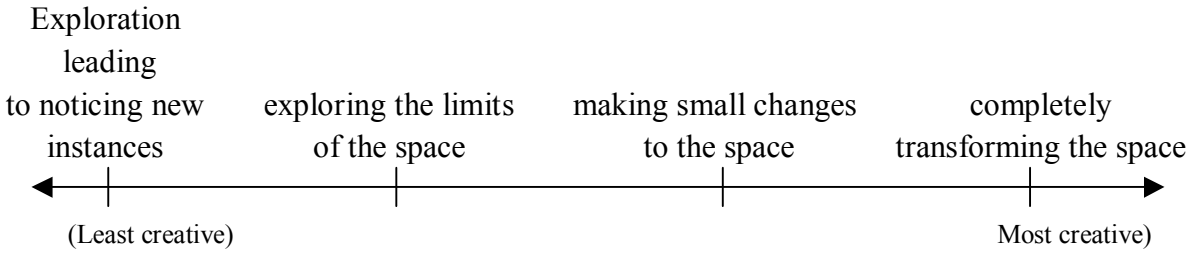


Fig. 6. Illustration of degrees of creativity in the theory of Boden (1991)

That an idea could not possibly have been generated before (was impossible) does only apply with respect to the particular conceptual space, and not to the mind's resources as a whole (Boden, 1994b, p. 559). There are many different heuristics for exploring and transforming conceptual spaces, some domain-general, others domain specific. Some drop constraints, others change generative rules, and still other heuristics change the heuristics themselves.

In this understanding, constraints on thinking are in fact what makes creativity possible, as creativity means exploring and sometimes going beyond the constraints set by the conceptual space. "Constraints map out a territory of structural possibilities which can then be explored, and perhaps transformed into another one." (Boden, 1991, p. 82).

But returning to the two kinds of searches – the exploratory (and least creative) one and the transformative (and radically creative) one. Exploring a conceptual space, Boden argues, sometimes has an ultimate goal, and sometimes not. Exploration such as 'playing around' can be an open-ended process, where the purpose is merely exploring mind itself (ibid., p. 47). During such explorations, the explorer uses representations (maps) as a guide in the conceptual space. The 'maps' can be preexisting or be generated in the exploration itself. These maps of (and in) mind are generative systems that guide thought and action into some paths but not others (ibid., p. 47). It is important for Boden to stress, that the conceptual space itself is changed by this mental exploration and mapmaking. As she writes:

> "In many ways, then, mental exploration is like the land-based variety. But there is a crucial difference. Mental geography is changeable, whereas terrestrial geography is not. […] In short, only the mind can change the impossible into the possible, transforming computational 'cannots' into computational 'cans'" (ibid., p. 49).

The heuristics themselves used in the generative system set a limit to the conceptual space. Dropping a heuristics (or modifying it) can put previously inaccessible parts of the search space back on the map of the mind. Thus, when we make a change in the generative system, we make a change in the conceptual space. The deeper the change in the generative system, the more different will the corresponding conceptual space be (ibid., p. 81). According to Boden, most AI systems are limited to exploration alone, and only a few can transform space.
This concludes my review of the IP theories. I will now discuss and review the limitations of a theory of creativity based on IP theory.

3.4 Problems with the information processing view of creativity as search

I will now take a closer look at the search concept used by Perkins and Boden, and in more detail discuss problems of the IP approach to creativity as search. There are a number of problems with the IP approach, despite (or perhaps because of) the fact that the theories of Perkins and Boden are both further developments for the search concept used Newell and Simon.

3.4.1 Boden

Margaret Boden's theory is a limited one. Her sole purpose with arguing for the potential for AI theory to contribute to the understanding of creativity, is that a generative AI system could potentially show us how novel production is possible in humans. In other words, she argues that by simulating the generation of exploratory-transformational novelty on a computer, we can learn how humans *could* potentially be creating (but not that they necessarily do it that way). This is artificial intelligence in a weak form. Her purpose is important, but it leaves out the explanation of a range of creative phenomena (e.g., the impasse phenomenon, preparatory and evaluative processes), the explanation of which is rendered impossible by the limitations she imposes on the generative system. Boden argues that what she calls P-creativity (psychological creativity, as opposed to historical creativity) should be the only unit of analysis for a psychological study of creativity (Boden, 1991). In doing so, she maintains a strict view on the individual creator, but what is more, on the individual creators mental processes! Creativity is seen merely as a feat occurring in mind without any reference to the outside world that the conceptual space is derived from. Creativity is viewed as merely exploring or transforming a conceptual space. But if creativity is exploring and transforming your personal conceptual space, does that mean that all exploration and transformation of your personal conceptual space is creative? Boden seems to believe so. I beg to

differ. Exploring and transforming your personal conceptual space can be done in a number of ways that should not be considered creative. For example, one could argue that Boden seems to consider all forms of learning and instruction as a creative process. Any learning situation, where someone widens his or her conceptual space, and gains new knowledge, would be creative, according to Boden. As such, reading a book or attending a lecture would be creative, as it involves exploring and transforming conceptual spaces.
The problem is that when Boden is arguing that creativity is about exploring and transforming your conceptual space, she is basically arguing that creativity is about expanding and changing *your mind.* What she seems to be missing, is *that creativity is not only about changing your mind – it is about expanding your world* (e.g., Feldman, Csikszentmihalyi, & Gardner, 1994)! It is a process operating in - and on - a world, a world it is also *about.* Creativity, in Boden's terminology, does not *bring anything into being* (i.e., a product), other than that which *comes to mind*.

This however, leads us into a much more severe criticism. On what grounds is a conceptual space altered? What causes the transformation of conceptual spaces in Boden's theory? What limits it? It does not at all seem clear just what it is that causes a person or system to alter a conceptual system and indeed it appears to be carried out by random dropping of constraints or heuristics. It is as if the conceptual system develops and is altered without reference to anything outside the system itself! And indeed, the conceptual space, and the mapping Boden argues takes place of the space, are both completely internal mental phenomena. The conceptual map acts (in exploration and transformation) upon the (internal) space, which again acts upon the map etc. This is constructivism in an extreme form. The model develops seemingly without reference to anything grounding the model in anything outside the system. Virtually any constraint seems to be liable for alternation in Boden's model, and it remains a mystery why one constraint relaxation was chosen in the model over another one. ANY constraint relaxation (i.e., conceptual space transformation) in such a model would be creative, as long as a goal-state is reached.

The problem with such a model is that it becomes impossible to explain why one transformation is creative, and another isn't. The reason for this is the (implicit) exclusion of the 'real world to conceptual space' relationship. Boden does not deal with this relationship, and hence it could be argued that she seems to believe that generative systems operate only upon the conceptual space, once it is fully established. But by implicitly excluding

the real-world from her model (by not dealing with it), she is undermining her own form of argumentation. As we saw in the previous section, the search metaphor is an inherently realistic explanatory model that relates a subject to an object through action. Boden's error is placing this explanatory model WITHIN a person, such that both space and mapping of the space is a result of internal processing. The explanatory power in the realistic search metaphor is primarily derived from having external constraints and possibilities that guide the search. However, by placing everything within the individual, everything also becomes relativistic, as literally any constraint relaxation can be done in mind. This reduces the possibilities of explaining why some constraints should perhaps NOT be relaxed, while some should. The notion of transforming into the RIGHT (instead of just any) conceptual space is lost.

As such Boden's generative system could be said to be conducting a search that is making a representation (mapping) of a representation (conceptual space). She ignores the fact that the first representation (the conceptual space) is actually more or less accurate in relation to a world. She just assumes that it is richly structured, which quickly becomes an assumption of the conceptual space being if not perfect, then at least good enough. This leaves no room for *failure* (attempting wrong transformations), *doubt* (inadequate conceptual space), or other problems with the conceptual space to real world relationship.

Boden's theory does have something to offer, however. The whole notion of the impossible is an important contribution to the creativity domain. Too long the focus has remained only with the possible states, largely ignoring impossibilities. But her version of impossibilities is a psychological one. Creativity is impossible because a generative system *could not* have created something before. This is to be distinguished from the logically impossible (something is self-contradictory), the nomological impossible (something violates the laws of nature) and the historically impossible (something has already been done) (Fetzer, 1994), which are three other kinds of impossibilities. Boden's kind of impossibility is of a psychological kind (i.e. something has simply been inconceivable up till this point). The fact that she regards impossibilities to be merely a matter of mental ('non-real') constraints, further underlines the constructivist nature of her model. Later (in part 4) I shall argue that impossibilities must be viewed in a different way in creativity.

Another important contribution is separating 'mere first-time novelty' from the exploratory and transformatory dimension from which creative endeavors is extracted. Creativity is not mere recombinatory play, as a number of other (primarily AI theorists) seems to be arguing. Such recombinatory generative systems cannot explain creativity, Boden argues. Unfortunately, neither can Boden! She incorporates the search concept in her model precisely to overcome the problems mere recombinatory theories have with explaining usefulness in creativity, but by implicitly discarding of the dialectical relationship between representation and real-world, she throws out the explanatory power of the very model she seems to be advocating. Placing both search and space internally, without any interaction with the outside world, cannot explain why some explorations and transformations are possible and useful, and why some are not, and Boden falls for her own criticism. It is all very well that she argues that the combinatorial approaches needs to limit creativity to exploratory and transformative processes in the generative system in order to explain usefulness – but if *useful* exploratory and transformative processes are not separated from *un-useful* ones in the first place then this is not much of a criticism! In her theory there is no divide between which constraints one can make a creative contribution by relaxing, and which constraints one will only make noise by relaxing. It lacks grounding.

If we view Boden's theory in relation to the entire creative process (preparation, incubation, illumination, verification), we see that her theory is an attempt to limit the unit of analysis to how rational incubatory processes can lead to illumination. She eliminates the focus on preparation (as does most AI theories of creativity), and effectively assumes that we start out with a richly structured conceptual space, that is basically correct and sufficient. This loses the dynamics of ordinary prepatory processes, such as having doubts, examining closer, being confused, etc. However, although the focus is on how one could generate novelty, she is unable to explain the impasse phenomenon. Where exactly does one *get stuck* in Boden's mind search? Her explanation of incubatory processes becomes one of either rational combinatorial play until a goal-state is reached (exploration), or rational (but somewhat random) constraint relaxation, transforming the space, again reaching a (previously impossible) goal-state. A problem with her model is, of course, that this model cannot explain why something is a goal-state in the first place. This is further related to the elaboration stage of the creative process. In creativity it is necessary to verify and elaborate on insights to make sure you are not mistaken. Again, Boden's internal

search renders such a process irrelevant. It would seem impossible to have a wrong insight in Boden's model. No reality check is needed.

Boden cannot explain developmental aspects of creativity either. She loses sight of the fact that radical transformations in part take place to create a more *adequate* conceptual space; i.e., a better 'conceptual space to real world' correspondence. For example, the reason why adults compared to the child have fewer radical transformations is because they have developed a more adequate representation of the world, and hence do not need the many naive transformations of the child.

Thus, by placing both space and search inside the creator, Boden is stripping the realistic search model of its explanatory power. The resulting constructivist theory cannot explain why a solution is a useful and possible solution in the first place.

3.4.2 Perkins

Unlike Boden, David Perkins does not place as much emphasis on the fact that the possibility space is an internal phenomenon. His version of the possibility space is called Klondike space, and includes some physical action in the problem solving attempt. Indeed, one of his major contributions to the understanding of the space concept is the characterization of different kinds of space, depending on the particular problem and domain one is faced with. Different problems have different kinds of space that again warrants different search strategies. His work has dealt with examining the 'topography' of possibility spaces. His findings have improved the understanding of why the creative process seems to include an impasse. Search in creativity, Perkins argues, is not of the rational and logical kinds argued by Newell & Simon and Boden, but is instead of an unreasonable kind warranting different search strategies where one is not necessarily able to estimate the distance to the goal state - or even to estimate if there is a goal state out there to be found!

However, like Boden, Perkins does not deal with the preparation and verification stages of the creative process. *Primarily* search is still an internal affair. Although far less extreme than the AI theory of Boden, he can still be criticized for placing too little emphasis on real-world constraints, and too great an emphasis upon search in mind. He also seems to be lacking the concept of the impossible, which Boden places such a great emphasis on. In his theory the concept of possibility space is expanded but still do not seem to include anything BUT possibilities. We search in spaces of what is

possible, only a few of which are actually goal-states. Again, such a view easily leads one to the position where reality testing and verification is rendered unnecessary as the subject's solution is considered possible in the real world as well. But this does not do justice to concepts of illusions, fantasy and others, which traditionally have been considered close in relationship with creativity. Separating the possible from the impossible is not always an easy task – especially in creativity.

This is especially so when you, as Perkins does, relativize the rule-governed and logical aspects of the problem space theory of Newell & Simon to make it a fuzzy space with fuzzy states. In such a space, what constitutes a logical and legitimate possible state is not always clear, increasing the chances of wrong answers and half truths. Perkins, like Boden, needs a further emphasis on real world constraints to explain why some creations are neither possible nor useful.

3.4.3 Limitations of the information processing approach to creativity as search

All in all the IP approach to creativity as search suffers from a number of shortcomings and problems as a theory of creativity. The main overall problem is that of focussing on mental search alone, rather than considering where the mental constructs came from, and how the conceptual spaces were made in the first place. Doing so is stripping the inherently realistic search model of its explanatory power, resulting in a constructivist theory without hold in reality (outside the mind of the creator). Real-world constraints on the creative process along with the actual product brought into being in creativity, is not considered.

It should be noted that Newell & Simon acknowledged that the problem can be viewed from a broader perspective (task environment) than the individual representation, but they do not include the concept in the theory of what it means to solve problems for the individual. The individual problem solver is viewed entirely in terms of the problem space. Perkins, in his latest revised theory (Perkins, 2000), regard physical activity as being part of the possibility space (e.g., sketches on paper), but it is clear, though, that the physical activity is regarded merely as a kind of 'external help' in solving the problem. That is, the sketches on paper, notes etc. are part of the possibility space only because it seems to be included in the *line of thinking* of the individual. Boden is even more radical than the other two theories and does not include any kind of reference to the real-world. Her AI theory is limited to internal mapping of a wholly internal conceptual space. The

space and the mapping thereof is entirely a matter of internal processing. In short, in the IP theories c*reative search is thought to take place in mind, be made by mind, and resulting only in a change of mind*. There are a number of sub problems to this.

Neglecting preparatory elements: First of all, the IP search theories all focus on internal search, either in an internal problem space, Klondike space or conceptual space. This takes the focus away from the 'real world to representation' relationship, where one can have doubts, have wrong knowledge, have limited views etc. Basically the IP theories (especially that of Boden) seems to be assuming an almost perfectly structured conceptual space as a starting point of creativity. This is problematic as it disregards the preparatory processes and their importance for the creative process, along with later gathering of knowledge during the creative process.

Rationality: Although Perkins argues for a less rational, and a more 'unreasonable' approach to creativity, there is still baggage from the language of Newell and Simon left in his and Boden's conception of the problem space. It is still rule-governed, logical, and there is still talk of 'legitimate states', operators, and other computational concepts maintaining the rational foundation for the theory, and underestimating the importance of less rational processes, such as intuition, tacit knowledge etc. The concept of 'states' is a bit confusing outside the purely rational examples of information processing (chess, cryptorithmetic etc.). If the size of a possibility space is determined from the number of possible, legitimate states, then is the space for dancing a dance larger or smaller than for painting a painting? Asking this question does not make any sense in real world creativity, as the concept of legitimate states is ill equipped to explain dances and paintings.

Neglecting verification: This lacking focus on 'representation to real world status' also influences and limits the view on the verification stage. Finding the solution to a problem is basically viewed as an internal process, where finding a solution within is basically seen as being the same as making it in reality. Discrepancies between knowledge of the world, and the actual world are not considered, thereby limiting the explanatory power of the model. It cannot explain why some solutions thought to work, did not actually work. All they can refer to, is that apparently the (thought) solution wasn't the (real) solution after all – a conclusion that in their model does not lead to anything other than a continued search in the very same conceptual space! But what real world creators do in that situation, is to recognize

that their model of the world is perhaps erroneous and that one should gain further knowledge of the domain and field before continuing with their mental search. In short, discrepancies between representation and real world are simply not a part of the IP tradition.

Creativity is solely a *change of mind*: Another limitation is the IP view on what *constitutes* creativity. Creativity is basically viewed as a change of mind, while disregarding the product (or products) of the creative process. Transformation and exploring or leaping across mental spaces is thought to constitute creativity. But the theory (especially that of Boden) cannot explain why some transformations are creative, and some are not. Boden's theory seems to be saying that the more radical a transformation of the conceptual space – the more radical the creativity. This makes no sense. Simply transforming space by dropping or relaxing any constraint is not creative, and dropping multiple constraints approximates schizophrenia before is approximates creativity! If I drop the rule in chess that the king can only move one space at a time, I am surely not creative, even though I have transformed a conceptual space to include more possibilities. And if I decide to drop *ten* rules in the game of chess, thereby exploding the number of possible states – does that make me a creative genius? Creativity needs grounding in the real-world to explain usefulness.

To the defense of the IP approach one could argue that they are mainly attempting to explain the internal mental generative processing of creativity – how a solution is reached in creativity - and not focus on 'real world to representation' issues. The problem with such a view is that creativity does not happen in isolation from the real world. Creativity is an in-the-world embodied experience and activity. It is not detached from the world.

The IP explanation of creativity as search remains fundamentally constructivist due to the lack of focus on the real world (and the products brought into being), despite the use of the inherently realistic search concept.

3.5 Realism and constructivism in creativity

Having reviewed and criticized three IP theories explanation of creativity as search, it is time to take a look at what it is more generally that I regard as the shortcomings of these theories, and how they should be overcome. I argued that in the IP theories, creative search is thought to take place in mind, be made by mind, and resulting only in a change of mind.. There is no focus on a product brought into being by the process, on any real-world constraints outside mind, or on the adequacy of the representation com-

pared to the real-world. This makes the IP approach to creativity a constructivist one, and therein lies the major criticism. The reader may be pondering: 'How can you criticize a theory of creativity of being constructivist?' It seems only natural that of course a theory of creativity must be constructivist, because creativity constructs!

However, in the present context 'constructivism' is used as an analog to a classical distinction made in theories of perception (see e.g., Eysenck & Keane, 1995). In theories of perception, 'constructivism' refers to:

> "… a general theoretical position that characterizes perception and perceptual experience as being constructed from, in Gregory's words, 'fleeting fragmentary scraps of data signaled by the senses and drawn from the memory banks – themselves constructions from snippets of the past.' The essence of all constructivist theories is that perceptual experience is viewed as more than a direct response to stimulation. It is instead viewed as an elaboration or 'construction' based on hypothesized cognitive or affective operations." (Reber, 1995).

Opposed to this view are theories arguing for direct perception (e.g., Gibson, 1979/1986). This position holds that there is much more information available in the environment than argued by the constructivist; information that just needs to be picked up by an active subject. Gibson's theory is often referred to as direct realism (Reber, 1995) or naive realism (Mammen, 1983).

The analog to this distinction in theories of creativity refers to the tendency of *constructivist theories* of focussing on the explanatory power of subjective constructive processes, while ignoring the objective structures and objects being altered in the process. In such theories, the subjective processes constructs seemingly 'out of nothing' (ex nihilo – see Perkins, 1988), as objective structures and objects do not constrain or guide the process. Constructions have no relation to what came before. Creativity becomes a matter of subjective processes detached from the world.

Opposed to constructivist theories in creativity are *realist theories*. Realist theories focus heavily on the objective structures and objects, and how they guide and constrain the creative process. Objective structures, rather than subjective processes, are analyzed to explain creativity. Realist theories do not construct out of nothing, but instead try to explain how something came to be something else. This can, however, result in attempts of trying to

eliminate the subjective processes and abilities to transform and construct. Materialistic attempts to describe the psyche as reflection of matter sometimes falls for this reductionism, thereby making individual creativity impossible. An example of this is the theory of Leontjev (see Mammen, 1983; Kristjansen et al., 1979; Christensen, 1998).

Below I will argue that a complete theory of creativity needs to synthesize the realist and constructivist approaches in order to be able to explain creativity. Both subjective processes and objective structures and real-world objects must be central to the explanation of creativity. Creativity may involve transformative and constructive processes, but is also in and about a world. It is not a detached process.

Let us for a minute return to the definition of creativity I argued for above. *Creativity occurs when someone brings a product with generalizable originality and with the potential for adaptive spread into being.* There are at least two ways in which the distinction between constructivism and realism underlies this definition:

First, *novelty* is most often explained as a process where a subject transforms or constructs. Theories trying to explain novelty often disregard *what* is being transformed, and merely focuses on the *how* of subjective processes. This places such theories close to a constructivist position. *Usefulness* on the other hand requires reference to an outside domain or context in which a product will spread adaptively. Further it places emphasis on the *product* being transformed in the creative process, and on where the product came from and what it is good for. As such, theories focussing on the usefulness aspect of creative products will more often come close to a realist position, implying heavy focus on the real-world (domain and context), and objective structures.

Second, the definition of creativity states that a product must *be brought into being*. We saw that the IP theories did this by using the (primarily realist) search concept in their constructivist explanation of how a subject reaches a goal state. This is not a contradiction, however. The IP theories use the term ‘space’ to refer to mental structures, rather than objective and real-world structures. In this sense, it is clear that the structures and spaces in the IP theories do not constrain or guide the mental search in any ‘objectivist’ sense. Further, although a search is always a relation between a subject and an object somewhere in a space, in the IP theories the goal-state is not ‘outside’ the subject, but merely outside the initial state of the search

(e.g., outside where attention is allocated or outside the content of the working memory). As such, search in the IP theories does not relate a subject to an object in the world, but merely relates a subject to the subject's own subjective structures (e.g., concepts). In the IP theories no real-world product is brought into being.

Here we see another way in which realist and constructivist theories differ in their explanation of creativity as search. Realist theories points to the solution or product being somehow already 'out there' to be found. Constructivists, on the other hand focus on generative subjective processes. Realists 'find' solutions, whereas constructivists 'create' them[29]. Putting it in these terms seems to put the realist position under pressure. After all creativity brings into being a product never before seen by man, so what we are searching for is, by definition, not out there to be found (if found means simply 'picked up or bumped into'). However, that should not lead us to discard of the realist position, or the search concept in creativity. Searching does not necessarily imply that *what* we search for is 'out there' (in it's entirety) prior to the search, just as it does not imply that we have *an idea* of what we are searching for (as Engelsted, 1989, argued). This dilemma, that the creative product or solution must somehow be *out there* prior to search, but not in the sense that it can simply be 'found', will be discussed in later sections.

This brief analysis of the definition of creativity in the light of the distinction between constructivism and realism has thus revealed that realist and constructivist theories have different foci.
Realists focus on the solutions and real-world objective structures (as being somehow 'out there') and on usefulness (i.e., the reason for the search in the first place; adaptability to a domain or context). A realist AHA! means 'I've found the solution'.
Constructivists, on the other hand, have a high degree of focus on the subjective processes of an individual creator and focus on novelty (recombinatory processes to form novelty). A constructivist AHA! means 'I've created a solution'.

A complete theory of creativity must of course include both the aspects of creativity focused on by realists (objective structures and products, *what*, search, usefulness), as well as the aspects focussed on by constructivists (subjective generative processes, *how*, novelty). Most theories dealing with creativity can safely be placed near the constructivist position (e.g., the IP theories, but also many theories in cognitive psychology). Hardly any theo-

ries have made a serious attempt of making a realist theory of creativity (although, see Harrington, 1990).

Both ends of the realism-constructivism continuum runs into trouble, if attempting to explain creativity entirely in their own terms. A synthesis or dialectic theory is needed. The IP theories tried to provide this dialectics by using the (realist) search model in their theory, but failed when the space for the search was viewed entirely as internal, thereby maintaining a constructivist approach. They did, however, point in important directions, when they argued for the existence of possibility spaces.

In the following sections I will discuss central dilemmas seemingly making the constructivist and the realist positions incompatible and hence hard to synthesize. I will try to overcome these obstacles, and then sketch out a theory of creativity that synthesizes the two approaches. This theory will have to contain both subjective constructive elements, along with a focus on real-world objects and constraints; novelty and usefulness. Hopefully, this synthesis will be able to explain how something can come to be something else by way of human productive processes. It will attempt to bring the real-world into theories of the creative process. In short, I shall try to sketch out an ecological approach to the creative process.

3.6 Summary

This part dealt with creativity as search. We started this section with looking at the elements of search, and (with Engelsted) that fundamentally search is a teleological process, and a realist explanatory model, due to the focus on the object of search, and the space within which the search takes place. Then the information processing (IP) approach to creativity was analyzed. It was found that IP theories view creativity as a search for a solution to a problem, in a space of possibilities. The IP theories taken together place a heavy emphasis on internal, mental, processing in creativity and problem solving. It was concluded that the IP theories view creative search as taking place in mind, be made by mind, resulting only in a change of mind. This neglects the fact that creativity is also a process that brings novel and useful products into being (i.e., in the real-world), and thus changes the world. Further it disregards preparatory and evaluative parts of the creative process, and places too heavy emphasis on rationality. It was argued that the IP approach to creativity could be considered *constructivist* in it's heavy emphasis on mental search. It was further argued that an ecological approach incorporating both subjective constructive processes and objective real-world structures is needed to explain creativity.

PART IV: STEPS TO AN ECOLOGICAL APPROACH TO CREATIVITY

"Nearly every man who develops an idea works it up to the point where it looks impossible, and then he gets discouraged. That's not the place to become discouraged."
- Thomas Edison

4 STEPS TO AN ECOLOGICAL APPRACH TO CREATIVITY

When one wants to develop an ecological approach to creativity encompassing both subjective processes and objective structures, the first step must be to determine the unit of analysis of such a theory. Bang (2000) argues that an ecological perspective has the subject's active connectedness with the world as the basic unit of analysis. Principally this means that if one wants to say something about the active psyche, you have to examine what characterizes the object and what characterizes the subject's concrete and active connection to the object (ibid., p. 10). It is not enough to direct your examination towards the subject. I agree with this characterization, and in developing an ecological approach to creativity, I will attempt to examine the object of creativity, as well as how the subject is actively connected (and connecting) to this object.

The following discussions will be an attempt to strike the thin, but necessary, line between a constructivist and a realist explanation of creative search. The discussion is structured around two dilemmas, each important in finding a resolution to the seeming opposition between realist and constructivist approaches to creativity. The first dilemma is directed at the object of creativity, and what it is in the world that creative processes are about. The second dilemma concerns how search can be carried out when one seeks an object that is non-existing.

1. The ontological dilemma: How can something be novel, and at the same time come from somewhere?

2. The search dilemma: How can you search for something you don't know what is, and which doesn't even exist?

4.1 The ontological dilemma: How can something be novel, and at the same time come from somewhere?

When reading IP theories one can easily get the feeling that problems and solutions in these theories are mere internal phenomena. They are discussed almost entirely in terms of a 'problem space' or 'conceptual space'. But are these possibility spaces mere figments of our imagination? Is there no corresponding reality out there to guide the search, and no real object that we actually search for in our creative process?

This is a hard question, because obviously when a creative product is novel that means that it did not exist before the act of creation. This soon leads us into thinking of the novel product as something entirely subjective with no basis in the real world. As such, a creative product is 'out-of-this-world'. But in arguing that something is 'out-of-this-world' great care should be taken to ensure that we do not for that reason alone call it purely subjective (which would be the constructivist approach). When we think of a creative product, it is 'out-of-this-world' insofar as it is not-yet-existing. But to maintain a realist approach we need something (an object in the world) to evaluate against. We need a source for preparatory processes along with evaluative processes, to test and verify against. We need something outside our knowledge base and mental processes to learn from and measure against. In other words we need to have something *objective* that our thinking of a creative product is *about*.

What we need is for something (some modality) to be *objective* at the same time as it is *not-yet-existing*.

But surely this is a contradiction in terms? For how can something be objective and non-existing at the same time – are these terms not direct opposites?
It is my contention that these terms are not opposites. It is merely a matter of stretching the term 'objective' to include more than the actually existing. The terms 'object' and 'objective' have many meanings. It can mean 'true' and 'real' (as in 'an objective fact'); it can mean 'the opposite of subjective'; it can mean that something has structure and is imaginable (an 'object of thought'); etc. What I wish to do here is to separate some of these meanings to characterize what is meant by something being objective in creativity. To maintain that novel thought can be about something objective even though that something is not-yet-existing means that whatever they are about is governed by laws and constraints and are far from arbitrary. (This of course does not mean that the thoughts are limited to staying within the boundaries of the laws and constraints. We can imagine things that are not governed by regular rules and laws, things that could never come into existence). This is where Newell and Simon's possibility space concept comes into the picture. Possibilities are exactly the kind of modality that is objective at the same time as it is not-yet-existing. They are 'objective' in that they are about something outside the individual, and are governed by constraints and laws and are far from arbitrary. But they are not 'objective' in the philosophical sense 'true' or 'existing'. Perhaps one could say that they are 'objectifiable' – meaning that we can imagine them, that they can be

object of thought. But at the same time they are non-existent. To exist means 'to stand out from'. Only the actual world 'stands out from' the space of possibilities. The possibilities themselves do not.

My realist extension of the possibility space concept (i.e., claiming that subjective possibility spaces are about objective, but not-yet-existing, possibilities) of course leaves a lot of philosophical questions unanswered[30]. I will remain somewhat philosophically naive in my contention of what it means for something to be possible. I do not (and cannot) intend to completely resolve an issue debated over thousands of years by philosophers – the question of what it means to be possible. What I will do, however, is make a series of exemplified claims about what is going on in the creative process, and what this necessarily implies about the concepts of possibilities and actualities.

The **first claim** I will make is that possibilities are used not only in creativity, but also in a large number of mental processes we do not usually regard as creative. Obviously we all think in terms of possibility spaces in a lot of daily dealings in the world. Every time we plan something, we are considering options and calculating the best way or sequence of doing things, whether it be shopping or chess or trips to the moon. We are in essence moving around in a space of possibilities, as argued by Newell & Simon (1972). This ability to stretch forward in time, into the future to foresee possibilities has often been regarded as an important aspect of creativity. Ohlsson (1992) calls it mental look-ahead; Rochhausen and Ilgenfritz (1975) talks of the mental function of acting like a flashlight that shines light on the future, and creativity tests (especially tests focussing on divergent thinking) often include several subscales directed towards measuring the ability to think of possible future consequences of events[31].

Obviously possibilities are related to the future in this way. But furthermore possibilities are also an inherent part of the present and the past, and not limited to the future alone. An example of this could be the feat of telling a lie. When telling a lie we are substituting what actually happened with what might have happened, had things gone differently, and people acted in other ways. Again we are moving into the world of possibilities, but this time the possibilities of the past. In psychological and philosophical literature it has been called counterfactual thinking (e.g., Roese & Olson, 1995; Roese, 1997). A similar kind of counterfactual thinking is thinking in terms of alternative outcomes to key events in our lives. Such thinking can either be of a more negative outcome (called downward counterfac-

tual thinking – e.g., 'Well, at least such and such didn't happen') or a more positive outcome (called upwards counterfactual thinking –e.g., 'Damn, why didn't I do *that* in stead…'). Such thinking is quite possibly an important ingredient in rumination, regret and depression (Sherman & McConnell, 1995), but also informs our sense of justice and blame (Mandel & Lehman, 1996). A thief that could not have acted otherwise (who had a small range of options and possibilities) is not considered as guilty and blameful as one that could.

In the scientific discipline of history the area of counterfactual thinking is currently gaining popularity. Traditionally counterfactual thinking has been ill conceived in history, and often thought of as mere fantasy without any value for the domain. However, adherents of the counterfactual method argue that only regarding what *actually* happened, instead of also considering *what might have* happened, necessarily lead to historical determinism: things happened the way they did, because they could not have happened otherwise. Hence, counterfactual thinking in the scientific discipline of history is a method meant to avoid determinism.

Theories of counterfactual thinking in psychology concern themselves merely with actually occurred events (typically dramatic events). However, possibilities are also a quality of objects (i.e., entities and products) in the world[32]. Entities and products in the world have properties and functions and meanings that are not limited to the functions and properties and meanings we see (recognize) in them and use them for. This is the difference usually referred to as the object in itself (the Kantian ding-an-sich as it were), opposed how we use and recognize the object. An object placed under different circumstances (than it's usual ones) may display emergent phenomena we did not know it had. Objects combined or taken apart may display new properties. And so on. My hammer may be used for hammering, but it can also be used as a paperweight, a door stopper, a weapon, firewood and so on. And it can be taken apart, and the wood used for other non-hammering purposes, or the parts recombined with other objects and so on and so forth. In this sense, objects have possibilities for different uses, meanings, recombinations and so on.

In short, possibilities are an inherent ingredient in our everyday line of thinking about our world. We think of what we have done, what we might have done, what might have been if we had, what we should do next, and what might happen if we do. And we do it all the time and no one seems to object to the fact that we are able to do it, and that doing it is valuable and

(most importantly) that it is ABOUT real possibilities and actualities. Such feats are not mere figments of our imagination – they are preparing us for our possible future world and informing us about how our world could have been. Thinking of alternatives to the actual is a valuable way of learning about our world, a way of exploring the space of possibilities. Possibilities are not merely about the future, but are a quality of the world at any temporal state in history. For example, some possibilities seize to exist if we fail to take advantage of them. Part of existential philosophy is based on this inherent truth. If we do not take advantage of the moment and seize the opportunity, then the possibility may no longer be available to us.

Returning to creativity, the **second claim** about possibilities I will make here has to do with the relationship between the actual and the possible. It is obvious that what is actual was possible in the previous state. What actually happened *could* potentially happen, because it did. This may seem like a silly claim, since it is so obvious. But it is important as it is the basis of one of the most important ways we learn about possibilities. We make hypotheses and theories and think of inventions and attempt to test if they 'will work'. Some of them prove to be impossible to carry out (i.e., make actual) in the manner we thought would work. The plane won't fly, or what we predicted would happen, did not. In essence, this is a reality check we carry out to see if our subjective possibility space map well enough on the objective possibilities. Essentially it is stating that if we can make something into an actuality, then it is possible! But we do it because we were not certain beforehand – we needed the reality check to see if the road from the possible to the actual is where we thought it was. Hence, reversing the initial statement: if we can make something into an actuality, then it must be possible! We have an entire scientific discipline (theory of science) directed at working out how best to evaluate and test if a theory corresponds to what is, or not. Should we verify, deduct, hypothesize, test? In what order should we do it?

But hang on, am I then saying that a creative product needs to be made actual to be creative? How does that relate to the fact that I defined creative products as having originality *of kind*, and stated that creative products essentially possess 'over-singular generalizability'? Am I then not claiming that creative products need to be singular (with numerical identical) with actual physical properties to be creative? Well, yes and no. I am claiming that creative products need to be exemplifiable – or actualizable if you will. The reason creative products are 'over-singular' is that the creativity itself is not bound on any one numerical product, but on the creative *kind*. But

there are of course *kinds* that are not exemplifiable or actualizable or realizable or whatever you want to call them. I can easily imagine a machine that can allow me to travel across the universe without using any energy. But the laws of physics do not allow me to build one, and hence such a *kind of* machine is not realizable into exemplars and cannot be creative.

Thus, even though creative solutions are out-of-this-actual-world, they must somehow be able-to-be-brought-into-actuality. Indeed that is, in essence, what it means to be possible. If a solution for some reason is not-able-to-be-brought-into-acrtuality, then it cannot be creative! Much (if not most) endeavor in the creative process has to do exactly with this: figuring out a way for a solution to be brought into actuality – figuring out a way to exemplify the kind. How can I make plane fly – how can I test if the theory is correct?

If that for some reason is not possible, then the kind cannot, of course, be deemed creative.

The **third claim** about possibilities and creativity has to do with that which is NOT possible. In the two previous claims I have only implicitly made reference to the anti-thesis of the possible – impossibilities. Most theories of creativity seem to make some reference to these mysterious instances, but without fully realizing their implications for creativity. For example, Newell & Simon rightly noted that a creative search is not completely bound by problem space constraints, but can go beyond them. Boden and Perkins both had similar remarks about the seeming *errors* of generative systems. What are we to make of these impossible instances? Most theories seem to categorize them as subjective errors, as pure fantasy without any hold in reality. But here I will make a radical claim: I claim that the impossible is just as objective as is the possible. The impossible is not to be regarded as mere fantasy without any hold in reality – impossibilities are as much a quality of our world as are possibilities. It has to do with limits and constraints and natural laws which disallows something to be made into actuality. Just as the possible is defined by it's being-able-to-be-brought-into-existence, the impossible is defined by it's not-being-able-to-be-brought-into-existence! It is a category of things and events that cannot be, for one reason or another. Of course the content of pure fantasy, paranoid hallucinations, and the like belong here. Not because of it's subjective nature, but rather because it is unable to become actual.

The distinction between the impossible and the possible allows us to distinguish between fantasy and creativity. Whereas fantasy in generation of novelty does not distinguish between what is possible and impossible in the world, creativity has to. Only products that are possible can be creative[33].

More important for creative endeavors is the space close to the boundary between what is possible and what is impossible. Indeed there is a line (or boundary) to be drawn there somewhere (where this boundary is exactly is an empirical question); it is a real distinction to draw, although the exact location of this boundary can seem somewhat fuzzy for us humans at times. In creative endeavors we are in fact exploring the very boundary between what is possible and impossible. The inventor fiddling around with a machine is trying out 'what works and what does not work' – he is essentially exploring the very boundary between the possible and the impossible. The scientist working to find new emergent phenomena in nature is basically exploring what the world can and cannot do under different circumstances – again it's an exploration of the boundary between the possible and the impossible. Now, in our everyday lives the boundary between the possible and the impossible can seem quite clear, because we mostly operate in areas where experience has taught us the difference between the possible and the impossible. We know quite well what we can and cannot do in most areas of life; what our options are and what they are not. But in creativity the line is far from clear and straightforward. The reason for this is that in creativity we are faring in unexplored territory, we are directed towards novelty and emergence, and we are of course hoping to find a solution that a reality check will tell us is possible. But we are not certain! We are fiddling around to figure out if what we *think* are possible states, *can actually* be made into actualities (and hence, determine that they were *objective* possibilities). Determining whether an objectifiable state is possible or impossible is far from easy and straightforward (especially in areas where we have not gone before – where our knowledge base is limited). Often you have no other way of determining it than attempting to make it into an actuality – and see if you are able to do it or not.

The IP theories focus almost entirely on what is *possible*; the space for creative search being made up of *legitimate possible* states within constrained boundaries. Of course, as Boden rightly argues, real creativity is not merely a matter of generating new combinatory instances. Creativity is about exploring and transforming your conceptual space, thereby generating a new space or an exemplar that could not possibly have been generated in the old space. In that sense creativity is 'impossible'. But Boden fails to

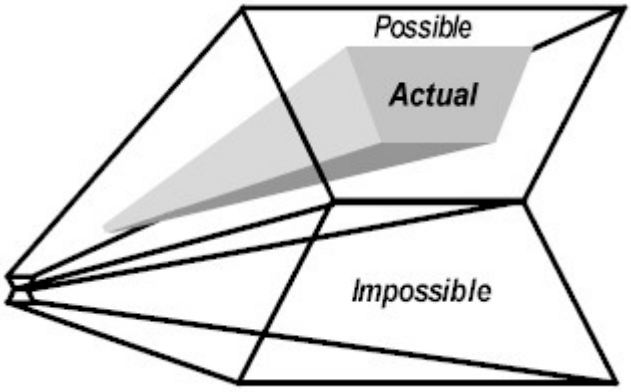
distinguish between the psychologically impossible and the objectively impossible.

When we include into our ontology a category of the objectively impossible (that which cannot be brought into being), we see that what Boden's creator is doing, is NOT, as she claims, making the impossible possible (in any ontological sense), but instead making a more accurate subjective reflection of objective, but non-existing, possibilities and impossibilities. The boundary between them is explored, and the subjective reflection of what can and cannot be done is altered on the basis thereof. As such, Boden was right in pointing out that creativity is directed towards exploring and transforming our conceptual space, but she forgot to include in her model the very thing your conceptual possibility and impossibility space is transformed on the basis of – that being the *objective* possibilities and impossibilities that we learn of e.g., by attempting to make them reality.

The point is that we learn of the impossible by exploring the boundaries between what can and cannot be done. And we use this information in our future attempts at solving problems and creating products. A failed attempt at solving a problem does NOT bring us back to square one! We incorporate the knowledge of the impossible instance into our knowledge of what cannot be done, and continue on from there.

Of course, the knowledge of what cannot be done, about the objectively impossible, is often not at the forefront of our thought processes[34]. In that sense, the IP theories are quite right in pressing that it seems like we are moving only in a space of possibilities. But knowledge of the possible *implies* knowledge of the impossible as well, just as figure implies ground.

In short, just as possibilities are objective (although non-existing), then impossibilities are objective (although non-existing). The difference being that the impossible *cannot* be brought into existence (made actual). Figure 7 shows how such an ontology of creativity could be portrayed.



The primitive ontology sketch illustrates that possibilities and impossibilities are qualities of the actual world. Possibilities and impossibilities are objective (and objectifiable in thinking for humans), but non-existing. Only possibilities can (of course) be brought into existence.

Humans gain knowledge of the possible and the impossible through their actions in the actual world. What we expect to be possible may turn out to be impossible (and the other way around), when we try to actualize what is believed to be a possibility. The number of possibilities and impossibilities of the actual world are infinite. The depth dimension of the sketch illustrates time, and is included to show that as the actual world develops and changes, so does the possibilities and impossibilities thereof.

Fig 7. Creative ontology

Because creativity is directed at novelty and thus areas of the world where we are not totally familiar with the 'topography', the boundary between what can and cannot be done (the possible and impossible) is unclear. Creativity explores this boundary. Often the creator is wrong, and what he or she thought was possible, proves impossible. But such an instance informs us *of the world and it's inherent possibilities and impossibilities* and does not leave us back at square one. We now know just a little bit more about what cannot be done. Creativity is about exploring the boundary between the possible and the impossible, in an attempt to find an instance (a solution) that proves possible.

A problem with the concept of the impossible has to do with what can be considered an impossible state. As mentioned above, the objectively impossible has to do with states that the world cannot display, things that cannot happen. The subjective reflection thereof can be a quite vivid imagery of worlds of unicorns and suspended gravity. But as it has been made clear in the above sections, quite often in creativity it remains unclear if a state is in fact objectively possible or impossible. The only way to find out is to try to make it into an actuality and see if it works. The problem here is what to

make of something that cannot come into existence. It seems somewhat odd that an imagery of unicorns in suspended gravity can be an accurate reflection of anything. How can we possibly imagine something that cannot be? Well, we can, and we do. But the concern is a legitimate one, if one understands the subjective as a mere unprocessed reflection of the world[35].

The subjective is not an unprocessed reflection of the world, of course. Subjective possibilities and impossibilities are *generated*, even though they are also a reflection of the objective possibilities and impossibilities. We do not have direct access to objective possibilities and impossibilities, and hence need to combine and synthesize and take apart existing objects and concepts and events to generate novel forms. But as I have argued here – that does not make the possibilities and impossibilities a mere figment of our imagination. They still reflect the objectively possible or impossible, no matter how they were generated, and can be a more or less adequate reflection thereof. Section five deals with how this generation takes place.

These three claims taken together can be said to sketch how a realist ontology could possibly explain how the basis of creative endeavors is the objective possibilities and impossibilities of the actual world, although the generation of creative products occur on the basis of more or less adequate reflections thereof.

4.2 The search dilemma: How can you search for something you don't know what is, and which doesn't even exist?

When IP theories discuss the concept of search, the concept of a 'goal-state' is central to the theories. Indeed, the subject's ability to monitor (progress in) the distance between the present location, and goal-state is central for several of the heuristics used by the IP theories. This means that the subject must somehow have an idea, or, at the very least, some evaluative criteria for determining what constitutes the goal-state. The subject is, thus, believed to have a more or less clear idea of a goal-state. This may seem reasonable in traditional problem solving (with well-structured and well-known problem types), but in creativity, this is problematic for two reasons: **First** of all, the goal-state does not yet exist (although it is objectively possible or impossible). The ability to search for that which is not yet existing (although possible) has been called 'the paradox of search' by Davydov & Zinchenko (1980; see also Engestöm, 1998):

> "To look for something that does not yet exist but that is possible and is presented to the subject only as a goal, something that exists as an idea and is

> not yet actual: this is the fundamental, cardinal aspect of the vital activity of every sentient and thinking being – a subject. […] In light of this the paradox of search consists in the fact that it combines within itself the possible and the actual." (Davydov & Zinchenko, 1980, p. 24).

This quote by Davydov & Zinchenko seems to place a great emphasis on the goal state of the search in a way that makes knowing (quite specifically) what the goal state is important in a search. However, in creativity, you search for novelty, and as such you cannot 'know' in the sense 'recognize' the goal (although you can certainly 'cognize' it). This brings us to the **second** problematic issue about goal-states: since we are dealing with novelty, the subject does not 'know' what the object of the creative search is. He has certainly never perceived it. To put it philosophically in Plato's words:

> "But how will you look for something when you don't in the least know what it is? How on earth are you going to set up something you don't know as the object of your search? To put it another way, even if you come right up against it, how will you know that what you have found is the thing you didn't know?" (Plato quoted in Moore, 1994, p. 174).

Putting it in Plato's terms makes creative search seem self-contradictory. Indeed, how can a subject search for that which is unknown, let alone non-existing? But Plato's assertion is false. The error is one of portraying search as necessarily entailing that the object of search must be known to the subject in it's entirety in order to be recognized (i.e., found) by a subject. This dualism makes development, learning and creativity impossible. If I cannot search for what I don't know (e.g., what seems to be missing, what I cannot explain, what is possible and impossible), then I cannot expand my knowledge to include novel kinds. I would already know the endpoint of my search! For example, in problem solving, if you know the solution to a problem in it's entirety before the search, then there is not much point in searching for it – you already have the solution!

I have already hinted to the solution of this dilemma in previous sections. When I followed Engelsted (1989), and argued that self-initiated movement (activity) implies a non-object in a search, I implicitly took a stance in relation to this dilemma. When activity implies a goal or non-object (regardless of whether the subject has any idea of this goal) then a search starts with activity – not the knowledge of what the goal state is going to be. The animal can search for feed, regardless of whether or not it knows what feed is, or what the specific feed it is going to find is going to be. In that sense, the

spontaneous nature of the process ensures that it can be intentional without requiring neither the consciousness of a goal-state, nor the path or direction to such a goal (Bang, 2000).

Arguing in this manner, makes it possible to initiate a search without the prior knowledge of what it is exactly there is to be found. However, it does not necessarily solve the dilemma of how you can recognize a solution or goal *as* a solution or goal, when you see it. This is where the distinction between the non-object and the object comes in.

If you argue, that to find something, you have to first know what it is you're searching for (i.e., what the *specific and concrete* object is going to be) then creative search is impossible. But fortunately, we need not know in advance, what the *specific and concrete* object of our search is going to be. Although there can be quite specific and explicit goals for a search to take place, there need not be. Perhaps merely a few necessary criteria for the goal are known. And the criteria for what you are searching for may evolve as the search takes place, and need not be set in advance. As we shall see below, in creativity there are different kinds of searches taking place, differing in the vagueness of the criteria for the object of search. The criteria for creativity can be as vague as the search for something 'interesting' or 'surprising' in a domain.

Bang (2000) argues that the ability to search for what you do not know is also present in children's appropriation of knowledge in learning situations.

> "If the pupil reaches an impasse (which is a frequent occurrence), then the pupil may think, that information is missing, and can then start to search for information that may prove useful. When this process starts the pupil does not yet know precisely which information it is relevant to search for. This does not prohibit the search, however, and in this manner the student is spontaneously intentionally directed towards material, which is not accessible in the situation. The pupil acquires (searches for) materials that are not perceivable. […] The pupil searches for something without knowing what it is the search is for. But it is nonetheless possible to find that which you did not know what was." (Bang, 2000, p. 31, own translation[36]).

The similarity between the above presentation of what occurs in the learning situation, and the creative process is striking[37]. The reaching of the impasse, and the paradoxal search initiated to overcome it, are key aspects of both the learning and the creative process. Bang (ibid.) goes on to argue

that since subjects cannot know exactly what they are searching for, there must be general and unspecific elements in the search process. The fact that there are no a priori *specifically defined* goals for thinking, should not be confused with the fact that thinking do have goals (of a general kind) (ibid, p. 36).

Although the creative process is a search process in the paradoxal sense, it also generates (…brings into being…) the object of search. Here we see the tension between realist and constructivist theories of creativity play out again. Although a paradoxal search among possibilities and impossibilities are taking place, the search also *generates* both these possibilities and impossibilities, and the exemplification of the creative kind. The objective possibilities and impossibilities that the paradoxal search takes place in are not directly perceivable (available for direct pickup) but must be constructed from the *knowledge* of the actual world, and it's possibilities and impossibilities. But that does not make them a figment of our imagination, as I argued above. I will discuss the cognitive aspects of creative search in more detail in part 5.

When, as I have argued, the creative process does not search for a priori directly specified goals, it is possible to extend the kinds of conative directedness taking place in the creative process from merely the specified problem solving kind, argued for in the IP theories. Creativity is also about searching by *playing around* in a domain, looking for interesting or surprising or contradicting facts. Discoveries are by definition 'discovered', meaning that the subject did not know in advance, that he was going to find this particular finding. Serendipitous findings are also creative in this manner. Polanyi suggested that scientists and other investigators rely on "intimations of something hidden, which we may yet discover" (Polanyi in Schooler & Dougal, 1999, p. 351) to guide us in fruitful directions.
All these processes are creative (paradoxal) searches.

The IP theories use of the concepts of initial state and goal-state is also limited in the sense that a concept of 'closeness to solution' does not do justice to the process of evaluating if ideas, recombinations and analogues are in fact viable creative products in their own right. Such an evaluation of whether an idea is actually a workable solution to a creative problem is a highly complex process (e.g., Runco & Chand, 1994). But it is reduced by the IP theories to being merely a matter of evaluating 'distance to goal', rather than the complex process of estimating which aspects of the solution need altering, what parts work, why it works, what the implications are, if it

is practically possible or impossible, how one should proceed, etc. During the creative process the creator is not alone with his or her thoughts in a rational thought process (as the IP theories believe), but actively constructing models, talking to people, gathering information, exploring the world and so on. Creativity does not occur in a detached mental space.

There are several different kinds of conation in the creative process that needs to be included in the explanation of the creative process (see figure 8).

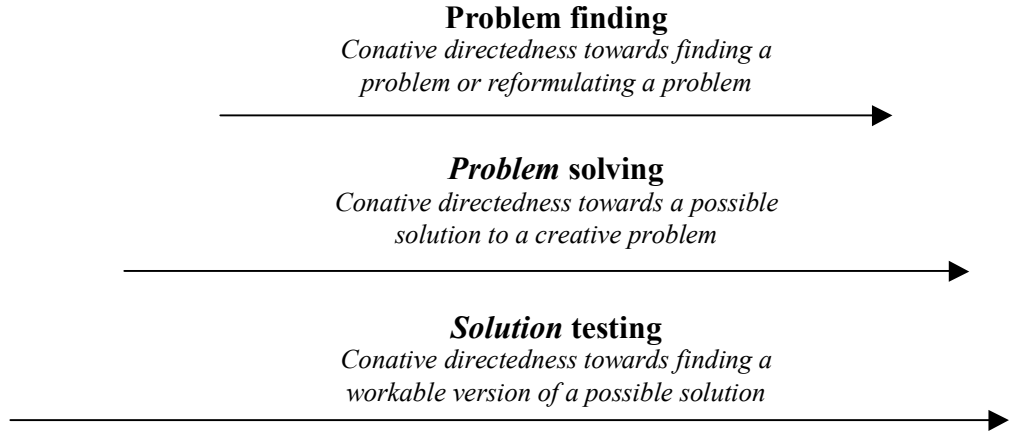


Fig. 8. Examples of kinds of conation in the creative process

Each implies different kinds of objects and non-objects. Three important (although not necessarily the only) kinds of conation are:

1) *Problem finding (PF): conative directedness towards finding a problem or reformulating a problem*. Searches by playing around in a domain, e.g., looking for interesting connections, or surprising elements. Such a search may transform or specify a domain, or find new problems or formulate existing problems in new ways. Any scientist will recognize thinking in this manner 'there is something fishy here… I wonder if I can find another way of looking at the problem…how can this best be perceived?' Such a conative directedness can discover discrepancies in research and facts.

2) *Problem solving (PS): Conative directedness towards a possible solution to a creative problem*. This is directed at finding a solution (object) to a creative problem (non-object). There are many different varieties hereof, including rational and irrational searches. Solutions appear with

various degrees of certainty of their correctness, the scope of the creative solution can be great or small. Some are conscious attempts, while others appear suddenly and surprisingly even to the creator. Again all researchers and inventors will recognize doing this 'hmmm… wonder how I can overcome this obstracle…will this work?…. hmmm no…. Im at a loss here … HEY! What about this?…. oh no …. OH but this might work!…. AHA! of course!… this will probably work'. There is of course no certainty that there is a solution to be found. The creator has to make what Hertz (1999) calls 'the ultimate assumption': that there is a solution out there to be found in the first place.

3) *Solution testing (ST): Conative directedness towards finding a workable version of a possible solution*. This process is directed at evaluating and testing a theory or novel kind of product, by searching for an exemplification of the kind. Here you have an idea you think may work – but you need to test it (e.g., by verifying or falsifying), and implement it. In essence the inventor trying to find a way to make his invention work, is looking to exemplify the invention (i.e., kind) he is assuming will work ('how can I make that plane fly?'). Whether or not it *actually* will work will determine if the product was possible, and hence could be creative. The researcher in need of testing and elaborating a theory may go though a process similar to this 'how can I test if this is correct?…. hmm this may work, but is seems to neglect this and this… so how about using that method instead?… ok, I'll try this…. WOW, it actually worked!'.

This is probably far from a complete list of different kinds of searches in the creative process. But it represents a start, and it illustrates the need to extend the list from merely entailing rational searches, looking for solutions to problems. The conative directedness in creativity *is* a (paradoxal) searching process (or rather entails a range of different kinds of searches), which must be extended beyond the narrow search concept used by the IP theories.

We have now reviewed two dilemmas contrasting a constructivist and a realist position in creativity, one concerning ontology, and the other concerning search. It is now time to try to incorporate the findings into an ecological model of creativity.

4.3 The creative cycle introduced

The dilemmas reviewed above has shown us two things about the creative process: The ontological dilemma showed us that the object of the creative process are objective although not-existing possibilities and impossibilities that are themselves qualities of the actual world. Further, the search dilemma contended that it is possible to search among and for these possibilities and impossibilities, even though the creative 'solution' is neither known nor existing at the onset of the search. These results indicate the necessity of transcending the IP theories' narrow constructivist focus on creativity as a mental search, into an explanatory model, that can incorporate both objective possibilities and impossibilities, as well as how the subject samples these possibilities and impossibilities.

I will now try to sketch out a model that can incorporate these findings, by making an ecological model for the creative process. The model will follow us through the rest of the thesis, being developed as we go along. As we saw above, such a model will have to incorporate an ontology of objective possibilities and impossibilities that are qualities of the actual world; It must include various types of searches (problem finding; problem solving; solution testing); it should highlight creativity as action in and about the world; the creative process should be viewed as a way of becoming increasingly better at reflecting objective possibilities and impossibilities, and thus increasing the adequateness of the subjective reflections thereof; but at the same time creativity is also generating creative products that have the qualities of generalizable originality and the potential for adaptive spread.

How can all these qualities be incorporated into a single model? Perhaps surprisingly, a model with a high degree of fit with the needed qualities exists in the literature on perception. I am referring to Neisser's (1976) model of *the perceptual cycle.*

Perception and creativity are certainly not the same phenomenon, and some may even argue that they are distinctly opposed (one being internalization - the other externalization). But in the creativity literature the two have often been examined and found to be of a related nature. For example, the Gestallt theory of perception have been argued to be closely related to creative processes such as insight and image-reinterpretation. Mayer summed up the Gestaltist approach in this way:

> "Just as perception involves building an organized structure from visual input, creative thinking often involves the reorganization or restructuring of visual information." (Mayer, 1995, p.10).

Recently, in an empirical study correlating the solving of insight puzzles with a battery of other psychological tests, Schooler & Melcher (1995) found that the number of solved insight puzzles correlated the highest with a test measuring the ability to recognize out-of-focus pictures (corr= .45). (For an overview of other empirical tests correlating perception with creativity, see Smith & Amnér, 1997).

I am, however, not after a *correlation* between perceptual tasks and creative tasks, as my usage of the perceptual cycle will be of a much more general kind. I am using the perceptual cycle here in it's function of a theory of knowledge. As such, I am using Neisser's (1976) model of the cyclical nature of perception as a base analog of what occurs in the creative process. In making the perceptual cycle, Neisser synthesized unresolved and apparently opposing approaches to the study of perception. In the model he emphasized, among other things, the cyclical nature of the process; the concept of exploration and anticipation in perception; the fact that perception is an active process occurring over time; the inclusion of the real-world in the model; and the modification of subjective schemata by the world. All these qualities of the model fit well with what I have emphasized in the creative process. Below I will take a closer look at Neisser's model, and then try to adapt it to deal with creativity rather than perception.

4.3.1 The perceptual cycle

Neisser's intention with making a model of perception as a continuous cyclical activity, was (among other things) the dissatisfaction with cognitive research of perception treating the subject as a passive recipient of stimulus imposed, by the experimenter, on the retina. He emphasized that perception was a directed process, taking place over time. As such the subject's explorations and anticipations should be considered part of perception. Perception is a skillful activity that depends upon preexisting structures (called schemata) which direct perceptual activity and which are modified as the process occurs (Neisser, 1976, p. 14). The perceptual cycle can be seen in figure 9.

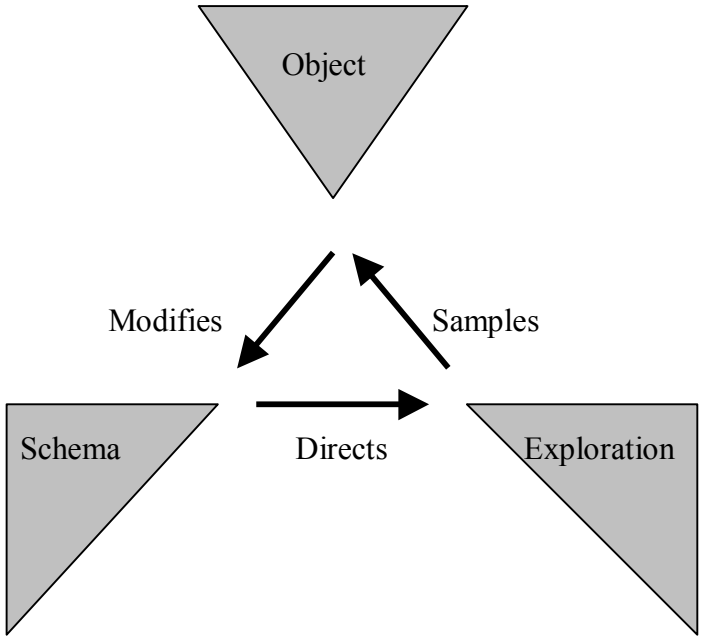


Fig. 9. The perceptual cycle (Neisser, 1976, p. 21)

Basically the model synthesized three approaches to perception. In emphasizing the anticipatory aspects of perception and directive function of the schema, the model incorporates the view that perception is testing and confirming hypotheses (e.g. Bruner and Gregory in Neisser, 1976, p. 24). The emphasis on the object of perception and how this affords action from the subject and allows the subject to pick up information, places the model close to the realist and ecological approach of Gibson (e.g., 1979/1986). And finally, in emphasizing the complex internal mental processing involved in accepting information from the environment, the model incorporates research from information processing theories (see Gardner, 1987, for an overview). These three approaches to perception are thus synthesized into Neisser's ecological cognitive approach to perception. I will now look a little more closely at the schemata, exploration and object in the model.

Schemata are defined as follows:

> "A schema is that portion of the entire perceptual cycle which is internal to the perceiver, modifiable by experience, and somehow specific to what is being perceived. The schema accepts information as it becomes available at sensory surfaces and is changed by that information; it directs movements

> and exploratory activities that make more information available, by which it is further modified."(Neisser, 1976, p. 54).

The definition underlines the duality of the schema; it "…is not only the plan but also the executor of the plan. It is a pattern of action as well as a pattern for action." (ibid., p. 56).

Schemata assures the continuity in perception though being anticipatory (linking the past with the future). However, this does not mean that we cannot pick up unanticipated information[38] (ibid., p. 23). Further, continuity in perception is found in some schemata that are temporal in nature, meaning that the schemata direct exploration that takes place over time. An example hereof is the modality of touch, which in its very nature is not a single point (frame) of reception, but rather consists of movement over time. Schemata can be seen as part of a larger cognitive system, consisting of cognitive maps (ibid., p. 112). It is important in that connection to note that imagery (i.e., imagination) is fundamentally different from perceiving according to Neisser. Having an image is the *inner aspect of a readiness* to perceive the imagined object (ibid., p. 131), whereas perception is a cyclical process which merely includes an anticipatory phase.

The **object** in the perceptual cycle is the real-world in space and time as it presents itself in the present situation. The information in the environment is structured and is sampled through exploration and modifies the schemata accordingly.

Exploration takes place upon the directions of the schemata, and, through movement, samples information from the environment. Perception is thus a skill and a kind of doing – although it differs from certain other skills in that it does not change objects or the world in any significant way (ibid., p. 52).

> "Although perceiving does not change the world, it does change the perceiver. (So does action, of course)."(Neisser, 1976, p. 53)

I will now try to adopt the perceptual cycle into a model for the creative process.

4.3.2 The creative cycle

Like perception, creativity is also an active process involving the acquisition of structured information from the environment. It involves various kinds of searches, which involves anticipation, exploration and acquisition of information through modification of mental structures. Thus, like perception, creativity is a cyclical process.

However, perception and creativity also differ. For one, creativity involves not just the change of subjective schemata, but also, and most importantly so, the change of the world by addition of novel and useful products. Another difference is that the actions involved in the creative process cannot exhaustively be described as 'exploration'. Below I will try to outline the three elements in the model, and the modifications needed to make this a model of the creative process.

Object: Neisser pinpointed the fact that perception occurs over time, in a world of structured information. However, perhaps one can say that the world is still defined merely as a world as it presents itself positively to the subject. The world, in the perceptual cycle, does not seem to include hypothetical possibilities or impossibilities, although it exists in space and time. When Neisser pinpointed that perception occurs over time, it was to avoid the traditional view of perception as a stimulus being imposed on the retina in an instance. But 'time' in the perceptual cycle only includes the time over which perception takes place[39]. It does not really include time prior to perception (the past history dimension), or time in the sense 'possible future versions of the actual'. In that sense, the object (world) seems quite static, and Neisser does not include transformations thereof made by a subject (i.e., any creative endeavor). As I have argued above, the creative process also entails incorporating objective, although not-yet-existing, dimensions. This is the dimension of possibilities and impossibilities. Possibilities and impossibilities are qualities of this world, but must be explored in a somewhat indirect manner. The actual world, with possibilities and impossibilities, together makes up what I have referred to as a creative ontology; a world in space and over time, with objective possibilities and objective impossibilities.

How does this creative ontology relate to creative search? Above, we saw how Engelsted (1989) argued that self-initiated action implies a 'non-object'. Any search is thus a movement from the 'non-object' to the 'object', a movement that in its most elementary form involves cognition. The dimension in which the 'non-object' exists is what I have termed the objec-

tively possible and impossible. The object, once it is created or found, is in the dimension of the actual. As such, in any search, you are moving back and forth between the possible/impossible, and the actual. In basic animal life, such as the protozoan, the activity required to bring the non-object into the dimension of the actual, is mere physical movement. By moving in space and time, the protozoan brings the non-object into being (or rather, finds it). This, of course, is not a creative action per se, as the animal merely 'finds' the object. However, in creativity it is somewhat different. Here we cannot simply move physically and expect to create (or 'bump into') a creative product. We need to generate as well. But the basic principles are the same: creative generation involves a cognitive activity that is moving back and forth between the actual and the possible and impossible (see fig. 10).

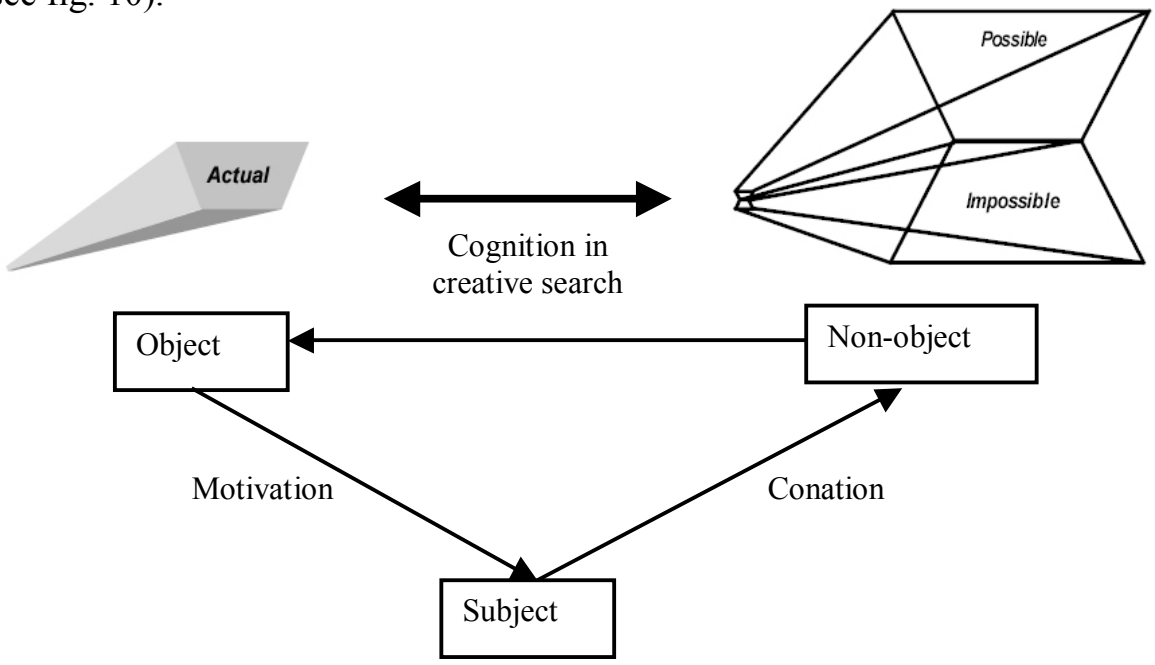


Fig. 10. Creative ontology, and Engelsted's (1989) concept of the 'non-obejct'

A potential problem for viewing creativity in an analog model to the perceptual cycle is the sense in which one can be said to be 'sampling' the possible and impossible in a process of creative generation. We are, after all, not able to directly 'pick up' information from this dimension. However, Neisser (and before him Gibson, 1979/1986) has made a strong point in arguing for perception as a active process that occurs over time. Similarly, creativity is a process that occurs over time through action. The action, in this case, involves the generation of variations of the actual world (otherwise it wouldn't be novel). But in the very process of generating variations, the subject is also sampling possibilities and impossibilities. So,

although we do not have the ability to directly 'pick-up' information from the dimension of the possible and the impossible, we can still learn of it through action. The action in this case happens to involve thinking. But, again, that does not mean that creative thinking is not *about* something. We may be generating, but at the same time we are sampling the objectively possible and impossible. Often we cannot know whether our generation will work in actuality. The only way of knowing for sure is trying it out by attempting to actualize it.

As I have argued, a creative product has 'over-singularity' in that it has a structure that is generalizable. At the same time, however, I deemed it necessary to exemplify the kind in the actual world in order to make sure that it was in fact objectively possible (and not impossible).

As such, the creative process generates products by sampling them from the possibilities of this world, and exemplifying them by bringing them into actuality. If a product turns out to be impossible to bring into this world, then that product cannot be creative.

This is the main difference between creativity and fantasy. In the creative process you have to determine that the end product is in fact possible. This can be extremely hard to do, and inventors and scientists spend years looking for ways to exemplify their theory or product. Sometimes the products are proven impossible, and dismissed as uncreative; others are proven *impossible to deem impossible* and termed bad science or superstition because of their circular or unprovable qualities, and so on. At other times the inventor or scientist is wrong, and an impossible product is believed to be possible for a while (or the other way around). The point is that creativity is about distinguishing between the objective possibilities and the objective impossibilities, and about the subsequent attempts at making the possible actual. It is essential for a product to be proven *possible* before it can be deemed creative. As such creativity is not merely an internal mental process detached from the world. Creativity may involve thinking – but it is thinking in the world, about the possibilities and impossibilities of the world, and directed at the world.

A detached process, on the other hand, would be fantasy (a process often thought to be closely related to creativity). Fantasy generates variations too, but the function of fantasy is not to try to make the fantasy real, or to determine whether the fantasy is possible or impossible.

Claiming that cognition in creative search is a process of oscillating between the objectively possible and impossible, and the actual of course does not explain how precisely this oscillation takes place. It does, however, set the stage for such an explanation. In part 5 I will look more closely at how exactly creativity can be an action proceeding from the actual to the possible and the impossible, and back to the actual.

Schemata: Neisser (1976) was right in pointing out that perception is a cyclical process, where the subject anticipates information in the environment, and performs directed active explorations, which samples information. However, the concept of 'schemata', which is believed to explain these anticipatory and directive processes has been criticized for being a sort of 'magical concept' that can explain any finding post hoc (even in later writings by Neisser himself, - see Neisser, 1994). The concept goes beyond the 'mental space' concepts used by some of the IP theories, and instead explains schemata as developed through a being-in-the-world. But in detail it is still somewhat problematic for a theory of creativity. First of all, Neisser limits his theory to merely perception, and processes, where the subject does not change the world. This obviously makes it impossible to explain creativity, without first changing the theory somewhat. The reason for this distinction may be in part a historical distinction between and separation of perception and thinking processes, and in part because of his heavy reliance on an ecological model for perception (inspired by Gibson) which leads him in a direction, where subjective processes that go beyond the positively given (i.e., directly perceivable) is somewhat unexplainable. The theory of perception he is left with (or rather theory of knowledge, as it were), seems to be limited to a static world, where the perceiver can only move about in an exploratory manner, but cannot 'change' anything. This static world leaves no room for creative processes. The static world-view, and the limitation to explain only processes that does not change the world, however, becomes very problematic when Neisser tries to explain imagery. As briefly described above, Neisser tries to explain imagery as having merely an anticipatory function.

> "To imagine something that you know to be unreal, it is only necessary to detach your visual readiness from your general notions of what will really happen and embed them in schemata of a different sort. When you have an image of a unicorn at your elbow – while quite certain that unicorns are purely mythical animals – you are making ready to pick up the visual information that the unicorn would provide, despite being fully aware that your preparations are in vain. […] According to the hypothesis being proposed,

> however, even counterfactual images are still potentially functional anticipations. If the right kind of unicorn were somehow to materialize at the elbow of a person who was imagining one, he would see it more quickly and easily than if he had been imagining anything else." (Neisser, 1976, p. 132-133).

This explanation of imagery must leave the reader pondering as to both the HOW and WHY of imagery. Although Neisser descibes the function of counterfactual thinking as being anticipatory (and indeed this can be a function), he seems to be missing the fact that the primary function of counterfactual thinking is creative, in the sense, creating something not-yet-existing! Imagery does not primarily prepare us to perceive the world as it is, but rather to change it into something else! *Why* a subject would imagine a unicorn in Neisser's example remains a mystery, since it is obviously *unreal* as Neisser points out.

Further, the schemata theory does in no way specify *how* exactly it is possible for a subject to imagine (or rather – to anticipate) a unicorn (i.e., a novel generation never perceived by the subject). Neisser is right in pointing to the fact that imagery has an anticipatory function - but it is not the only function! Neisser is obviously right in objecting to the homunculus theory of some previous cognitive theories (i.e., where imagery - metaphorically - is carried out by an inner being). But in the case of imagery and creativity, his theory (qua theory of knowledge) is overly restrictive

The concept of schemata in the perceptual cycle, although useful to an extent, leaves several elements to be explained for a theory of creativity. Not least, how a subject can change the world; how a subject can think of the not-yet-existing (although objectively possible or impossible); how a subject through anticipatory action can sample the objective possibilities and impossibilities of the world (rather than merely the actual world); and so on. I will thus not make use of the concept of schemata in the remainder of this thesis, but will for now broaden that aspect of the perceptual cycle out to the concept of the *subject*. Neisser (1976, p. 1) correctly defined cognition as "…the activity of knowing: the acquisition, organization, and use of knowledge", but limited his analysis to exclude processes that change the world. Due to these limitations I will make an extensive analysis of cognition in creativity in part 5, and thus try to specify how knowledge is acquired, organized and used in the creative cycle. We will see that creative cognition involves many of the same mechanisms as Neisser pointed out (anticipatory functions; directing activities; etc.) as well as additional ones.

Exploration: In the creative cycle, exploration is changed to the broader concept of 'action'. The basis for this is of course that exploration alone does not do justice to the many and varied forms of activity taking place in the creative process. Many of these are thinking processes, such as generating and selecting variations. But verifying results, evaluating, exploring, acquiring, and so on also takes place.

These elements together makes up the creative cycle (see fig. 11).

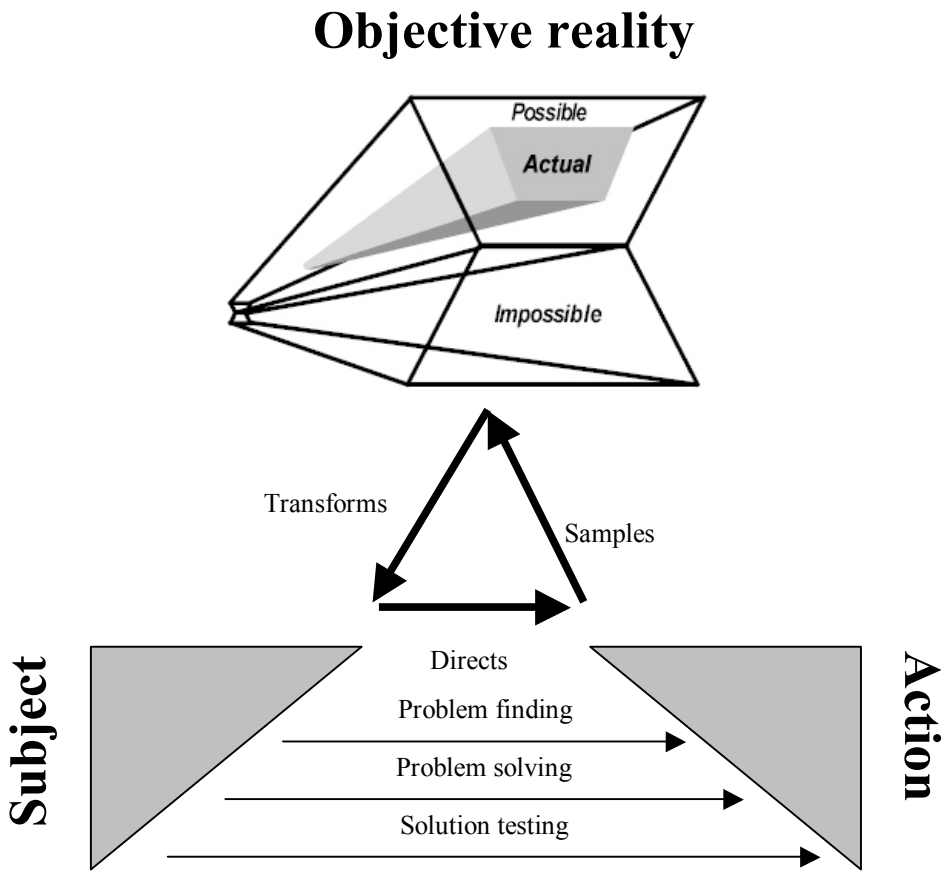


Fig. 11. Sketch of the creative cycle.

Perhaps this model of the creative cycle does not seem to leave much behind of Neisser's original perceptual cycle. 'Object', 'exploration' and 'schemata' are extended into objective reality (a non-static world with objective possibilities and impossibilities), action (including thinking) and subject (in a broad sense). But the general explanatory model (i.e., the relations between the different elements) remains. This model thus maintains the fundamentally realist explanatory model of the perceptual cycle, although it is extended to incorporate creative processes alongside the perceptual ones in the model. The different kinds of search conducted in the

creative process are listed under the way the subject is actively directed towards the objective reality

Perception and creativity are not viewed as opposed (e.g., internalization vs. externalization), but as part of the same basic developmental process.

There are still a number of shortcomings of the model. Indeed, a cognitive psychologist may not be too impressed with it in its present form.

First of all some thoughts should be given to the distinction between physical creative action, and creative thinking. I have criticized Neissers explanation of imagery, but have not yet provided an alternative that can be incorporated into the model (without resolving to a homunculus explanation). Second, it needs to be specified what types of action are taking place in the creative process. Third, it needs to be specified how exactly the process of oscillating between the objectively possible and impossible, and the actual takes place in the creative process. Fourth, and most importantly, it needs to be specified what and how information is represented subjectively, and how this information can help generate novel and useful products. And finally it needs to be made explicit that the creative cycle is generating real-world novel and useful products, and not just transforming thoughts. It was Neisser's contention that the perceptual process did not significantly change the objects being perceived. In creativity, it is obviously a requirement that a product is being created. Hence, I need to explain, in principle, how the model changes the world, and brings creative products into being. I will deal with all these limitations in the next section on creativity as cognition.

4.4 Summary

In order to overcome the problems and limitations of the IP theories, it was suggested that an ecological approach to creativity should be developed. Two dilemmas such an approach would face were discussed. One concerning the object or *ontology* of creative action, and the other concerning how creative *search* for such an object was possible.

The ontology dilemma was reanalyzed into the question: 'how can something be objective and at the same time be not-yet-existing?' The solution to this dilemma was to regard possibilities and impossibilities as at the same time objective and non-existing. We live in a world of actualities, where some things are possible, and others impossible. From the pool of the possible we draw our future actualities. Possibilities and impossibilities

are qualities of the actual – they are not separate from it. There are not an infinite number of possible worlds 'out there'. But there are an infinite number of things this actual world allows (and disallows) as something that could possibly come into existence. Although possibilities and impossibilities are not a 'somewhere', they are objective in the sense that they are objectifiable by human beings in thought and governed by constraints and laws and are far from arbitrary. We learn of these possibilities and impossibilities through our intentional (and anticipatory) action over time in the actual world. The possibilities and impossibilities are an inherent ingredient in our everyday line of thinking about our world. In creativity they become especially important, as we are producing novelty. This novelty has to be tested against the actual, to see if it is in fact possible to produce it or not. Only kinds that are possible to exemplify can be creative, but an exemplar that turns out to be impossible further directs the search and increases knowledge of what cannot be. In creativity the boundary between the two can be hard to find, as we are dealing with novelty and faring in uncharted waters. We do not have direct access to these possibilities (i.e., the ability to 'directly pick them up'), and thus have to generate them from actualities and past experience. But that does not make them figments of our imagination without hold in reality. They are still objective, and our generations of possibilities and impossibilities can be more or less adequate reflections of what is and what might be.

The search dilemma: 'How can you search for something you don't know what is, and which doesn't even exist?' In creativity, the object of search is an objective, although not-yet-existing possibility or impossibility of the world. Searching for possibilities has been referred to as 'paradoxal search'. Theories of a dualistic nature will object to the ability to search for objects that are not known in advance. Therefore a theory of creativity must involve an active search, where the search activity itself implies what Engelsted called the 'non-object'. Any search that is to involve development, learning or creativity must necessarily entail that the object of the search is not beforehand known. The object of search in creativity is not limited to being merely a search for a solution to a creative problem. Since the object of search need not be known beforehand (the criteria for the search can be as broad as looking for something 'interesting' or 'surprising'), several kinds of searches can take place in creativity, including problem finding, creative problem solving, solution testing.

To implement these findings into a model for creativity, that goes beyond the problems facing the IP theories, *the creative cycle* was proposed. In the

creative cycle the subject is actively directed towards the real-world with its objective possibilities and impossibilities – in a process that samples information from the world that again modifies the subjective representations. As such, creativity is viewed as an active way of being in the world, where your anticipatory action in the world over time informs you of it's possibilities and impossibilities. Through action you can bring some of these possibilities into being in the creative process. The cognitive aspects of the creative process are described as an oscillation between the actual, and the possible and the impossible. Here variations are at the same time generating and sampling possibilities and impossibilities. Unlike the IP theories that view creativity as a search in a mental space (only changing this mental space), the creative cycle views creativity as exploring and actualizing possibilities of the real-world.

PART V: COGNITIVE ASPECTS OF THE CREATIVE CYCLE

"Only when we surprise ourselves is creativity truly at work."
- David N. Perkins

5 COGNITIVE ASPECTS OF THE CREATIVE CYCLE

This section will concern the cognitive aspects of the creative process. Many theorists in creativity research have traditionally focussed on creativity as a mental feat; as a thinking process or ability. Above we saw how the IP theorists did this (Newell & Simon, 1972; Boden, 1991; Perkins, 1981), but many others have done the same (e.g., Guildford, 1962; Mednick, 1962; Koestler, 1964; Rothenberg, 1979; Torrance, 1977; Osborn, 1963). Recently, however, the attention towards the cognitive elements and processes of the creative process has been getting even more attention, due to the new approach to creativity research called Creative Cognition (e.g. Finke, Ward, & Smith, 1992; Smith, Ward & Finke, 1995; Ward, Smith, & Vaid, 1997; Ward, Smith, & Finke, 1999). In this approach, creativity is viewed as a common feature of basic mental processes (i.e., seeing creativity as some of the 'nuts and bolts' of cognition). My challenge in this section is to specify what goes on in creative cognition and incorporate knowledge from some of these approaches into the framework I termed the creative cycle, while maintaining the balance between realism and constructivism needed. As such, I will attempt to fill some of the, primarily cognitive, gaps left in the model while maintaining it's ecological virtues and grounding. However, to determine which questions are the right kind of question to be asked and answered in the present section, I will start with returning to the schism between realism and constructivism, and it's relation to cognitive aspects of creativity. Viewed from certain perspectives (most notably, cognitive psychology), the creative cycle as it stands before the upcoming analysis of cognitive aspects, can seem rather problematic. The model certainly needs to be clarified in terms of what the difference is between thinking and physical action in the model (because surely such a difference is present). Furthermore, the actual processes and operations performed in creative cognition needs to be explicit. And finally, *what* is being processed and transformed (structures, elements, entities, events) remains to be specified, along with an explanation of how these structures remain grounded in the real-world.

Simply presenting these questions makes the model seem rather simplistic, and in need of serious specification. So, before I will proceed, I will remind the reader why the model appears the way it does. The model was constructed in the present manner to be able to overcome the limitations of what I termed realist and constructivist perspectives respectively, in order to create a complete theory of creativity capable of grounding creative action in the real world. The grounding was found in adding the qualities of

objective possibilities and impossibilities to the real world. Indeed, it is in these dimensions that the aboutness of creative action is to be found.

However, in choosing a model of perception (i.e., Neisser's perceptual cycle) as the base analog for the creative cycle, perhaps I have gone too far in emphasizing objective structures, and thereby underemphasized subjective processes in creativity? Asking the above questions certainly makes it seem so. So, before we continue in our analysis of cognition in creativity, I will make some further remarks about realist and constructivist theories of perception.

In the cognitive psychology tradition, perception and cognition (or conception) are usually separated (Barsalou, 1999). Theories of perception usually deal with how the outside world becomes 'recorded' in mind, while theories of conception deals with categorization, propositions and production by combining and relating symbols that are 'transduced' from perceptual states. The transduction process takes perceptual states and 'translates' them into amodal symbols, and stores them in long-term memory (sometimes along with the original 'recordings', i.e. the perceptual states of the event). How exactly this 'transduction' from modal perceptual states into amodal symbols occurs remains a bit of a mystery (Barsalou, 1999). But the theories have nonetheless been successful in focussing on the constructive aspects of cognition. The constructive aspects can be seen in the way symbols are manipulated in propositions and productive thinking.

Realist (i.e., ecological) theories of perception (e.g., Gibson, 1979/1986) focus much more on the object of perception. In focussing on the object, perception tends to be seen as highly constrained by outside structures, reducing the need for adding explanations based on subjective transformative processes (i.e., top-down processes), that could supposedly add this structure.

In other words, there is a tendency where cognitivist theories are well equipped to explain conceptual thought (i.e., how subjective processes constructs objective structures), whereas realist theories are well equipped to explain perception (i.e., how objective structures constrains subjective processes). In a perfect world, the two would fit perfectly together and complement each other. But due to a number of seemingly incompatible assumptions, they do not. Realist theories tend to focus on the acquisition of knowledge at the expense of changing it; whereas the opposite can be said of constructivist theories. **Constructivist** thought processes eloquently

deal with constructive processes, while loosing grounding of the elements being combined and related (i.e., they are amodal, unspecific, and not referring to anything in the real world). As explained previously, this has been a big problem in creativity research, and has been referred to as the 'ex nihilo' problem. **Realist** thought processes, however, eloquently deal with how knowledge is acquired from the outside world. Knowledge is neatly grounded in outside objects and structures, but in these theories heavy emphasis on grounding often has the side-effect of making knowledge static and inflexible, with productive (novel) thought remaining a mystery. Apparently one has the choice between ungrounded and static theories of perception. Is there no in-between?

What Neisser (1976) did, was an attempt to synthesize the realist and constructivist approaches of perception. However, his model has implications beyond the cognitivist understanding of perception. As explained above, 'perception' in cognitive psychology is somewhat different from conception (i.e., thinking). But Neisser on the contrary emphasized the use of 'schemata' in the model, along with the ability of the schemata to direct exploration in the world. In making the model, Neisser (1976) thus made more than a theory of perception (in the narrow sense whereby cognitivist theories uses it) – he made *a theory of knowledge based on perception*. And such a theory of knowledge is exactly what is needed to explain creative action. It is a theory that grounds knowledge in the real-world, while simultaneously explaining productive thought as action occurring upon this knowledge. Importantly, however, the productive thinking must never loose its grounding. This is what happens in cognitivist theories, where symbols are 'transduced' from perceptual states, thereby loosing their relation to the real-world. However, in the creative cycle grounding of creative action can be found in the fact that it is *about* objective possibilities and impossibilities (although it is also a process involving generation). In order to explain creativity, a theory of knowledge must be able to explain how objective structures constrain subjective processes, while still enabling the subjective processes to construct novel objective structures, without loosing grounding. Perception and conception are thus not two different processes (Goldstone & Barsalou, 1998) to be studied separately, but highly interrelated constructs that cannot function independently. Both are needed to explain creativity. Neisser is not the only one to go beyond a narrow theory of perception, to make a theory of knowledge combining perception and conception. Theorists in the Activity Theory tradition have never separated perception from thinking (e.g., Vygotsky, 1978; Leontjev, 1977; Mammen, 1983; 1994), and recently Barsalou (Barsalou & Prinz, 1997; Barsalou,

1999) has explicitly tried to show how the two are interrelated to overcome problems in cognitive psychology.

Below I will deal with four important questions for the creative cycle that are in need of specification in the model. All deal in one way or another with cognitive aspects of the creative cycle. We will first look at 'where' creative action occurs (inside the head of the creator, vs. out in the real-world). Then we will take a look at the processes involved in creativity, followed by a look at the structure of knowledge that allows such creative processes to occur while remaining grounded. Finally we will look at what constrains the generation of variations in creativity.

As I argued in part 4, cognition in creativity occurs in the oscillation between the actual and the objectively possible and impossible. As such, creativity is a movement from the actual, into the possibilities and impossibilities of the world, and back to the actual. The first question deals with how this relates to the distinction between inner and outer worlds.

5.1 What is the difference between physical creative action and creative thinking?

A question on the creative cycle that needs to be asked and answered is the question of *where* the creative process occurs. Is it an 'inner' process occurring in the head, or an 'outer' process in the world? As explained above, cognitive theories try to explain productive thinking processes by placing the creative process '*in thought'* detached from the world. Realist theories would account for the creative process as one occurring '*in the world'* and as such maintain a strict grounding – but often at the expense of being able to explain thinking as *more* than mere reproduction. Needed is a model that can maintain grounding in the world, while explaining creative thinking, and thus synthesize the two approaches. I believe the creative cycle makes up such a synthesis, but the distinction between inner and outer still merits some remarks. Even though the creative process is, as we have seen, a direction from the actual to the objective possibilities and impossibilities, and back to the actual, there seem to be a question about *where* the possible and impossible is located in the process. Obviously it is both 'inside' and 'outside' (ref. my remarks on the *subjective* possibilities and impossibilities being more or less adequate in relation to the *objective* possibilities and impossibilities that are qualities of the actual world). As such creative thinking occurs on the foundation of the subjective reflection of objective possibilities and impossibilities – a reflection that can be more or less adequate. However, that does not mean that the productive aspects of the crea-

tive process are detached from the world. It may be indirect, in that possibilities are not directly perceivable in the world but derived from our knowledge thereof (tacitly, bodily, explicitly etc.). But it is still *directed towards the objective possibilities and impossibilities* just as perception itself is directed at the actual world, no matter the inadequacy of subjective representations thereof.

The indirectness of our access to the objectively possible and impossible also makes our certainness with the creative thinking more or less on shaky ground. In some areas, where we have a great deal of knowledge, we can be very certain that what we think will work, actually will work. But in areas typical in creative endeavors (directed at novelty), our degree of certainty with our sampling from the possibilities and impossibilities of the world is not at all high, and often the only way of *actually* being certain, is to try it out in the actual world.

Most theories would probably acknowledge the difference between inner and outer action in creativity. However, as we have seen, most theories also assume that creativity is occurring *in thought* rather than *in the world*. This can be seen in all the above IP theories, where the creative process occurs *in* a conceptual space, problem space etc. Many other cognitive theories agree with this view. The creative cycle, however, disagrees with referring to the creative process as occurring *inside* the subjects conceptual space. But on the other hand, there clearly is a distinction to be made between what is occurring in creative thinking, and what is occurring in physical creative action[40]. Imagining building a flying machine is not the same as actually building one. The difference, according to the creative cycle, is one of viewing creative thinking as a matter of *simulating* the objective possibilities and impossibilities. Such a view secures the aboutness of creative thinking, while maintaining the indirectness of the process.

A simulation is indirect, but not detached. A simulation may involve thinking, but it is still grounded in the objective possibilities and impossiblities. Simulation is *in the world* (as opposed to *in thought*) at the same time as it is *active thinking*. Thought, as such, is not a place or space, but an activity[41]. In figure 12 this difference is illustrated on the creative cycle. Unlike Neisser (1976) who viewed imagination as having a mere anticipatory function in the perceptual cycle, here creative imagination is viewed as a simulation of the possibilities and impossibilities of the world. As such, imagination and simulation involves all aspects of the creative cycle; directive and anticipatory; sampling and modifying.

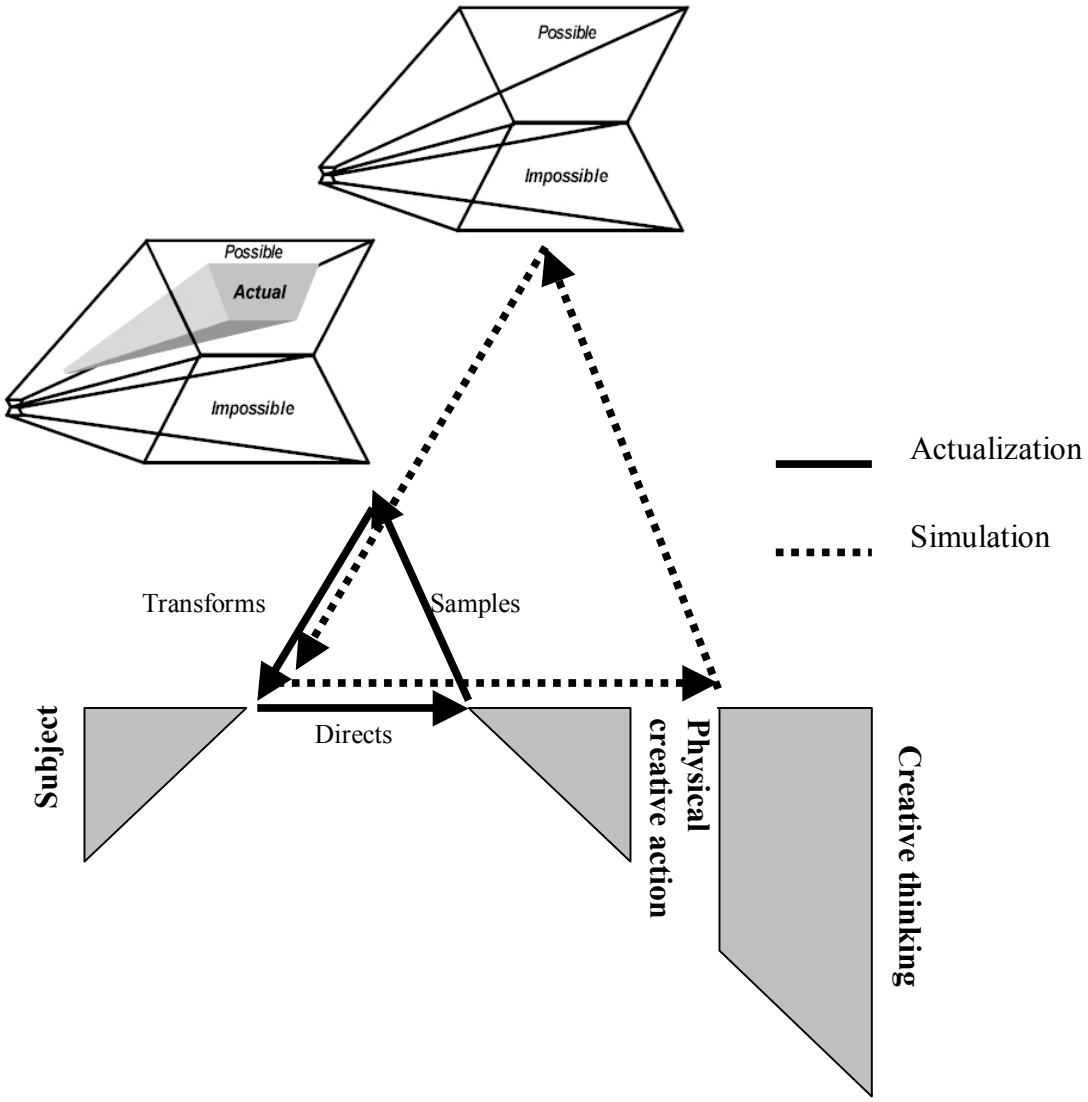


Fig. 12. The creative cycle, and simulation vs. actualization

A few things should be clarified about the model: **First** of all, it is of course not every conceivable possibility and impossibility that is involved in a simulation. In creative thinking, a so-called *variation* of the real-world is made. This variation is based on the attended problem knowledge, and produced under the constraints of several factors, to be reviewed later (see part 5.4). It can take the form of a simulated object, but simulated action and events is also involved. As such, both *events* and *entities* are involved in a simulation. At present the grounding of such 'objective, although non-existing' variations can seem problematic, although it has been specified that they are possibilities and impossibilities. The problem is that they are *generated*, although they are *also sampling* the possibilities and impossibilities of the world (we will look at the grounding of these variations in

part. 5.3). Just as, in the perceptual cycle, exploration of the real-world samples information that transform the schemata, creative thinking through generation of variations samples information about possibilities and impossibilities –information that transforms knowledge. For example, a person imagining how a machine can be made to fly is at the same time *generating* possible actions and objects, and *sampling* them. **Second**, subjects are clearly able (at least in the vast majority of cases) to separate the variations they have created physically from what they have merely simulated in thinking from each other in memory. I am assuming that we are able to, in the vast majority of cases, to separate physical action and real-world products from simulated variations, but will return to this point later. **Third**, although the division of actualization from simulation does *not* separate creativity into 'thought vs. action' (as e.g. IP theories seem to be doing), it may nonetheless appear to be separating the creative process into two distinct processes. However, the model is intended to portray two highly integrated processes in the creative process. Creative thinking is (as is physical creative action) a movement from the actual into the possible and impossible, and back to the actual. The two processes (actualization and simulation) should not be viewed separately, but as occurring, if not simultaneously, then at least in an integrated fashion. They should not be studied as separate processes. Think for example of the inventor tinkering physically with his invention, while maintaining a mental plan for progress. The tinkering leads to problems, he stalls, sits back, and tries to think of options for possible progress, thinks of some ideas, and continues tinkering. Thinking and physical action are not separated processes, but highly integrated processes. The creator is clearly able to pick up cues in the environment for possible progress or solutions to creative problems. The integration of creative thinking and physical creative action is perhaps no where more visible than in the making of models in the creative process. The making of external models seem to be serving the purpose of clarifying relationships and constraints in the attended problem knowledge, in order to produce a simulated variation that will constitute a possible solution (see e.g., Freska, Barkowsky, & Klippel, 1999; Cheng & Simon, 1995). By actually drawing the model on paper, or otherwise making it object of perception, it seems to be easier to continue in a creative direction, and make further creative connections. Here so-called 'inner and outer' actions work together in producing simulated variations. **Fourth**, although the present environment may facilitate creativity (e.g., through cuing), it may also hinder creativity in other respects. The creativity literature is full of examples of cues in the environment that hindered a creative discovery through e.g., functional fixedness (Dunker, 1945/1972). Glenberg (1997) has argued that imagina-

tion requires the suspension of clamping to the environment. That means that the imaginative individual should suspend relations and objects of perception in the present situation. Intuitively one may think of this suspension as a *withdrawal* from the world, but more accurately it underlines the *attention* and *involvement* (Finke, 1997) required to pursue such imaginative aspects of the creative process. So attention towards imaginative simulations may detract from attention towards the present environment. But it should not be viewed as a detached process or lead one to think in terms of 'inner' and 'outer'.

This concludes our discussion of the distinction between actualization and simulation in creativity. We have not yet determined *which* thinking processes are taking place in creative simulations. This has been a much researched area in creative cognition, and we will take a closer look at these processes now.

5.2 What kinds of processes are included in creative cognition?

As we saw above, the creative cycle hypothesizes that creativity is much more than thinking processes occurring in the head of a creator. This section will however deal with the various processes involved in creative cognition (i.e., processes involved in simulation), as this has been a major focus in creativity research. But in doing so it is important to remember the limitations of this approach. As Ward, Smith, & Vaid put it:

> "Creativity is not conceptual combination. Nor is it conceptual expansion, metaphor, analogy, mental model construction, or any other single process. It is an outcome of subsets of those and other processes acting in concert to expand the frontiers of knowledge and conceptualization in a given domain. Creativity may even better be thought of as the entire system by which processes operate on structures to produce outcomes that are novel but nevertheless rooted in existing knowledge." (Ward, Smith, & Vaid, 1997, p. 18).

So creativity is not just a single generative process, or even simply an expansion of knowledge (although Ward, Smith & Vaid could be interpreted to believe this), but rather concerns the generation of novel and useful products. In such a generative task, many different kinds of processes (not limited to the generative ones) are involved. However, that being said, I will focus on various cognitive processes discussed in the creativity literature to determine what seems to be the consensus on which processes are involved in creativity. WHAT is being processed (i.e., the problem of

grounding) will be dealt with in part 5.3. Here attention is directed towards the HOW.

Creativity theories generally suggest that creative thinking involve both *generative* and *analytical* (sometimes called divergent and convergent) processes (see Isaak & Just, 1995 for a selection of such theories). Most creativity theories incorporate both aspects into their theories. Here we shall review only two general creativity models, illustrating this duality of creative processes.

The first model views creativity as Blind-Variation-and-Selective-Retention (BVSR) (Campbell, 1960; Simonton, 1995; 1999a; 1999b; 1999c; Cziko, 1998). The BVSR paradigm was developed by Donald T. Campbell, and is a secondary[42] Darwinist approach to the development of human knowledge, and has been greatly expanded later by Simonton. In analog to primary Darwinism, creative ideas are viewed as variations created somewhat blindly or randomly[43], with only a few of these variations surviving selection mechanisms in mind or society, to be retained in memory.

> "1. There exists some process that generates *variations*. Just as biological evolution must begin with numerous genetic recombinations and mutations, so must creativity begin with the production of many diverse ideational variants.
> 2. These variations are subjected to some consistent *selection* mechanism. For biological evolution the fitness of variants is decided by natural or sexual selection. In the case of human creativity, the selectors are more likely to be cognitive or cultural in nature.
> 3. There is some *retention* procedure that preserves and reproduces the variations so selected. Whereas natural selection retains and propagates the best genes through biological inheritance, the mental evolution that produces creative ideas requires a memory system, plus an ability to communicate the stored ideas to others." (Simonton, 1999c, p. 27)

A central element in the model is the notion of 'blindness' or 'randomness' of the variations. The basic argument is that the outcome of a variation is unknown when it is first proposed or generated. But it need not be unconstrained, and it need not be unsystematic. All genuine forms of human creativity and invention involves BVSR, in that they require coming up with new types of knowledge and novel solutions to problems, and not just adding knowledge easily deducible from known facts. Blind variations are produced by a mechanism which has *no advance knowledge* of the conse-

quences of the variation it produces. If a variation is not blind in this sense, it cannot be creative (Cziko, 1998). In short, the BVSR paradigm points to three general processes in creativity: Generative, selective and retentive.

A second model of the processes involved in creative thinking is Finke, Ward, & Smith's (1992) Geneplore model. 'Geneplore' is short for *generate* and *explore* thus making up both generative and analytical processes, in a general cognitive model of creativity.

> "The Geneplore model consists of two distinct processing components: a generative phase, followed by an exploratory phase […]. In the initial, generative phase, one constructs mental representations called preinventive structures, having various properties that promote creative discovery. These properties are then exploited during an exploratory phase in which one seeks to interpret the preinventive structures in meaningful ways. These preinventive structures can be thought of as internal precursers to the final, externalized creative product and would be generated, regenerated, and modified throughout the course of creative exploration." (Finke, Ward, & Smith, 1992, p. 17).

The Geneplore model is illustrated in fig. 13.

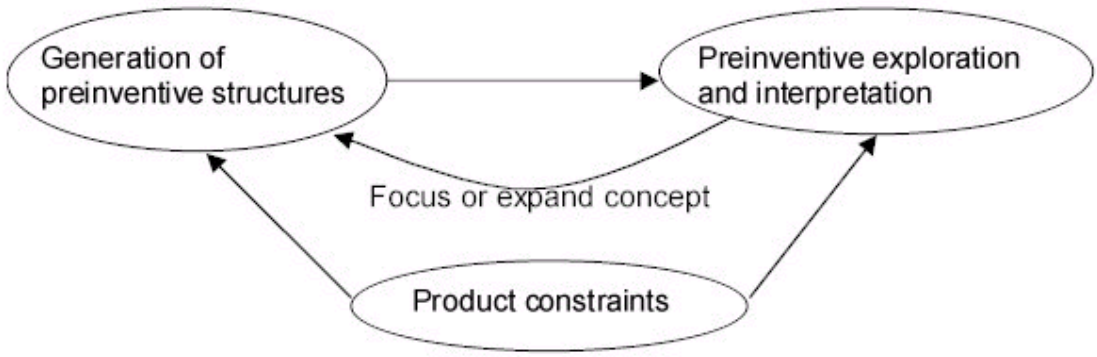


Fig. 13. The Geneplore Model (Finke, Ward, & Smith, 1992, p. 18).

Specific examples of generative processes are retrieval, association, synthesis, transformation, analogical transfer, and categorial reduction. Examples of explorative processes are attribute finding, conceptual interpretation, functional inference, contextual shifting, hypothesis testing, and searching for limitations. In case of unsuccesful exploration of a preinventive structure, one of two things happens: either the preinventive structure is abandoned and another one generated, or the initial structure is modified (ibid., p. 17).

These two general models (i.e., BVSR and Geneplore) of the processes involved in creative cognition highlight the fact that both generative and analytical processes are involved. The similarities are striking, and Simonton (1999c, p. 45) has argued that the Geneplore model fits well into his model of BVSR. However, I think caution should be taken in equating BVSR with the Geneplore model. It occurs to me that while the Geneplore model is well equipped to explain how *a single or a few* creative variations are *developed and modified*, BVSR focus heavily on the generation of *multiple* variations, from which a few are selected. Martindale has made similar remarks:

> "Simonton gives a nice account of the birth of creative ideas, but he does not explain the life of ideas. The story of an idea does not stop with its birth. A theory is tested and changed as the results of experiments." (Martindale, 1999, p. 341).

I believe that it is the heavy emphasis placed upon the so called preinventive structures by the Geneplore model that makes up this difference. Whether creative thinking does involve the generation of many variations of which a few are selected, or the generation of a few that are extensively explored and modified, will have to depend on a number of factors, not least the particular task at hand. This argument is similar to Perkins' (2000) theory that different kinds of creative searches will provide a better or worse fit with the 'topography' in the particular *Klondike space* at hand.
In some tasks it may be better to generate many variations, if one has little or no clue as to where to search for answers, and only retain a few. On the other hand, sometimes it is viable to generate only a few, or just one, preinventive structure, and then explore it for emergent features, reinterpret it, and modify it until it becomes novel and useful. The difference between the two views relies very much on whether one considers the preinventive structure to have some kind of 'object (or variation) permanence' across modifications. Any modification would, for the BVSR model, be considered *a new* variation, while the Geneplore model would concern a modification and exploration of *the same* variation.

I believe a distinction should be made between the two approaches, one concerning many different variations, the other concerning explorations of a single variation. As such, I conclude that three general kinds of processes are involved in creative thinking:

1) Generation
2) Exploration and modification
3) Evaluation and selection

Retention follows these processes. It should be remembered now, that all this talk of processes in creative cognition leaves out the discussion of *grounding* of the variations, categories and elements of creative thinking. For example, where do the elements used to generate preinventive structures come from? How is the link to the real-world maintained in creative thinking? The next question deals with these problems.

5.3 How is knowledge structured in a way that makes it possible to simulate variations and anticipate novelty?

As I have argued, variations are made in creative simulations, and these variations are themselves objective, although non-existing, possibilities or impossibilities. As such, a variation is simultaneously sampled from the objective possibilities and impossibilities, and is generated as these possibilities and impossibilities cannot be directly 'picked up'. For example, we are able to simulate cars and other objects we have never seen, and simulate sequences of action we have never seen performed. How are such variations generated and grounded? The difficult part of explaining grounding of variations is the explanation of how variations adequately reflect *objective* possibilities and impossibilities, rather than being mere fantasy that does not seek to distinguish between the two. In order to explain this, we must look at how we know about the actual with it's possibilities and impossibilities, and how such knowledge is structured and tested for accuracy. Then we must look at the ways in which this knowledge can be restructured or recombined into novel generated variations (that also sample objective possibilities or impossibilities). And then finally, look at how this variation can be actualized through action in the world. These are the right kind of questions seeking to maintain the cyclical nature of the creative process, following the objective structures through the entire creative process, from the actual, into the objectively possible and impossible, and back to the actual. Unlike most creativity theories it does not start with subjective processes that alter already acquired structures, but commence with the acquisition of these structures themselves. In doing so, it becomes possible to see how grounding of the structures in creative thinking is possible. One might say that it is a question *of how the mind can recycle matter in novel ways*. As such, it is a question of both the *objective basis* and the *subjective representation* of objects, categories and concepts, while keeping in mind that

objective reality is not limited to the actual, but include the possible and the impossible.

The general explanatory principle for acquisition of knowledge of the possible and impossible relies on Neissers (1976) perceptual cycle, - a principle that is incorporated into the creative cycle. As Neisser pointed out, schemata are anticipatory structures. They can anticipate (e.g., through imagery) and direct exploration and attention towards certain objects, and not others. The anticipatory nature of exploration allows for surprises, as when the anticipated is not found, or found in ways dissimilar to the anticipated. In this way, schemata are anticipatory, but also constantly being tested against reality – a test that modifies the schemata. In creativity, when generating (possible or impossible) variations, the subject can similarly test these variations against reality, by attempting to bring them into reality (by actualizing them). The ways in which this reality check plays out will inform both about the adequacy of the subjective representation of the present variation – and about objective possibilities and impossibilities. As such, anticipating something to happen, that prove not to happen, informs the subject that 1) his representation is in need of revision, and 2) this particular variation is in fact *impossible* in the manner anticipated. In this way we can, through anticipation, learn of what can and cannot be – and where the boundary between the possible and impossible lies.

However, this explanatory model only explains how variations are tested against reality, but does not explain how the novel variations are made in the first place. I have hinted to the fact that a number of generative processes are involved in their production; recombination, synthesis, transformation etc. All importantly, variations are not random, but directed at products that are possible, novel and useful, and must adequately reflect knowledge of objective possibilities or impossibilities. In short, variations must simultaneously be *novel*, and attempt to *adequately reflect* objective reality. This leads us to a discussion of the structure of knowledge. Knowledge must reflect the actual world, with it's possibilities and impossibilities, while simultaneously making it possible to generate novel variations.

The problem should be easy to spot: The structure of knowledge must somehow allow for two apparently opposing processes to occur. It must allow for the generative production of novelty, and attempt to adequately reflect objective reality. While the production of novelty introduces uncertainty into the system (as it has no advance knowledge of which variations will work, and which will not), the adequate reflection of knowledge at-

tempts to reduce uncertainty. In short, it is the problem of how knowledge can be structured in ways, that makes it possible to produce novel variations, while simultaneously incorporating knowledge of the existing, the possible, and the impossible, into this variation.

Below I will take a closer look at two questions dealing with grounding in creativity, and how novel variations are generated and tested against reality.

1) How is knowledge structured, so that it can lend itself to processes that can produce novelty, while simultaneously adequately reflecting objective reality?
2) How is knowledge anticipatory?

These questions will be approached, first by briefly looking at what variations are. Then we will look at how the first question has been researched in the framework of cognitive science. This approach is then criticized and extended with the theory of Mammen (1983) and Barsalou (1999). Finally we shall look at how these knowledge structures are anticipatory.

5.3.1 Variations in creativity

The ability to produce variations in thinking is not limited to creativity. Indeed, it is a general ability stretching beyond the relatively narrow creativity concept I am employing here. Simulating flying through the universe at the speed of light; simulating combining two objects together; simulating being Napoleon; simulating using my hammer outside its normal function (e.g., as a paperweight); simulating what might have been (as in counterfactual thinking); simulating that tomorrow is really yesterday and so on are all variations. Not all of these variations will be possible (i.e., actualizable), and thus creative. Some are pure fantasy. Not all of these variations produce a spreadable product, and thus fail the creativity definition on that account. And not all variations will be novel.

The number of different kinds of variations is thus very large. For the present purposes (i.e., examining variations in creativity) I will limit variations to variations of events and entities.

A natural place to begin examining the kinds of variations that can be produced in creative thinking, seems to be the preinventive structures discussed briefly above in relation to the Geneplore model (Finke, Ward, & Smith, 1992). Preinventive structures are generated without full anticipation of their resulting meaning and interpretation, and after generation they

provide a frame for such interpretation, modification and exploration in creativity. Examples of such preinventive structures are: visual patterns, object forms, mental blends, category exemplars, mental models, and verbal combinations (ibid., pp. 21-22).

An experimental example of preinventive structures could for instance be a subject generating an object through combining simple physical shapes, such as cubes, circles, and cones, into more complex physical forms. Afterwards the subject explores what the function of such a figure could be, and what it would be good for. The people behind the Geneplore model has extensively examined this method, and they found, that in cases such as this, where *form* comes before *function*, some quite ingenious inventions can be created. In a series of experiments the subjects invented hip exercisers, shoestring unlacers, and hamburger makers in this manner (ibid.).

In this example, a form is initially generated, and then the possible functions and meanings hereof are interpreted and explored. But in other cases function precedes form. The Geneplore model thus primarily concerns itself with how general properties (meanings and functions) become related to other general properties (forms). In both function-to-form and form-to-function bindings, two things must be explained for the process to remain grounded in existing knowledge: where did the form come from, and where did the meanings and functions come from?
However, forms and functions are all what could be called general (or generalized) properties. But properties in variations need not be restricted to general-universal ones. Indeed, I can also recombine the past history of individual objects (such as myself) to produce variations of my life history, or imagine what would happen if someone else were me (although it could be argued that such thinking is closer to fantasy than creativity). Further I can also imagine recombining *that* particular individual wheel over there onto *that* car over there. In short, in making variations of entities and objects, what is recombined can be general (universal) properties, specific properties (belonging to a particular individual obejct), as well as the history of the individual object.

But simulations are of course not restricted to objects. In creative simulation, it is not enough to simulate the product itself. It must also be tested and evaluated in the situations it is to function, and as such be simulated across situations and contexts. Variations are not static phenomena out of context, but are viewed over time in operation in simulated real-world situations. As such, it is necessary to simulate *events* along with entities. By

including events in variations, cause and effect relationships can be recombined and tested, along with the possibility of emergent features appearing under certain action sequences and in certain contexts but not others. By directing attention to *events* along with *entities* I am pointing to the fact that variations are not static phenomena made up of static elements in an additive fashion. Rather, variations are complete simulations of real-world events and entities.

For the present purposes of examining the structure of knowledge that can produce variations in creativity, I will look at the structuring that makes it possible to create novel variations from events and entities.

5.3.2 Explanations from cognitive science

Research in creativity has traditionally mainly occupied itself with explaining the *processes* by which novelty arise, while ignoring the problems of how structure and elements are transformed, and where they came from in the first place. This may be part of the problem that creative ideas has been seen as arising 'ex nihilo' (out of nothing) (Perkins, 1988). But recently an approach called Creative Cognition has sought to explain creativity in the language of cognitive science (Finke, Ward, & Smith, 1992; Smith, Ward, & Finke, 1995; Ward, Smith, & Vaid, 1997). This has led researchers to examine, in Ward's (1995) terms, 'what is old about new ideas'[44] – and thus, how creativity can be linked to traditional cognitive science research on e.g., categorization.

I will briefly review two studies from this tradition below displaying how creativity has recently been seen in the light of findings from cognitive theories of categorization.

Ward (1994) asked college students to generate a novel exemplar of a category that would be appropriate to an imaginary setting. In particular, they were asked to imagine and draw animals living on others planets. Ward argued that novelty most often manifests itself within a definite structural framework – which also applies for imagination. He called this 'structured imagination'. Ward expected that the novel animals generated, although fitting into an imaginary setting, would be structured by the same principles as normal categorization. These principles include (after Ward, 1995): that people are in agreement of attributes that are characteristic of category members; typicality of category exemplars can vary with the context; people are sensitive to correlations between attributes; much of categorization is guided by the broad naive theories that people hold about the workings

of the world and by processes of structural alignment that help to determine the most relevant features and feature matches.

Together with specific things known of animal categorization, these general principles of categorization were expected to structure the imaginary drawings of the non-earthly animals. And indeed, despite the infinite number of possible variations that *could have* been produced, the animals imagined exhibited highly predictable properties (Ward, 1994; 1995). The vast majority of imagined animals possessed attributes that are characteristic of typical animals on earth, such as symmetry, appendages (e.g., legs), and sense organs (e.g., eyes), exactly the attributes predicted from traditional feature listing studies. Within-species animals were more similar (varying typically only in size) than between-species animals (varying in shape, sense, appendages etc.). Attributes were correlated (e.g., if the subject was told that the novel animal was feathered, the subject was more likely to imagine animals with wings and beaks). These and a number of other findings suggest that the production of novelty in imagination is structured by the same principles as has been found in traditional categorization tasks.

Cacarri et al. (1997) replicated Ward's findings in children for both conceptual and linguistic tasks, and found that imagination is structured in both language and conceptual recombinations. They concluded that imagination seems to exploit the same schemata and knowledge sources that govern everyday mental life.

In short, research from cognitive science has shown that simulated variations in the creative process, like categorization, are structured by the knowledge of what is frequent, normal and similar.

5.3.3 The inadequacy of cognitive explanations

Although it is surely correct that typicalities and similarities structure simulations of variations, this explanation may be too narrow. Cognitive theories of categorization have been criticized for reducing human categorization of entities and events to merely their general and universal properties (i.e., similarities) (Mammen, 1983). Below I will look at this criticism and how this view affects the structure of knowledge. The task of criticizing cognitive theories of categorization in its entirety is obviously beyond the scope of the present thesis, so I will have to settle with pointing to a few major criticisms made by Mammen (1983) and Barsalou (e.g., 1999), that are of direct relevance to how knowledge (especially of possibilities and impossibilities) must be structured in creativity.

The overarching criticism that Mammen (1983) and Barsalou (1999) directs at the explanation of categorization held by cognitivist theories, is the neglect of the ability of subjects to represent *individuals*. Individuals are singular objects existing in the world over time. Individuals have both qualitative identity (i.e., the sum of properties of the object) and numerical identity (i.e., the identity of an object with itself over time and place and across changes). Cognitivist theories focuses merely on the qualitative identity of objects, and hence the properties that objects share with other objects – their general and universal properties.

Both common sense (Mammen, 1983), and empirical evidence (Barsalou, Huttenlocher & Lamberts, 1998) tells us that humans represent entities as numerically identical individuals, along with representing their general, universal properties. Barsalou (1999) has argued this inability of cognitivist theories to incorporate individuals stem from the fact that *events* rather than *entities* are the basic unit of analysis.

Barsalou, Hottenlocher, & Lamberts (1998) made a series of experiments to determine if subjects categorized merely in terms of events, or merely in terms of entities (i.e., individuals). The experiments turned out to show a complex pattern that proved that both events and entities were stored, and as such, that hybrid models incorporating both were needed. They concluded:

> "In retrospect, it is not surprising that the cognitive system categorizes on the basis of both individuals and events. If the cognitive system didn't establish representations of individuals that exist across events, it couldn't construct the history of an individual, it couldn't represent the fact that the appearance of an individual might vary widely across occasions, it couldn't count the number of repeating individuals observed across occasions, and it couldn't determine the properties that occur most often across the individuals in a category. Establishing representations of individuals capture the physical structure of the world, such that important inferences about the entities in it are possible.
> In contrast, if the cognitive system didn't record information about events, it couldn't distinguish individuals that occur frequently in a category from individuals that occur rarely. Similarly, it couldn't distinguish the frequent properties of an individual from the infrequent ones. In general, the representation of events captures what is likely happen to an agent in his or hers experience. Whereas frames for individuals capture what exists in the world,

> event memories capture how the world is likely to affect an agent in a given event. [...] Undoubtedly, a representational system must have basic statistical capabilities, such as pattern completion, generalization, frequency sensitivity, and adaptive learning. However, it must also find a way to represent entities in the world, so that reasoning can proceed at the level of individuals as well as at the level of events." (Barsalou, Huttonlocher, & Lamberts, 1998, p. 257-58).

Barsalou et al. (1998) here points to the need for representing individuals, but also points to the continued need for the representation of events.

Mammen (1983) similarly criticized cognitivist theories for not incorporating the representation of individuals (with numerical identity) into their theoretical framework, thereby reducing representation of objects to only the qualitative identities of objects (i.e., their general universal properties). Indeed, 'categorization' in cognitive psychology seem only to refer to categories and concepts that are abstracted from *properties* in the world, without any relation to the *individual objects* from which these properties came! Once established, concepts are believed to have little or no relation to the objects or situations that helped make them in the first place (they are abstracted from them). For example, the concept of 'red' is believed to be based on statistical similarities of the occurrence of the property 'red' in the world. And once established, the concept of 'red' does not rely on specific instances or specific objects that happened to have the property of 'red', but exists independently of these concrete objects and instances. This may not seem so farfetched when dealing with the concept of 'red', but try replacing 'red' with 'my mother' in the above explanation. When this explanation is generalized to individuals it becomes absurd. I think most people would be offended if their representation of their mother were referred to as being based on 'a statistical similarity without reference to specific objects or instances'.

As would be apparent, categorization in cognitivist theories looses grounding of concepts (i.e., they are unrelated to real-world objects and events) as soon as the concepts themselves are developed. Such thinking is, in Rubinsteins terms (Rubinstein in Mammen, 1983, p. 184), reduced from being 'thinking in concepts about objects', to being merely 'thinking in concepts separated from objects'.

This cognitive approach has shown itself to deal quite well with how people would categorize in a laboratory setting, where the objects to be catego-

rized are defined by their general-universal properties alone (e.g., a cuecard with the word 'hammer' on it, or a schematic picture symbolizing a hammer, rather than an actual individual hammer). In such a well-defined laboratory setting with only a finite number of 'objects' (possessing only a finite set of general-essential properties), it is possible to distinguish objects from each other by referring only to their properties. However, in the real-world with an infinite number of individual objects, each with an infinite number of general and specific properties, Mammen (1983) illustrates mathematically that different rules apply. Another kind of category is needed to distinguish objects outside the well-defined laboratory setting. We will look at this second category below.

By dealing only with the general-universal properties of objects and events, the cognitivist explanation renders the explanation of the *development* of the concepts theoretically impossible. If individuals consists only of properties, and concepts are linked to individuals only through properties (the usual explanation is that certain properties ('attributes') have a high degree of 'cue-validity' in relation to the concept, e.g., Rosch, 1978), then how is a concept established in the first place? All you would perceive in the first instance of seeing an individual would be properties, but no 'concept' would emerge from the 'sense-chaos' of perceived properties, demarcating the extension of the concept. To categorize in this way, you have to possess the categories a priori (Mammen, 1994).

Mammen (1983) argues that there are a number of problems with this approach, I will only mention a few of importance to creativity: First, by not dealing with individuals, cognitive psychology positions the subject in a world consisting of only *universal* properties and attributes. No numerically identical objects are found. No tracking over time and place occurs. Second, by reducing individuals to their general universal properties, the *development of concepts* from real-world objects and events is rendered impossible. Third, such a theory separates concepts from the category of individuals that helped create it, thereby loosing grounding in the real-world. Because of the ungrounded nature of the concepts, they are nothing but *empty variables* related to other empty variables in a network (ibid., p. 117).

An especially important critique for creativity research is that when a theory excludes numerical identity and object constancy it is rendered impossible for a perceiver to know whether he is positioned in front of a novel object, or a known object that has changed properties (Mammen, 1983).

Furthermore, adding up the (infinite) properties (of an object) does NOT describe the object in its entirety, and therefore it is a reduction to state that properties alone constitute that object! Such an approach would still leave the numerical identity of the object to be explained, it's history, it's development, it's positioning in space-time coordinates. This line of argumentation and criticism applies for what could be called the *individual to concept* generation, meaning that individuals reduced merely to their universal properties cannot explain concept development, as Mammen (ibid., p. 193) argues. But much more importantly for creativity research, it also applies for what could be called the *concept to individual* generation. Adding up any number of concepts (in the cognitivist sense) will never make an object! For example, adding 'redness' to 'firmness' (or 'carness') does not constitute a 'something' (i.e., an object in the real-world). At the most it makes up another abstracted and ungrounded concept. Therefore cognitivist theories, when excluding individuals, cannot explain how objects are brought into being by mind - how we change the world.

In short, cognitivist theories, by not incorporating representation of *both* qualitative *and* numerical identity of objects, are making it impossible for creative thinking to remain grounded. If properties loose grounding in the individuals and events they are properties *of,* creative thinking will create ex nihilo because all connections to the real-world and what came before is lost. We shall now see how Mammen (1983) try to incorporate individuals into a perceptually based theory of knowledge.

5.3.4 Mammen, and the category of choice

As explained above, Mammen (1983) argued that psychological theories (including cognitivist ones) have left out the ability of subjects to represent individuals with qualitative and numerical identity. Only qualitative identity has been considered by these theories, thereby reducing categorization to a matter of general, universal properties, with the consequences reviewed above.

> "The individual's identity with itself and the generic connections [with other individuals over time and place] points to objective realities, an objective structure of unbroken connections over time, that cannot be reduced to the identity of even the longest exclamation of special or unique properties. The 'singular' as a philosophical category cannot be dissolved into an addition of generals or specifics." (Mammen, 1983, p. 193, own translation[45]).

By arguing that individuals cannot be reduced to a mere listing of properties (e.g., the 'feature lists' so often examined in cognitive psychology), Mammen is pointing out that individuals can be identified by other means than through attributes or properties. Along with the categories for general properties and specific properties, there is a second kind of category for *the concrete.* Mammen calls this category, 'the category of choice', and it refers to the ways in which objects can be distinguished by their presence in space and time, in their relation to a subject in space and time, and through their numerical identity over time. Opposed to this category, is 'the category of sense', which is the category where objects are distinguished from their (general or specific) properties (Mammen, 1983; 1998).

'The category of choice' refers to the human ability to pick or select objects without beforehand knowing what their properties are, simply by pointing to them, or otherwise referring to their place in space and time. Furthermore, we can then keep track of the objects over time and space, and across changing properties, without loosing touch of the fact that we are still dealing with the very same individual. The objective side of this ability is the numerical identity of objects (object constancy). The subjective requirements for this ability, Mammen argues, consist of two conditions:

> "The first is a categorical condition: The ability to recognize the difference between an object's identity with itself (numerical or material identity) and its identity with other objects concerning one or more properties (qualitative identity, formal identity, similarity or equivalence).
>
> The second condition is a practical one: To have the sufficient cognitive means to make correct decisions concerning the (numerical) identity of the object in reality." (Mammen, 1983; p. 268-269, own translation[46])

The ability, provided by object constancy and the two subjective conditions, Mammen calls the 'human sense', which in its most general form is a sense for the concrete. As we saw above, it, among other things, allows us to *track* individuals over time and place, and across changing properties. The human tendency to keep track of individuals by making sure they are located certain places, Mammen (1993) calls 'pocketing', which is a necessary ability in scientific thinking, where the history of individuals must be tracked to discover the laws that govern development. If Mendel had not 'pocketed' his beanstalks to keep track of both their history and special and general properties, he could never have discovered the laws governing in-

heritance of properties. As such, reasoning, even the most general of sorts, is only possible if the general properties of concepts is somehow linked to (grounded in) the special properties and history of the individuals (ibid., p. 185-186).

This 'human sense', Mammen argues, provides us with a range of abilities. By having the ability to distinguish both qualitative identity and numerical identity of individuals, humans are able to distinguish not only concrete objects, but also concrete connections between objects; and further, Mammen argues, concrete connections between individuals and their societal meaning. These concrete connections are of course not directly perceivable, but they are nonetheless part of human reality. This means that the human sense for the concrete enables us to live in a world where individuals are connected to their space-time history and societal and personal meaning, although these concrete connections are not directly perceivable. Leontjev has called this implied dimension of meaning 'the fifth quasidimension' (Leontjev in Mammen, 1986). It enables us to sense that an object is specified, and has meaning, beyond the directly perceivable properties, through concrete connections with objects, subjects and meanings in time and space. The fact that objects are determined beyond the properties we presently recognize in them makes appropriation possible – both appropriation of societal meanings (through other subjects), but also more generally the appropriation of nature through scientific discoveries.

But in relation to creativity, this 'human sense', by being a sense for 'the concrete', enables us to distinguish whether we are positioned in front of a novel individual, or in front of an existing individual that have changed properties. As Mammen writes, the 'human sense' provides…

> "…an understanding that things are not just defined by their already known universal properties, but are determined beyond that. Thereby concepts of an object's not-yet-known properties can be made, as well as concepts of an object's change under changed circumstances.
>
> The object can now in thought be loosened relatively from all of its general, conceptual conditions and viewed under different conditions without thereby loosing its identity, and without thought looses the possibility of returning to the starting point.
>
> By understanding objects as concrete, the object can also in thought be loosened from any of its connections, released from its societal meaning, only to

> finally be reinstated in its connections." (Mammen, 1983, p. 271, own translation[47]).

This ability to 'hold on to' individuals despite their changing properties is exactly the ability we need to keep creative cognition grounded during simulations. *Variations* can thus be thought of as a simulation of individuals under changed circumstances, with different properties, across time and space, *without* the individual ever loosing it's identity with itself, and without ever having to resort to abstracted (ungrounded) conceptual combinations as being the explanation.

At any point in the process we can reinstate the concrete individual into it's original general and specific properties. As such, creative thinking can remain grounded by *simulating concrete individuals under changed properties and circumstances*. That allows us to exchange functions, meanings, physical shapes, histories between concrete objects – and view objects under changed circumstances in different contexts, without loosing track of the fact that we are still dealing with the same concrete objects. The 'human sense' makes it possible for us to represent objects as concrete, and thus know that an object has an infinity of possible properties that I am currently not aware of or attending to.

How does this relate to concepts? Mammen's (1983) theory is not a theory of concepts, but he ascribes to a materialistic view of concepts, that he states in the following manner:

> "Our concepts are subjective reflections of sets of objects, reflecting the objects as both individuals, in their connections, and their similarities.
>
> We know, then, that the content and extension of concepts are mutually conditioning, and that one does not necessarily precede the other.
>
> In our stepwise appropriation of knowledge of nature and society and the laws they are governed by, we have to let our determination of content and extension act reciprocally. An increase in the knowledge of content and in the regularities of shared properties, lead to new determinations of extension; and novelties, discoveries or the addition of novel exemplars leads to adjustments of the content of the set." (Mammen, 1983, p. 128, own translation[48]).

Even though Mammen's (1983) theory is not a theory of concepts and their development, it is clear that this materialistic understanding of individuals and concepts is necessary for concepts to remain grounded in thinking. In conceptual thinking, the *general* must be seen *in* the concrete individual, but the individual must also be specified *beyond* the general. As such, concepts are connected to concrete individuals, and do not exist independently thereof.
All in all, Mammen has shown us how the 'human sense for the concrete' allows us to distinguish individuals in a sense-categorial way, involving qualitative identity; and a choice-categorial way, involving numerical identity. As such, he has pointed to the objective foundation as well as the subjective ability to know of more than merely general-universal properties, and the ability to think in novel ways about the existing.

However, Mammen's theory of the 'human sense' is not formulated at a level of specification that explains exactly how knowledge is structured. We will now look at another theory that could potentially help explain how in particular knowledge is structured in order to enable the generation of variations.

5.3.5 Barsalou, and perceptual symbols

Mammens theory of the 'human sense' is a very general one, and it carries many implications for cognitive science. The general nature of the theory, however, makes it somewhat difficult to formulate a specific theory of creativity that would incorporate the implications carried by 'the human sense', into a formulation with the degree of specificity of the usual cognitivist theory. Much empirical and theoretical work remains before such a specified theory will emerge. We shall now look at a theory combining perception and conception that I believe could help specify the theory of 'the human sense', so as to explain how simulation of variations can remain grounded and knowledge is structured in creativity. The theory is one proposed by Barsalou (Barsalou & Prinz, 1997; Barsalou 1999).

The basic problem with present day cognitive psychology according to Barsalou (1999), is that it assumes that perception and thinking (conception) are two rather different processes. Perception is basically viewed as a 'recording system' that stores attenuated (not exact) copies of events, while conceptual systems interpret the entities in the recordings, by binding specific tokens in perception (i.e., individuals) to knowledge for general types of things in memory (i.e., concepts) (ibid, p. 581). Theories separating perception from conception in this manner, often hypothesize (explicitly or

implicitly) that conceptual symbols are amodal (meaning non-perceptual – often referred to as 'propositional'). Somehow the theories assume that from perception to conception there is a leap where perceptual states are transduced into amodal symbols. There are, however, a number of serious problems with such an approach (following ibid.): There is little direct empirical evidence that amodal symbols exist; theories have been unable to account for how exactly the transduction process (from perceptual state to amodal symbols) takes place; conversely theories have been unable to account for the grounding of these amodal symbols in perceptual states and entities in the real-world; in the absence of physical referents, amodal symbol systems cannot comprehend its own reasoning. If there is nothing in the perceived environment to ground these symbols, what is it about?; etc.

In the light of the above mentioned separation of perception viewed as a recording system, and a conceptual system based on amodal symbols, Barsalou concludes:

> "As long as perceptually based theories of knowledge are viewed as recording systems, they will never be plausible, much less competitive. To become plausible and competitive, a perceptually based theory of knowledge must exhibit the properties of a conceptual system." (Barsalou, 1999, p. 582).

In creative simulation, these properties of a conceptual system would include the ability of performing type-token bindings and other propositional construals, along with productivity (Barsalou & Prinz, 1997). To overcome the limitations of traditional cognitive theories, Barsalou has argued for a unified theory that seeks to reintegrate perception and conception in psychology (Goldstone & Barsalou, 1998).

Barsalou (1999; Barsalou & Prinz, 1997) has since formulated a theory of *perceptual symbol systems*, that try to incorporate the representation of both events and individuals. I will briefly review this theory below.

Perceptual symbols result from an extraction process that selects a subset of a perceptual state and stores it as a symbol. This means that the form of the symbol resembles the perceptual state to which it refers, and that the similarity among different perceptual symbols to one another is informative about the similarity of their referents (Barsalou & Prinz, 1997, p. 275). This means that (unlike amodal symbols) perceptual symbols do not have an arbitrary relation to their referents (e.g., turning or somehow changing the

symbol implies a change in the referent as well). This does not mean, however, that perceptual symbols are physical pictures or merely conscious mental images. There are five basic assumptions in the theory of perceptual symbols (following ibid; Barsalou, 1999):

The first basic assumption is that perceptual symbols are constituted by brain states, i.e., neural representations in sensory-motor systems. Here Barsalou proposes that the neural systems common to imagery and perception underlie conceptual knowledge as well. This means that perceptual symbols function both unconsciously and consciously. The second assumption is that perceptual symbols are schematic. They do not contain the entire perceptual state, but are only - through selective attention (filtering out) and memory transfer (storage) - constituted by a small subset of the perceptual state. It is important to note, that perceptual symbols do not necessarily represent specific individuals (even though they can). The same symbol, depending on contextual factors, can link to different referents.The third basic assumption is that perceptual symbols are multimodal. By multimodal, Barsalou does not only mean that they operate on the five senses, but includes in his theory proprioception and introspection as well. Here Barsalou points out that since perceptual symbols can be extracted from all aspects of experience, he is not using 'perceptual' in it's standard (cognitive psychological) sense. The fourth basic assumption is that perceptual symbols underlie simulation competence. This assumption is very important to the framework of the creative cycle, as the reader will recall, since simulations here take the place of what usually has been regarded as internal mental workings (out of alignment with the outside world). In the creative cycle, simulations are the part of the model, where a subject engages in creative thinking about the possibilities and impossibilities of the world, thereby generating, exploring and modifying, selecting and evaluating *variations*. I will thus examine this assumption closely.

> "Perceptual symbols do not exist independently of one another in long-term memory. Instead, related symbols become organized into a simulator that allows the cognitive system to construct specific simulations of an entity or event in its absence [...]" (Barsalou, 1999, p. 586)

Perceptual symbols are extracted from perceptual states, representing entities and events. These symbols are then organized into symbol systems (simulators).

> "Thus, the primary purpose of extracting perceptual symbols is to support simulation competence. Symbols are extracted and organized to provide the cognitive system with the ability to simulate, at some adequate level of competence, entities and events in their absence. The construct of simulation competence leads to a somewhat surprising definition of concepts: Having a concept is having the ability to simulate its referents competently in their absence." (Barsalou & Prinz, 1997, p.280)

By focussing on simulation *competence*, Barsalou is pointing to the same problems of cognitive psychology, as I pointed to regarding the IP theories. First of all, that creative thinking is indeed about something. But also that the simulation can be more or less competent, depending on, among other things, the amount of experience with and knowledge of the world. And finally, that simulations can be partial, flawed, erroneous, and otherwise distorted, compared to carrying the action out in reality (i.e., actualizing them).

> "We hasten to add several important qualifications to this account. First, we do not assume that simulation competence is ever complete. Instead, it is always partial and sketchy. [...] Second, we do not assume that simulation competence is always accurate. Instead, it can contain errors, as when a perceptual symbol is stored incorrectly in a spatial or temporal configuration, or retrieved incorrectly from it. [...] Third, inherent biases may underlie the construction of a simulation competence. [...] Fourth, simulation competence is not simply a collection of 'sense impressions'. Instead, innate biases select, interpret and organize perceptual symbols during the construction of simulation competence." (Barsalou & Prinz, 1997, p. 280-81).

The fourth qualifier (that simulation competence is not merely a collection of sense impressions) can be qualified further by looking towards Mammen's theory of the human sense. Indeed Barsalou is right in stating that simulation competence is not simply a collection of sense impressions. This is also what Mammen pointed out by pointing towards the human sense for the concrete. But Mammen would rightly object to calling the human sense an 'innate bias'. Instead the human sense, having both subjective and objective aspects mediated by human action, is more than an 'innate bias'. It is grounded in the numerically identical aspects of the objective world, but also requires subjective conditions to function. As such the human sense points as much towards objective qualities in the world as to subjective requirements. In short, while Barsalou tries to balance the rational ('innate bias') with the empirical ('collection of sense impression'), Mammen tran-

scends this distinction in pointing to the human sense for the concrete (see also Engelsted, 1994).

Returning to simulation competence, simulators lie at the heart of thinking in new ways of, not only concrete individuals, but also categories of objects and concepts.

> "Simulators do not arise in a vacuum but develop to track meaningful units in the world. As a result, knowledge can accumulate for each unit over time and support optimal interactions with it [...]. Meaningful units include important individuals (e.g., family members, friends, personal possessions) and categories (e.g., natural kinds, artifacts, events), where a category is a set of individuals in the environment or introspection." (Barsalou, 1999, p. 587)

This characterization is in alignment with Mammen's conceptualization of categories (i.e., sets of individuals) as well as of tracking individuals. Returning to concepts, Barsalou defined (as we saw above) having a concept as having the ability to simulate the concept's referents competently in their absence[49].

> "In this theory, a concept is equivalent to a simulator. It is the knowledge and accompanying processes that allow an individual to represent some kind of entity or event adequately. A given simulator can produce limitless simulations of a kind, with each simulation providing a different conceptualization of it. Whereas a concept represents a kind generally, a conceptualization provides one specific way of thinking about it. For example, the simulator for chair can simulate many different chairs under many different circumstances, each comprising a different conceptualization of the category."(Barsalou, 1999, p. 587).

This definition of course allows for the production of an endless number of conceptualizations. Conceptualizations that are directed towards the novel and useful possibilities of the world can be one kind of variation in the creative cycle. In this way, one could say that Barsalou, by pointing to perceptual symbols organized in simulators, have pointed to how the necessary subjective conditions for simulating variations could operate.

Returning to the fifth and final assumption of perceptual symbols: a frame is an integrated system of perceptual symbols that is used to construct specific simulations of a category. Together, a frame and the simulations it produces constitute a simulator. A simulator, thus, contains two levels of

structure: the frame that integrates perceptual information and the potentially infinite set of simulations that can be constructed from the frame (not limited to mere retrieval). As Barsalou states, a frame is never experienced directly in its entirety. Experience is limited to a subset of frame information that becomes active to construct specific simulations in working memory (ibid., p. 586).

From these five basic assumptions about perceptual symbols, Barsalou argues that he is able to derive a number of properties of the theory of perceptual symbols. Some are of great importance to creativity (albeit creativity of a so called 'mundane' kind), and they include: (1) the capacity for productivity, which is the ability to construct an unlimited number of complex representations from a finite number of symbols using combinatorial and recursive mechanisms (ibid., p. 592). (2) The capacity for construing a given situation in an infinite number of ways by an infinite number of propositions. Because an infinite number of aspects can be propositionalized, selecting the propositions to represent a situation is an act of creativity, according to Barsalou (ibid., p. 595). (3) The capacity for variable embodiment, which is the idea that perceptual symbols bear structural relations to their referents. This means that structural changes in a symbol imply structural changes in its referents (ibid., p. 598; Barsalou & Prinz, 1997). This implies important adaptive functions in human cognition (such as individual adaptation of symbols to their environments), which, unlike the two other kinds of 'mundane creativity (productivity and propositions) is not found in the amodal symbol theories used by cognitive theories.

Barsalou (Salomon & Barsalou, 2001, under review; Wu & Barsalou, 2001, under review) has made some experiments establishing his theory that concepts are grounded in perceptual simulations. Wu & Barsalou (2001, under review) showed that when subjects generate properties from concepts (e.g., 'what properties are typically true of *cats'*), they do so in a manner suggesting that they are perceptually simulating the concepts. For example, subjects in these property generation tasks typically situated their concepts in physical settings, and predictions from perceptual theories applied (e.g., predictions about occlusion, perceptual effort, and attention were all supported). In one particularly interesting experiment for creativity, subjects were asked to generate properties for novel conceptual combinations (e.g., glass car), and even in this instance, Wu & Barsalou found strong evidence that the subjects were simulating the referent perceptually. Salomon & Barsalou (2001, under review) found similar evidence that subjects in property

verification tasks (e.g., 'is *tail* a property of *cat?'*) were simulating conceptualizations perceptually.

For the present purpose of investigating the structure of knowledge, Barsalou has shown us how knowledge used to simulate variations could be constituted by neurally based, schematic perceptual symbols, organized in frames, and which can be changed through simulators, while remaining grounded. This simulation, he shows, has the capacity to produce novel conceptualizations and simulate individuals in novel ways. He further shows that having concepts implies having the ability to simulate it's referents competently in their absence.

5.3.6 Conclusions concerning the structuring of typicalities and possibilities

It is now possibly to make some concluding remarks on the first question posed at the beginning of this section concerning the structure of knowledge in creativity. The first question asked how knowledge is structured, so that it can lend itself to processes that can produce novelty, while simultaneously adequately reflecting objective reality. It will be answered by first looking towards how the typical and the atypical is structured, followed by some remarks on how the possible and the impossible can be structured.

5.3.6.1 Structuring typicalities and atypicalities in concepts and categories

I will start out with a couple of obvious statements: What is actual is possible and informs us of what might be. Further, what is probable is also possible (even the improbable is possible under certain circumstances). Thus, when, as we saw, cognitive scientists points to the fact that what is typical, frequent or similar structure our categorization as well as our imagination, they are pointing out that the probable is possible (as well as likely). For example, a frequent occurence such as bus rides will structure our thought of what bus rides (and trandport in general) can be like. However, it is problematic that such theories reduce the objects of study to mere general-universal properties; to their similarities, when dealing with concepts[50]. Are the a-typical bus rides not also *possible* bus rides?

If we, like Mammen and Barsalou, link concepts to sets of individuals, the structure of knowledge goes beyond the mere categorization of abstracted properties, and include individuals and events, organized in sets, that are linked to concepts. When concepts are linked to sets of individuals (rather than being transduced or abstracted from them), that means that the indi-

viduals can be compared, and all the atypical, infrequent and dissimilar aspects of the individuals in the set can inform about what is possible, yet improbable. For example, properties of unusual cars can inform about what cars *can* look like (what is improbable, yet possible).

Such a view of concepts and categories is necessary for simulations and thinking to remain grounded in creativity. The alternative usually regarded in cognitive science (i.e., amodal symbols) cannot ground thinking, as it does not seem to be about anything other than empthy variables organized in a network, as Mammen (1983) argued.

By grounding concepts in categories of individuals, and arguing that having concepts means having the ability to simulate its referents and variations thereof competently in their absence, it is possible to produce novel variations from the very same knowledge structures that adequately reflect objective reality.

5.3.6.2 Structuring possibilities and impossibilities

A mechanism that follows from the above view of concepts and categories should be mentioned. Having concepts, as Barsalou (1999) argued, can be defined as having the ability to simulate its referents competently in their absence. However, I would have to add a qualifier to this definition: having concepts is having the ability to simulate both its referents *and variations thereof* competently in their absence. When viewing objects as concrete individuals (with Mammen, 1983), and concepts as linked to sets of individuals, then this definition of concepts enables possibilities and impossibilities to become a natural part of what it means to have concepts. Here concepts exists as not only knowledge of what is, but also anticipatory knowledge of what could be, and could not be.
Variations can then be simulated (recombined, viewed under changed properties or changed circumstances) while remaining grounded in (sets of) real world individuals or events.

This allows the psychological researcher to ask different questions about concepts than the questions about general-universal properties, that cognitive science have traditionally focussed on.

Traditionally subjects have been asked to list properties of concepts on for example feature lists (e.g., what properties are typically true of *cats*), or to verify properties of concepts (e.g., is *tail* a property of *cat?*). However, the

present view of concepts can ask different questions of concepts than these general-universal properties.

This could be questions such as:
Is it POSSIBLE for concept X to have property Y?
Is it IMPOSSIBLE for concept X to have property Y?
Is it UNCERTAIN whether concept X can have property Y?

It is a hypothesis of this thesis, that the knowledge behind answers to questions such as these, structure subjects thinking and simulation of members of categories and conceptualizations, just as knowledge of the typical and frequent does. Such implicit structuring in concepts is one way we represent the possibilities and impossibilities of the world. By drawing on this (probably largely tacit) knowledge of what is possible and impossible for both concepts, events and individuals, we can generate novel variations. Our degree of *certainty* with whether these variations will eventually turn out to be *actually possible*, will vary depending on many factors, not least experience. Much empirical work needs to be done to assess to what extent subjects use such knowledge, how explicit it is, and so forth.

5.3.7 Anticipatory knowledge structures

So far the description of structure of knowledge have only hinted to the fact that knowledge is also anticipatory. As we saw with Neisser's (1976) perceptual cycle, schemata are anticipatory structures, that direct action in the world. The same kind of anticipatory structures are in play in the creative cycle. This is important, as simulating variations allows the subject to anticipate what will happen when he attempts to actualize the variation. Discrepancies between the simulated variation and how the actualization plays out will inform the subject of inadequacies of his representation, as well as of what is, but also of what could and could not be. Such knowledge extends beyond mere reflection of what actually has occurred, and includes knowledge of what is possible and impossible.

The question now is how such anticipatory knowledge of what is possible and impossible is structured. How is knowledge from anticipation, subsequent reality testing, and discrepancies between the two 'stored' and used in future generations of variations? Mammen has pointed in the right direction when arguing for the existence of, and human ability to recognize, represent, and track, individuals. With this 'human sense', it becomes possible for thinking to remain grounded in real-world individuals and events despite changing properties, and across changing circumstances – in simula-

tions. Further, this human sense allows us to have concepts of the not-yet-recognized properties of objects – of the possibilities and impossibilities of entities and events. But the actual cognitive mechanisms generating variations and anticipating remains to be specified. It is not possible in the present thesis to completely specify these mechanisms. Future research will have to reveal them in their entirety. But below I will hint towards two such anticipatory mechanisms.

5.3.7.1 Anticipating through opportunistic assimilation

Explaining how novel variations can be simulated in the creative cycle through a certain structure of knowledge, like I have attempted above, leaves certain aspects of the creative process unexplained. For example it does not relate directly to the fact that creativity is a search process, and does not explain why the creative process goes through various stages (preparation, incubation, illumination, verification). How is the impasse in the process to be understood in terms of cognitive mechanisms? How is the illumination or insight to be understood etc. I will look at these shortcomings below, by looking towards an explanation of insight put forward by Seifert et al. (1995), called the opportunistic assimilation hypothesis. This explanation examines certain anticipatory cognitive mechanisms, and their function in the creative process.

It has been a long debated issue what exactly is going on in the stage of the creative process called 'incubation', a stage where the subject has reached an impasse, and is not working consciously on the problem. The traditional explanations have typically involved either just additional time to work consciously on the problem (e.g., most IP theories, which thereby ignores the fact that this stage is precisely characterized by *not* involving conscious processing); time for unconscious processing (e.g., unconscious random idea combination) or some other kind of mental processing function (e.g., selective forgetting). However, recently Seifert et al. (1995) has put forth a theory that explains incubation and insight, not in terms of mental processing, but in terms of environmental cuing – in terms of the real-world!

Interestingly this theory is formulated in the vocabulary of information processing, but attempts to explain the characteristics of the creative process and the phenomenological characteristics of 'insight' in terms of memory mechanisms and environmental cuing, rather than conscious or unconscious mental processing. Like other IP theories, Seifert et al. (1995) views creative search as a search for solutions to problems (which is a limited view, as I have argued). In essence this model (termed 'opportunistic as-

similation') states that in the creative process, the subject after initial solution attempts on the problem reaches an impasse. This impasse stores so called 'failure indices' in memory, which can be seen as 'signposts' guiding thought back to these failing attempts (to the problem), in case later encounters with objects or events occurs that can help solve the problem. The anticipatory nature of these memory structures places this approach in what has been called the 'prepared mind perspective' (after Louis Pasteur who stated that '…chance favours the prepared mind' – quoted in Posner, 1973). After the impasse and the storing of failure indices, the subject stops working (both consciously and unconsciously) on the problem, and goes about his or her daily business. If he or she then later, opportunistically, runs into an event or object that can help solve the problem, then the memory for the problem is reactivated, and an insight will occur with the familiar characteristics of suddenness, spontaneity, unexpectedness and satisfaction.

This simple explanation of the stages in the creative process, and the characteristics of the insight phenomenon is made up of a few cognitive mechanisms, that are all well established empirically. A couple of these empirical results are:

- It has been shown that, under at least some circumstances, people exhibit greater recall of problems on which they have been interrupted than of problems on which they have reached a successful solution (e.g., Patalano & Seifert, 1994). This has been termed the Zeigarnik effect. However, on some occasions this finding has not been replicated. Seifert and Patalano (Seifert & Patalano, 1991; Patalano & Seifert, 1994) hypothesized that this could be due to the fact that the subjects were interrupted, rather than allowed to reach a natural impasse (i.e., failure to reach solution). This hypothesis was supported by research, which showed that memory for unsolved problems were greater for problems on which the subjects had reached an impasse, compared to where they had been interrupted – and compared to problems they had actually solved.

- Exposing problem solvers to relevant new information after an initial failed solution attempt best promote ultimate successful solution (rather than simply allowing for time to incubate or process)(Seifert et al, 1995; Dreistadt, 1969).

- People can (and do) postpone pending goals that do not fit into the current ongoing activity. Predictive encoding ensures that subjects can recognize later opportunities that allow them to achieve these goals. This allows people to defer work on goals until they are in a better position to achieve them (Patalano & Seifert, 1997).

This opportunistic assimilation model of the creative process, and insight, may seem to be taking the 'finding' aspect of creativity to an extreme. Focus is on creative solutions and how they are found in the real-world (through objects or events that somehow display aspects that help solve a problem), rather than mentally processed or generated. This is probably taking it too far, as the model itself states that reaching an impasse (through processing in the preparatory stage) in the first place is a prerequisite for the failure indices to be established. But the processes and mechanisms pinpointed by the model (e.g., failure indices) fits very well into the creative cycle, as a possible explanation of the sudden and surprising nature of the insight phenomenon, and the anticipatory structure of knowledge.

However, this 'prepared-mind' perspective should extend it's view of what it means to 'search' in creativity. Creative search is viewed as 'a solution to a problem', rather than the extended view of conation I have proposed, which included e.g., problem finding and solution testing. The search for a solution to a problem is only one kind of creative search. The failure indices (achieved through reaching an impasse on a problem) pointed out by Seifert et al. (1995) could well be just one kind of a whole range of anticipatory knowledge structures in play in creativity.

We will now briefly look at another way knowledge is anticipatory in the creative cycle: When a variation has been simulated, the subject anticipates that it can be actualized in a certain way.

5.3.7.2 Anticipation and simulation-to-actualization discrepancies. Uncertainties, surprises and call for action.

I have argued that the simulated variations the subject comes up with may not reflect the world in adequate ways, and hence may not be possible in the ways the subject expects. During the creative process the subject can try to actualize or think up ways to test whether what he is currently assuming to be the case – what will work, and what will not – is correct. This is a natural part of the process for the inventor, as tinkering itself provides some of this information. Scientists, trying to uncover the laws of where the possible meets the impossible, must likewise perform experiments on critical

issues. So when the simulated variations are tested, the subject has anticipations (both im- and explicit), about how this will play out. Will the invention or theory stand the test of actualization?

Any discrepancies between what the subject thought was the case about the simulated variation, and what actually turns out to be the case in the exemplification and verification process, will inform the subject about the adequacies of his or her representation of the possibilities and impossibilities of the world, as well as call for action. Hence discrepancies between simulation and actualization in this manner become a very important concept in the creative cycle.

The subject's expectations that a variation is possible, impossible or uncertain, will be informed by how it actually plays out, when attempted actualized. The discrepancies are of course not a mere 'yes' or 'no', but a series of actual events, and exploration of actual entities, that will inform the subject about any misrepresentations he or she may have had. Discrepancies, thus, not only tells the subject about the impossibility of a variation he believed possible (or the other way around), but also guides action towards the aspects of the events and entities that turned out in unexpected ways. The areas where discrepancies occur may call for further examination and knowledge acquisition. For example, the scientist trying to test a hypothesis may find certain discrepancies between his expected results, and what turns out to be the case. A closer examination of these data may reveal certain areas of disagreement between his expectations, and the actual results. A good researcher will examine these areas closer, in order to try to determine if they are caused by various biases or should be taken seriously, and inform the hypothesis he was testing. Discrepancies between simulation and actualization are thus one way surprises and serendipitous discoveries can occur in the creative process.

An important concept concerning discrepancies is 'certainty'. Since creativity is directed towards novelty, the creator most often fares in relatively uncharted waters. As such, the simulated variations may occur on the basis of inadequate knowledge, and may prove to result in erroneous anticipations and variations. No one is perhaps more aware of this than the creating scientist or inventor. And yet it seems to be a neglected research area: how is the degree of certainty with the possibility of simulated variations estimated? When the inventor exclaims that he is 'fairly certain' something will work (or won't work), what is he talking about?

This 'certainty-measure' is *not* the same as the IP measure of judging *distance to a goal-state* (e.g., what Metcalfe (1986a;1986b) call's Feeling-of-Warmth). The subject estimating his degree of certainty that something will work has made the very best variation (i.e., goal-state) he could presently come up with, and is trying to estimating how certain he is that this variation is *actually* going to work. This is not the same as estimating how *close* you are to a solution. Neither is this certainty measure estimating the *probability* that a variation will work. When an inventor exclaims that he is '50% certain' that his invention will work, he is not predicting that in half the cases (or half the times) his invention will work, and in half it will not. Rather he is making an estimation of how certain he is, that this variation is based on an *adequate* representation compared to the objective possibilities and impossibilities of the world, and as such that he has simulated a *possible variation* (and not an impossible one). Here he is 50% certain it will work *at all* (and thus 50% certain it will not work at all). In this manner a 'certainty estimation' is an estimation of the adequacy of our own representation, by looking towards factors such as amount of knowledge we have in this area, how many similar actualized and simulated variations we have performed etc.

This measure of certainty is unique to theories arguing that discrepancies between simulated variations and actualized creative products can exist. Uncertainty is a very important concept in creativity, as we are dealing with novelty, and the generation of knowledge and products. Confusion and uncertainty, along with discrepancies between what is anticipated in simulation and actualization processes, can all be seen as calling for action that can acquire knowledge and examine the world further to gain knowledge on the particular issue involving uncertainty or discrepancy.

In conclusion, anticipatory knowledge structures are involved in the creative process in at least two ways (but probably many more). (1) As Seifert et al. (1995) pointed out, anticipatory knowledge structures (involving mechanisms such as failure indices and opportunism) may account for some of the characteristics of the creative process, including the impasse and insight phenomena. (2) Performing creative simulations build up anticipation about how a later actualization of the simulation will play out. Discrepancies between simulations and actualizations are of the utmost importance in creativity, as are the degree of certainty the subject is experiencing with whether the simulation will eventually turn out to work and prove itself to be possible. Future research will have to determine more ways anticipation is involved in the creative process.

In this section we have repeatedly encountered the problem of how the generation of novelty could potentially occur, based on existing knowledge. The next section will extend this discussion, by looking at all the different constraints there are upon the generation of variations in the creative cycle. As we will see, the constraints are not limited to knowledge structures alone.

5.4 What constrains the simulation of variations?

When simulated variations are generated in the creative cycle, they are at the same time sampling the possibilities and impossibilities of the world. Both subjective processes and (acquired or sampled) objective structures influence this process and constrain the simulated variations. In this section we shall take a closer look at what kinds of constraints are determining the boundaries of the space of possibilities and impossibilities from which variations are drawn. But first we will take a look at how constraints on the problem space are typically explained in creativity theories.

In the creativity literature there is practically no dealings with the *objective basis* for the formation of the subjective representation of the possibilities and impossibilities. Unlike the creative cycle, the creative process is not viewed as a process in which the subjective representation becomes increasingly more consistent with the objective possibilities and impossibilities. Questions of how such an increasing approximation (due to build up of experience, learning and knowledge) is possible do not seem to interest creativity researchers. Or rather, perhaps they consider those aspects of creativity to belong to other areas in psychology, such as learning, instruction, general psychology etc. In any case, the acquisition and construction of the representation (what the IP researchers call 'problem space') that is the basis of all creativity is not at the moment subject to creativity research. The major focus point of creativity researchers dealing with representation ('problem space') issues seems to be the tendency for *subjects to overconstrain their representation*.

Much research has been conducted in an attempt to show that the subjective representation is less than optimal, and that a restructuring is necessary for the solution to appear. And the researchers have indeed succeeded in doing this. This point was a major research area for the Gestalt psychologists, who phrased terms like 'mind set', 'mental block', 'fixation' , and 'functional fixedness' (e.g., Duncker, 1945/1972; see Mayer, 1995 for an overview) to highlight the tendency of subjects to overconstrain their repre-

sentation and thus exclude the solution. This tendency to focus on subjective overconstraining of the subjective representation has continued in present day research, and is visible in the IP theories view on creativity and insight as well. As seen above, Boden (1994b) argues creativity is impossible in the sense that it *could not* have been generated before in the conceptual space. As such creativity always involves changing a conceptual space, either by exploring it or transforming it. Boden exemplifies how this is done, by mentioning crossing limits, dropping constraints, or negating constraints (all meant to expand the conceptual space to include new possibilities). A few further examples: In the insight literature we find Kaplan and Simon's (1990) heuristic tool 'notice invariants' meant to lead to insight. By noticing and deliberately altering invariant features of the failing attempts to solve problems, one increases likelihood of success. The same line of thinking is seen in Knoblich, Ohlsson, & Raney (1999) who suggsted that overcoming past experience is a fundamental component of creative thinking. They proposed that insight should be explained in the following manner: "…constraint relaxation extends the problem space by changing the status of certain problem elements from invariants to variables that can be manipulated, and that chunk decomposition extends the problem space by allowing features or components of the problem situation that are normally perceived as linked in a particular configuration to be separated and reconfigured. When these processes occur, previously unheeded possibilities suddenly come to mind and problem solving can continue" (Knoblich, Ohlsson, & Raney, 1999, p. 280). And further, the so-called *fixation forgetting* hypothesis of incubation and insight (Smith, 1995a; Smith, 1995b, Smith & Blankenship, 1991) explicitly argues that insight occurs because the memory search is temporarily blocked (fixated) on certain elements, and that time alone will allow for forgetting, thereby resulting in increased performance (i.e., the so-called incubation effect), and possibly insight. Of course it could be argued that *insight* and *creativity* are two somewhat distinct phenomena (with insight being merely a part of creativity). As such it could be argued that it is only insight (i.e., merely the AHA! experience) that can be accounted for with the constraint dropping explanation. The problem is, however, that the two far from always have been distinguished in the literature (see e.g. Schooler & Melcher, 1995 for a discussion).

All these theories highlight the tendency of the creative subject to overconstrain his representation (problem space) to exclude the solution, and point out the need to relax constraints in order to have insights into what the problem is really about, and what the solution is. This is obviously an im-

portant contribution as mental flexibility and the ability to go beyond what is - to what might be – is a crucial aspect of creativity. Too often, however, the theories simply state that a 'constraint relaxation' is needed because the problem space is 'overconstrained'. They seem to forget that it is not just ANY constraint relaxation that is needed, but more specifically, *the* constraint relaxation that will make the subjective representation correspond more closely with the objective possibilities and impossibilities of the situation, problem or domain!

What these theories are also saying is that the subjective representation is – or can be - somehow inadequate, or fallible, or mistaken. However, they seem to loose sight of the fact that overconstraining is but one of a number of ways the 'problem space' can be inadequate. Sometimes it is not the relaxation of constraints that is needed, but rather the specification of existing constraints, or the making of further constraints in order to make the representation adequate in the present situation.

Overconstraining *can* be a problem in creativity and may keep the creator from reaching a solution – but so may other kinds of inadequate representations. What is needed is a theory that highlights that overconstraining is *one* form (among many) where the subjective representation of the problem space is an inadequate reflection of objective possibilities and impossibilities. To overcome such a situation and reach a creative solution one needs to alter the problem space to become a closer approximation of the objective possibilities and impossibilities. This MAY include relaxing invariants into variables. But it may also include adding further constraints, specifying constraints, altering constraints etc. In stead of estimating the adequacy of the problem space in terms of whether the solution lies within the boundaries of the space, the adequacy needs to be estimated against the objective possibilities and impossibilities of the situation. Whether a solution lies within the problem space *should not and does not* affect the adequacy of the representation. As we all know sometimes there simply isn't any solution to be found, a situation apparently incomprehensible to the IP theories. The quality of the representation is determined by it's adequacy – not it's inclusion of a solution.

That does of course not mean that constraints are unnecessary in thinking, as constraints keep our thinking in accord with the world. Focus should be on having the right kinds of constraints in creativity, rather than assuming that creativity and insight always needs to drop constraints. Simply dropping constraints is not creative and does not help the creative process ex-

cept in the very particular situation where constraints need to be dropped in order for the representation to become adequate (i.e. in accordance with the objective possibilities and impossibilities of the situation).

Below I will take a closer look at the different kinds of constraints on the *generation* of simulated variations in the creative cycle. As argued above, simulated variations are generated by recombining represented events and entities in novel ways through simulators. Such a view implies a vast space of subjectively represented possibilities and impossibilities – a space that is 'sampled through generation'. The vastness of the space of possibilities (and impossibilities) derived from such a view has led creativity researchers to talk about a combinatorial explosion (e.g., Simonton, 1999c), as the number of potential variations will grow roughly exponential with the addition of concepts, individuals or events. Fortunately the subject does not generate variations completely at random in this space. If I am to create a new kind of computer, I am not going to simulate the recombination of my sister's haircolor with a tropical fish in the hope that it might turn out to possess supercomputer potential (unless I had some kind of reason to assume that such a simulated variation could prove worth while). This example illustrates that there are obviously an incredible amount of constraints operating on the generation of variations in the creative process. Below I will look at a few of the different kinds of constraints on the extension of the space of possibilities and impossibilities from which we derive (sample through generation) simulated variations. The list will be far from perfect, and further research should add more kinds of constraints. But it will give some idea about the complexity of the constraints imposed.

A natural place to commence this list of constraints is to look towards the three kinds of constraints pointed out by psychological researchers in the tradition of *counterfactual thinking*. This tradition so far has only dealt with the mutation of *events that the subject has experienced*. Thus, in the below arguments, 'counterfactual thinking' refers only to mutations of experienced events. Seelau, Seelau, Wells, & Windschitl (1995) argued that counterfactual thinking is constrained in three ways: Purpose constraints, availability constraints, and natural-law constraints. Similar constraints may operate in creativity, as creativity like counterfactual thinking, deals with the possible and impossible. However, specifications and further constraints are also needed in creativity, as creativity does not deal with merely thinking in alternative ways of *actually occurred events*, but primarily with constructing (and recombining) entities, in order to bring novel and useful products into being.

5.4.1 Purpose constraints

In counterfactual thinking, purpose constraints deals with the purpose for thinking in alternative ways about past events: Is the subject assessing causality, controlling future outcomes, assessing blame, consoling other, or is some other purpose in play (Seelau et al., 1995). In creativity, however, the overall purpose of simulating variations is clear, it is, as the definition states, to *bring a product with generalizable originality, and with the potential for adaptive spread into being.* But as we saw in the discussion of the different types of search (in part 4), there can be several different conations in play in creativity, for example problem finding, problem solving, solution testing. Each type of conative directedness will constrain the simulated variations in different parts of the process. Naturally playing around in a domain, trying to find or clarify a problem will imply a broader search space than will a narrow search for a creative solution to a problem. Further, creative endeavors will be directed (more or less clearly) at a particular (or a few) domains, which in itself will set boundaries for what is relevant. For example, problem finding, problem solving or solution testing in the scientific field of chemistry, will set up relevance boundaries (albeit fuzzy ones) for what is relevant for discoveries and innovations in chemistry. This does not mean that inspiration cannot come from other domains (indeed analogical transfer is a oft used means of inspiration), but simply that the creative product will not be just anything novel and useful, but rather something novel and useful *in a domain*[51].

5.4.2 Availability constraints

In counterfactual thinking, availability constraints deals with how mentally available different events are for mutations. This is decided by, among other things, the knowledge of the factual events; if the events are normal or exceptional; if it contained a 'near miss'; the order of events (e.g., last and deciding events are more likely to be mutated); and action – inaction (action is more likely to be mutated) (Seelau et al., 1995).

In creativity, we are not dealing with a single event that is to be mutated. Rather we are dealing with a phenomenon that recombines entities as well as events, with a purpose that is rather different from counterfactual thinking, as we saw above. Many of the factors constraining counterfactual thinking will thus not constrain simulated variations (i.e., order of events, action-inaction, near misses). However some will (i.e., knowledge of events, normality), and creativity definitely will have availability constraints of many different kinds. For example, availability constraints in creativity needs to incorporate various knowledge of events and entities

since creativity is about bringing products into being. I will look at a few of these constraints below:

Knowledge of entities and events: The subjective representation of real-world events and entities can be more or less adequate, as I have argued above. The adequacy will constrain the simulated variations both in terms of the *amount* of knowledge possessed on a particular domain, but also of whether the knowledge *adequately determines where the boundary* between the possible and impossible is to be found. Knowledge is thus not only knowledge of what entities and events *exists*, but also of what could and could not be. This implies knowledge of not only the typical and normal (general-universal), but also of the atypical, the possible, and the impossible. We have knowledge of not only what *is* in the world, but also how the existing could change into something else, and the rules governing such change. Further knowledge of what is possible and impossible can be generated through simulating variations. The adequacy of these generations must be measured against the actual world.

It should noted, that knowledge of functions and meanings of objects can constrain thinking so as to limit the possibilities recognized in the object (as Duncker, 1945/1972, pointed out with the concept of functional fixedness).

As cognitive psychology has pointed out, *knowledge of normality, frequency, typicality of events and entities* structure our thinking about the world, including thinking about novel variations. An example is what Ward (1995) called *structured imagination*, which refers to " […] the fact that when people use their imagination to develop their ideas, those ideas are heavily structured in predictable ways by properties of existing categories and concepts" (Ward, 1995, p. 157). As we saw above, theories of concepts and categories in cognitive psychology tend to place such a great emphasis on this, that they often reduce concepts to dealing merely with general-universal properties, without any link to concrete real-world *entities*. As I argued (with Mammen (1983) and Barsalou (1999)), this reduction must be avoided, although the typical and similar certainly does influence creative thinking and the generation of simulated variations.

When concepts are not reduced to merely the general-universal properties of objects, but rather remain grounded in sets of individuals (with both numerical and qualitative identity), knowledge can include typicalities and normalities, *but also possibilities and impossibilities*. These are not limited

to knowledge about e.g., whether a car under changed properties and circumstances will *still be a car*, but also to knowledge of whether a car under changed properties and circumstances *is actualizable and hence possible* or not. Certain properties can be changed (e.g., color) with the car remaining possible, while other cannot (e.g., changing the frame to liquid water). Much research remains to determine how this knowledge is structured and used by subjects in creativity.

Another kind of availability constraint should be pointed out. It has often been pointed out in the creativity literature that problems can be (and often are) solved by *analogy*. Indeed, a scientific research area focussing on analogical transfer has sprung up which heavily influence theories of creativity (see e.g., Holyoak & Thagard, 1995; Reeves & Weisberg, 1994; Dunbar, 2001; Keane, 1988). Theories of analogical transfer focus on how novel problems can be solved by looking to similar known problems, with a subsequent attempt to transfer the solution to the novel problem. Important distinctions between which similarities between problems secure transfer are made in this literature. Translated into the terminology of this thesis, one might say, that theories of analogical transfer pinpoint constraints that help make distinctions between what solution transfers are possible, and which are impossible. The distinction between deep structure and surface structure (or between structural similarities and surface features) is important in that connection.

> "Similarity between two problems can exist on any level, although true analogies are considered to be those problems that share a similar deep structure but not necessarily specific content (e.g., the analogy of the atom as a solar system)." (Reeves & Weisberg, 1994, p. 382).

As such, one may argue, that by looking for deep structural similarities between problems, or domains, one may secure that transfer of solutions or additional structure or theories is possible rather than impossible. Research have shown that novices and experts differ in that experts rely more on structural similarities, whereas novices rely more on surface features when attempting to transfer analogically (e.g., Novick, 1988; Novick, 1990). Further examinations of the objective aspects[52] of what constitutes this 'deep structure' constraint are needed to find out how and why it secures the possibility of transfer.

These are probably far from the only kinds of availability constraints in creativity. Further research will have to reveal more.

5.4.3 'Uncertainty directed' constraints

In counterfactual thinking, Seelau et al. (1995) argued that so called 'natural-law' constraints constrain the mutations of events. However, this view can be clarified when dealing with creativity. Obviously the reason for including these 'natural-law' constraints in counterfactual thinking, is to separate counterfactual thinking from mere fantasy or day dreaming. However, as I have argued above, what separates fantasy from creativity is that creativity is directed towards the boundary between the possible and the impossible, whereas fantasy is not. A creative process must seek to separate the possible from the impossible, whether it is directed at an invention or a scientific theory, or whatever else. Fantasy need not make this distinction. These boundary directed constraints make sure that simulated variations are discarded or modified if they are evaluated (or known) to be impossible. Only variations that the subject believes (prior to variation) *could be* possible (and thus actualizable), or is *unsure of*, will be considered. Unfortunately, as we are dealing with novelty, most of the variations simulated are uncertain prior to simulation, and can thus only be discarded *after* the simulation, when it has been evaluated whether it could be possible or not. But even the variation that turns out to be impossible informs the subject. As such, it is not merely 'natural-law' constraints that limit the simulations in creativity, but rather any factor that the subject believes (a priori) will make the simulated variation impossible. Creativity is directed towards simulating variations with *uncertain* outcomes, in order to find novel, useful and possible variations to bring into being. This means that in the generation of variations, creativity is directed towards uncertainty, whereas evaluation and selection processes are directed towards clarifying whether this variation is actualizable, and hence possible. Variations with a priori known high degrees of certainty of what is to be possible or impossible (or where this knowledge is easily deducible) are usually not generated.

Besides the above three general kinds of constraints (purpose, availability, uncertainty), inspired by counterfactual thinking research, at least two more kinds must be included in creativity.

5.4.4 Search strategy constraints

Whereas the purpose of counterfactual thinking may be to prepare the individual to an uncertain future (in terms of preparing the individual for action in future events similar to the one being mutated), creativity is about bringing the future into being as well. It is a search process that entails search strategies, as the IP theories have argued. This means that the subject will often actively (but sometimes also automatically) follow search strategies

in the pursuit of the more or less clear 'goals' of the process (however, please remember that many different kinds of searches are taking place in creativity, not limited to problem solving). These strategies will constrain the generation and simulation of variations. This is a point made frequently by information processing theories, where different kinds of (usually rational and conscious) heuristics constrain the search space (e.g., Kaplan & Simon, 1990). As Perkins (2000) has pointed out, different problem spaces will fit different search strategies.

A somewhat different (less rational, and more automatic) kind of search strategy can be found in the literature on creative intuition. Recently a number of theories have stressed that intuition guides discovery (e.g., Bowers et al., 1990; Bowers et al., 1995; Policastro, 1995; Policastro, 1999). Policastro defines creative intuition in the following manner:

> "First, creative intuition can be defined as a vague anticipatory perception that orients creative work in a promising direction. [...] Second, in more technical terms, creative intuition can be understood as a tacit form of knowledge that broadly constrains the creative search by setting its preliminary scope." (Policastro, 1995, p. 99-100).

When defined in this manner, creative intuition fits well into the creative cycle, as another kind of search strategy employed in creativity. In this manner it is certainly possible for subjects to use both rational and less rational search strategies. The extent to which they are useful is of course another matter, depending on many factors. But they certainly do constrain the generation of variations.

5.4.5 Situation constraints

A very important point about the creative cycle, is the fact that simulations are not 'detached-from-this-world', although they may involve thinking. Creative thinking is an active process in and about the world linking a subject to objective, although not yet existing, possibilities or impossibilities. Because it takes place in the present situation (including objects, cues, models, etc.), it is naturally affected by it. Theories have shown how cues present in the environment affects the creative process. For example, Maier (1931), in his famous 'two string' experiment showed how a cue from the experimenter could lead to insight. A subject is brought into a room where two stings are hanging from the ceiling some distance apart (too far for one string to be reached by simply holding on to the other one). There are various objects in the room. The subject is to tie the two strings together, op-

tionally using some of the objects. One solution implies using a medium sized object (e.g. a pair of pliers) as a pendulum, whereby one string can be caught by catching the pliers-on-string on the upswing, while holding on to the other one. The cue was that in the experiment the experimenter 'accidentally' brushed against one of the strings thereby making it swing slightly. However, Maier found that some of the subjects were not aware that it was the cue that had led them to insight. This ability to utilize information present in the physical situation has also been highlighted by researchers such as Dreistadt (1969), Seifert et al., (1995), and Simonton (1999c). Again it should be remembered, that the creative process is not an 'inner' process detached from the world. The process always occurs in a setting, which may both help and hinder the generation of novel and useful products.

All these different kinds of constraints on simulated variations help limit the number of pointless simulated variations. Many more types of constraints are probably in play. However, no matter how many constraints are imposed there will always be an infinite number of possibilities and impossibilities from which to generate novel and useful variations. Adding together any number of constraints will not leave us with just a single variation, the one that is novel and useful. When dealing with novelty, fuzzy boundaries and more or less adequate knowledge structures, along with uncertainty loom large, and many variations are generated that, in retrospect, can seem pointless. But the point is that a priori the subject did not see the pointlessness of the variation. The extension of the 'possibility and impossibility space' is so large, that the subject needs all the constraints he can get, to narrow it down (to an infinity of smaller cardinality). As Gardner has pointed out :

> "The mind of the expert creator is so well honed that only an infinitesimal proportion of all conceivable 'moves' is considered. [...] Better to say that we have 'extremely constrained variation' followed by 'highly reflective selection'." (Gardner, 1999, p. 339).

Gardner's comment is a reaction against the Campbell-Simonton theory of creativity as blind-variation-and-selective-retention. Here Gardner is objecting to calling creativity 'blind' or 'random' by pointing towards how the expert creator is better able to constrain his search space. However, according to the creative cycle, there is no need for calling the expert's remaining number of possible variations 'infinitesimal'. Although an expert may have more and better *constraints* on the search space, it should be re-

membered, that the expert will also have many more (and more complex) represented concepts of his domain, compared to the novice. The expert may reduce the number of irrelevant simulations greatly though constraints and a more adequate representation, but he has at the same time many more domain specific concepts to generate simulations from. No amount of constraints will ever reduce the search space to merely one variation. And even if it did, such a process would probably not be considered creative. Simulated variations in creativity are always uncertain in outcome before they are produced. This is no different for experts than for novices. As such, creativity is both blind, and highly constrained at the same time.

5.5 Summary

This section has dealt with several cognitive aspects of the creative cycle. It was made clear that creative cognition is not to be viewed as an 'inner' process occurring in the head of the creator. Rather it is active processes that links a subject to objective possibilities and impossibilities through actualization processes (where products are created through concrete physical action), and in simulation processes (where variations are generated in creative thinking). Such a view secures the aboutness of creative thinking of novel variations, as they are grounded in objective possibilities and impossibilities. Creativity involves different kinds of processes. They were summarized to involve generation; exploration and modification; evaluation and selection. These processes operate on (generate variations from) existing knowledge structures, although the variations are also sampling the objective possibilities and impossibilities of the world. These knowledge structures are characterized by the ability to lend themselves to the simulation of novel variations constrained by knowledge of objective reality (including knowledge of what can and cannot be). The processes are structured by ordinary mechanisms of categorization (as pointed out by cognitive science), and thus constrained by what is similar, frequent, and normal. But this is not the only way knowledge structures variations. It was shown with Mammen (1983) and Barsalou (1999) how the cognitive science explanation of categorization builds on restricted premises, in that they neglected what Mammen has called the 'human sense for the concrete'. Barsalou further showed how having knowledge of individuals and concepts can be viewed as having the ability to simulate it's referents (and variations thereof) competently in their absence. As such, the generation of variations builds on existing knowledge implied in concepts, categories, individuals and events of what is possible and impossible. As knowledge structures are anticipatory structures, any discrepancy between simulated variation and actualized variation, or uncertainty concerning the possibility of a variation,

will be a call for action to acquire information and explore the world further in that particular area. Further, having encountered a creative problem prepares the subject for later encounters with events or entities that could potentially help solve the problem. This has been termed the opportunistic assimilation hypothesis.

Finally it was examined what constrains the generation of variations. Several different kinds of constraints were listed, including: purpose, availability, search strategies, and situation constraints, as well as constraints that direct the creative process at variations where the boundary between the possible and impossible is uncertain.

PART VI: THE CREATIVE CYCLE AND STAGES IN THE CREATIVE PROCESS

”Every inventor, even a genius, is always the outgrowth of his time and environment. His creativity stems from those needs that were created before him, and rests upon those possibilities that, again, exists outside him. That is why we notice strict continuity in the historical development of technology and science. No invention or scientific discovery appears before material and psychological conditions are created that are necessary for its emergence. Creativity is a historically continuous process in which every next form is determined by its preceding ones.”
- Lev Semyonovich Vygotsky

6 THE CREATIVE CYCLE AND STAGES IN THE CREATIVE PROCESS

Above I have argued that creativity and the creative process should be explained by the ecological cognitive framework that I termed 'the creative cycle', in order to avoid the traditional constructivist mentalistic approaches to creativity (e.g., IP theories), and strike a balance between realist and constructivist theories of creativity. It is now time to take a look at how this model relates to traditional explanations of the stages of the creative process. In this section I will do this by going through the four stages pointed out by Wallas (1926) that are still used today (see part 2 for a summary of the stages). This is done to show how the creative cycle relates to these stages, and explains key characteristics and empirically established transitions in the process.

At a general level Wallas' description of the creative process and the creative cycle seems to have the same structure. Both emphasize the importance of preparation and knowledge of a field and domain; both acknowledges the difficulty and problematic aspects of searching for novelty; both acknowledge sudden and surprising affect as a key element; and both emphasize the reality testing nature of the process in that simulated variations are elaborated, evaluated and actualized. Although the creative cycle is circular (as opposed to Wallas' linear descriptive process), that does not mean that no progress is taking place – on the contrary. The creative cycle is a movement from the actual, into the world of the possible and impossible, and back to the actual, resulting in a novel and useful product.

However, there are also key differences, such as the fact that Wallas emphasized unconscious idea recombination as a key element in the model, in order to explain the function of incubation. Although emphasizing 'simulation of variations' as an important element in the creative process, random unconscious idea generation is not part of the explanation put forth in the creative cycle. Instead, the creative cycle emphasizes that creative search takes place in the real-world, through the simulation and actualization of variations.

Below I will go through the four stages, commenting on their relation to the creative cycle as we go along. I will further make a few comments (inserted as sections starting with ….*a note on*…) on issues that have been central in discussions on creativity in the literature.

6.1 Preparation

Creativity is not simply a sudden flash of insight appearing from out of nowhere. Rather, the creative process involves knowledge acquisition, preparation, and other processes as a precursor to any impasse or insight. Anticipatory knowledge structures are a prerequisite for the sudden and surprising insight. The preparatory stage sets up these anticipations in a number of ways, including through the simulation of variations.

What has been termed the 'preparation' stage is probably the most extensive phase of any creative endeavor; the acquisition of knowledge and initial search. As I have argued, the quality of these knowledge structures are determined by how adequately they reflect objective possibilities and impossibilities – and not by whether they happen to include a 'solution'. Creative search is paradoxal, and is not limited to the search for solution to clearly formulated problems, but can proceed (among other things) as a search for problems to solve (e.g., playing around with ideas), or ways to actualize or implement simulated variations. This means that formulating a particular problem; solving it; and implementing it can each imply different creative processes, each producing a novel and useful product in a broad sense.

The preparatory and verificatory stages in the creative process pinpoints what has often been neglected: that the creative is a *work* process proceeding from the actual into the possible and impossible, and back to the actual. The eye catching insight phenomenon does not constitute creativity – and creativity cannot be explained by simply looking at this aspect. One thing must be stressed concerning the preparatory stage: it would be wrong to associate knowledge acquisition solely with the preparatory stage. This is the line of thinking seen in IP theories, where mental processing occurs in the creative process on the basis of previously established problem or possibility spaces. Rather, the creative process relates to the real-world in all stages, sampling information from it. Even the simulation of novel variations is 'knowledge acquisition' in the sense that although the process involves *generation* of variation, it simultaneously *samples* possibilities and impossibilities. This means that all aspects of the creative process are *in* and *about* the world - even the parts involving thinking and simulation!

A certain phenomenon in the preparatory stage requires explanation. The stage is thought to end with an *impasse*, where the process seemingly comes to a halt, and the subjects cannot seem to go any further on the pre-

sent problem, solution or implementation. How is this impasse to be understood?

Explaining *why* subjects can get stuck and reach an impasse in the creative cycle is not hard. The creative process is dealing with novelty and usefulness; the simulation and actualization of variations this world has never before seen actualized. Indeed it would be strange if the process didn't strand on a few occasions where a particular problematic aspect had to be worked out. Such an impasse can of course be due to many different things. A traditional explanation (often used in the IP theories) is that the subjective knowledge is overconstrained, and that subjective constraints need to be relaxed. Additionally the same traditional explanations has sometimes assumed that the subject is in fact *competent* to solve the problem although overconstraining is presently keeping him from doing so (e.g., gestalt theories focussing on restructuring, see also Ohlsson, 1992). Such views seek to explain creativity wholly through mental barriers that needs to be overcome. But the creative cycle points to the fact that perhaps the subject does not possess the knowledge required; perhaps his or her knowledge is inadequate. And at other times it may simply be real-world constraints that have to be overcome. For example, Edison examined thousands of variations before he found the substances that worked satisfactorily in his new invention, the light bulb. Such a search process was directed at real-world constraints, rather than being a function of a mental overconstraint of Edison and his staff.

In any case, the reaching of the impasse is easily explained. What is less easily explained is how it can be overcome, as we shall see in the next stage.

An important feature of reaching an impasse, is the acknowledgement thereof. As Seifert et al. (1995) argued, reaching an impasse means that failure indices are stored in memory that will make sure that later opportunistic encounters with objects or events that could help solve the problem will remind the subject of the problem. In general the human knowledge structure is anticipatory, and it is not only the finding of solutions to problems that will remind the subject. Also discrepancies between what the subject thought (i.e., had simulated) were going to happen – and what actually happened - will inform creative search. There are probably many more ways the preparatory stage help the subject anticipate information – I have only hinted to a few here.

6.1.1 … a note on expert vs. novice creativity

An important discussion in creativity has been *who* to study. Certain researchers have argued for the study of experts and people who have actually performed high level creativity (most notably Simonton, 1999c). Research like this has led to the formulation of the so-called ten year rule. The ten year rule states that a person must be immersed in a domain for at least ten years before anything radically creative is created. Others have not made such a distinction, and do not limit the study of creativity to experts or creative geniuses – but study creative processes in everybody. This is for example the case in the study of insight, where insight tasks, requiring no special knowledge, are often given to college students.

The view that creativity is 'spontaneous' or 'fantastic' has sometimes led researches to point to 'the return to childhood' in order to harvest creative energies. In such a view, children are more creative than adults, and preparatory processes are unimportant for creativity to occur. The creative cycle would disagree with this view. Creativity in children is most often 'childish', which means, that although a created product may be new to the child, it is not novel or useful in the sense required for a product to be creative in the sense used here. As a number of researchers have pointed out (Vygotskij, 1995; Ward, Smith, & Vaid, 1997), and empirical research has supported (e.g., Cacciari et al., 1997), children can be seen as less creative than adults, as the level of creativity increases with knowledge acquisition, and the acquisition of skills and processes involved in creative action. This is a direct consequence of considering subjective representations of possibilities and impossibilities as more or less adequate in comparison to objective reality. The adult does not need the many naive variations of the child.

In the present thesis I have limited creativity to the kind of creative products that are deemed creative by experts, and which are novel and useful to an entire domain. At this level, preparatory processes, where knowledge of the field and domain is acquired, is of immense importance, and takes years. But that does not mean that one should limit the study of creativity to creative geniuses. Rather it points to extending the focus of general creative *processes* to include, not merely insight, but also preparatory processes. Preparatory processes are of immense importance in the creative cycle.

6.2 Incubation

After having reached an impasse, the subject goes about his or her other business, not paying much, if any, conscious attention to the problem, solution or implementation. The traditional explanation for the function of this

stage is to allow some internal mechanism time to operate. This could be the generation of unconscious random recombinations, or selective forgetting, or some other mental operation. The term 'incubation' itself refers to this function of allowing something to have time and place to grow. However, in the creative cycle, it can seem strange why 'putting the problem aside' and not working on it consciously, is the right approach in creativity. If an impasse is reached due to lack of knowledge or the existence of a real-world constraint, then why would simple incubation help? So rather than arguing that the function of the incubation stage is inner unconscious processing, I argue that the function is to allow for time to explore and gain further knowledge of the world and its inherent possibilities and impossibilities. This shifts the focus away from internal mental processing, and towards action in the world. This, however, does not necessarily mean that the exploration is due to intentional actualization or simulation of variations (although it may). The exploration may simply consist of 'going about his or her own business', whereby a chance encounter with an object or event will bring the problem, solution or implementation back in conscious awareness of the subject (what Seifert et al., 1995, called opportunistic assimilation).

6.2.1 … a note on (inner vs. outer) cuing

One of the reasons why external (situational) cuing have not traditionally been considered a viable explanation for incubatory processes, may be that the research tradition focusing on insight typically involve subjects attempting to solve the so-called insight puzzles. In this tradition, it seems rather problematic to 'cue' the subjects with answers or partial answers, as this could possible be seen as 'cheating'. After all 'cheating' in problem solving involves the use of information not included in the problem itself, and hence provides the individual subject with an unfair advantage on the problem (compared to other subjects). However, in real-world creativity, there is no cheating of course, because creativity is not a normative comparison of individual differences. This has been increasingly acknowledged, and several researchers are now pointing to anticipation, cuing, and transfer as essential elements in the creative process (e.g., Seifert et al., 1995; Holyoak & Thagard, 1995; Dreistadt, 1969). Simonton (1999c, p. 44) has argued that during incubation the mind is primed by both external (e.g., everyday events as well as work on other projects) and internal input (e.g., retrieved memories, chains of associative thought). Future research should reveal more ways the environment influences the making of creative products.

6.3 Illumination / insight

What first and foremost characterizes an insight is the phenomenological aspects thereof. These include the sudden, spontaneous, unexpected and satisfying nature thereof. This occurs in sharp contrast with the incubatory period preceding it, wherein the subject may not be consciously working on the problem, solution or implementation. These characteristics has led philosophers and psychologists over the years to ponder where these insights came from – appearing seemingly out of nowhere, as they sometimes do. One answer has been to ascribe insight to a sudden restructuring of knowledge. Such a view maintains that insights occur because the mental representation is somehow structured in the wrong way, blocked or fixated, and needs to be restructured for insight to occur. Some of these theories assume that the subject is in fact competent to solve the present problem, or reach an insight, but his mental structuring prohibits this. The view taken in the creative cycle is a somewhat different one. Although restructuring may occur in some cases, the primary cause of insight is the exploration of the objective, although non-existent, possibilities and impossibilities of this world. Insight does not primarily occur due to overcoming overconstrained mental representations, but due to creative exploration of objective reality in a creative search. The creative search is anticipatory, and may be automatic to a large extent, which means that the subject may experience the characteristics of suddenness and surprise because the present action was not intentionally directed at the problem, solution or implementation of the creative product.

6.3.1 … a note on 'sudden and surprising affect' in creativity

Creative affect is not limited to insight. As a number of researchers have examined, the creative process involves a range of different affects, operating in different stages of the creative process (e.g., Csikszentmihalyi, 1996; Russ, 1993; Shaw, 1994). However, an important question concerns whether there are more than one kind of *sudden and surprising* affect in creativity, besides the insight ('AHA!') phenomenon. If insight can mainly be explained through anticipatory knowledge structure, and environmental cuing, then it would seem obvious that other types of sudden and surprising affect can be in play as well. Below I will make a few tentative suggestions as to what these types of affect might be.

Comprehension ('Ahhh'): Sudden and surprising comprehension is another affect operating in creative search. Seeing clearly that you were looking in the wrong place, or simply being told that someone else has already come up with a satisfying answer can provide this form of affect.

Serendipitous discovery ('HEY!'): This is a very important form of sudden and surprising affect in creative discovery. It clearly illustrates that one can find what one is not consciously looking for, and which have not even been clearly formulated as a goal! Although one may not be actively and consciously looking for a serendipitous discovery, a prerequisite for making the discovery is still a prepared mind and anticipatory knowledge structures. Accidentally stumbling into something of immense importance, and recognizing it as such, is a very important mechanism is science and invention.

Confusion ('What??'): Expecting (through simulation of variations) a certain chain of events to unfold, or certain qualities to emerge in actualization, but seeing them unfold otherwise, can lead to confusion. Discrepancies between what was expected, and what was actualized creates this tension.

These and other kinds of sudden and surprising affect should be considered part of the creative process, and should be examined in future research.

6.4 Verification / elaboration / evaluation

The last stage in the traditional description of the creative process is the so-called verification stage. The name implies that not all insights are correct (although some theories would have us believe this), and that an insight should be elaborated, evaluated, and tested. An insight must be tested against reality to make sure it is in fact possible, rather than impossible, and reflect objective reality adequately. This underscores the fact that creativity neither begins nor ends with insight. In the creative cycle this stage is not merely a *verification* of the correctness of an insight, but includes the generation of an exemplification (actualization; objectification) of the insight (e.g., making a prototype; writing a book). Insight is after all defined by the creation of a novel and useful *product*. And as we saw in part one, the usefulness aspect means that the product has the potential for adaptive spread in context or domain. The way the product spreads varies from domain to domain (e.g., through publication, or through bringing the product 'to market'). In the present thesis I have dealt with creative products that are deemed novel and useful by experts and which spread in an entire domain. Hence, the actual evaluation of whether the product is ultimately creative is done by experts in the field.

6.5 Summary

The present section dealt with the degree of fit between the creative cycle, and the traditional explanation of the four stages of the creative process (preparation-incubation-insight-verification). It was argued that preparatory processes are immensely important, and that creativity never occur 'ex nihilo'. During creative search, the subject may reach an impasse, due to objective constraints, or subjective misrepresentations. This may lead the subject to put the problem aside, and go about his or her other business (initiating the incubation stage). The traditional explanation of the function of incubatory processes (i.e., time perform unconscious mental processes) was criticized. Rather real-world exploration may lead the subject to opportunistically encounter an event or entity that leads to insight. Insight is characterized by the phenomenological aspects of sudden and surprising affect, but so are a number of other phenomena (e.g., comprehension, serendipitous discovery, confusion) operating from the same principles (anticipation-cuing) in the creative cycle. The final stage of the creative process is verification, where the product is carried to a final and useful completion (actualization; objectification), enabling it to spread to other subjects in a domain.

PART VII: CONCLUSIONS AND FUTURE RESEARCH

“If we knew what we were doing, it would not be called research would it?“
- Albert Einstein

7 CONCLUSIONS AND FUTURE RESEARCH

This thesis commenced with pointing out that a central concern for the scientific study of creativity is answering the question of where creative ideas and products come from. Many psychological creativity theories, by theorizing that the creative process takes place inside the head of the creator, ignores the fact that creative ideas and products do not come into being out of nothing ('ex nihilo'), but rather is a process taking place in the real-world, by changing something into something else. These two different approaches were termed 'realist' and 'constructivist' approaches respectively. The present thesis has been an attempt to highlight the need for a synthesis between realist and constructivist approaches to the study of creativity, as well as an attempt to actually generate a framework for such a theoretical synthesis capable of explaining the creative process in reality.

The tension between realist and constructivist theories of the creative process could be seen in a number of ways, including unit of analysis ('objective structures' vs. 'subjective processes'), the search concept ('finding' vs. 'creating'), and the definition of creativity ('usefulness' vs. 'novelty'). Constructivists tend to focus on creativity as resulting in a changed mind, whereas realists change the world by bringing a product into being.

It was argued that a synthesis was needed in order to explain the creative process, and an ecological cognitive framework was created as a result. The framework was termed 'the creative cycle', which ties realist and constructivist approaches together in dialectical opposition mediated through action. In the creative cycle, subjective structures direct activity, which samples information from objective reality, which again modifies the subjective structures. Objective reality includes objective, although non-existing, possibilities and impossibilities which are qualities of this world. The activity in the creative process can involve both physical creative action that actualizes possibilities, as well as creative thinking that merely simulates and samples possibilities and impossibilities. The subjective knowledge structures provide the basis for creative cognition processes (generation, exploration and modification, selection and evaluation), but cognition is not for that reason out of touch with reality. Creative ideas and products are not created 'ex nihilo' but is not simply 'picked up' from the world either. Rather, creativity is a paradoxal search for novelty that finds ideas and products in the possibilities of this world through a constructive process. As such, novel variations are *sampled* from objective reality through a *generative* process. The creative process is a movement from the actual, into

the possible and impossible, and returning to the actual in the construction of a product with generalizable originality and the potential for adaptive spread in a domain.

In short, it was argued that the ecological cognitive framework I called the creative cycle provides a necessary synthesis between realist and constructivist approaches to the study of the creative process.

The road to this appreciation and conclusion is sketched out below:

I started out by following the recent consensus on a definition of creativity: that creativity occurs when someone brings a novel and useful product into being. However, this was qualified by specifying usefulness to mean 'potential for adaptive spread' and novelty to mean 'generalizable originality'. These qualifications points to the fact that creative products spread adaptively in the domain or context within which they are created, and as such it points out that use of creative products extend beyond the individual creator, to society. Then a number of limitations of the present analysis of search and cognition in the creative process were pointed out. First of all, the analysis is limited to products that are deemed creative by experts and which are novel and useful to a domain. This view is taken to direct the analysis at creativity that extends *beyond* what Vygotsky (1978) called the zone of proximal development. Further, the analysis focuses primarily on an individual creator in the world, and less so on the social aspects of creativity. And finally, the domains that are the focus in the present analysis are those of science and invention.

Following these preliminary sections, the information processing (IP) approach to creativity was analyzed. The IP approach views creativity as a search for a solution to a problem in a 'problem space'. I argued that the 'search' explanatory model was basically a realist one, implying a few basic elements of a search: a subject, an object of search, a space, activity, and a non-object that is implied in the activity of search. Search is a realist model, as it implies an object in the world to be found, regardless of whether the subject has any idea or concept of this object. Three IP theories were analyzed (Newell & Simon; Boden; Perkins). It was concluded that these theories of creativity all view c*reative search as taking place in mind, be made by mind, and resulting only in a change of mind*. Such a view places IP theories close to a constructivist approach to creativity, wherein the real-world is not included in the analyses of creative processes. The problems with this approach include underestimating the preparatory and

evaluative elements of creativity; overemphasis on rationality; neglecting that creativity also results in products in the world. But although such an approach to creativity is extremely problematic, the IP theories did point in some important directions, when emphasizing creativity as search in possibility spaces; i.e., a cognitive space for the generation of hypothesis that extends beyond the actual.

The problems in the IP approach were led into a discussion between realist and constructivist theories, and it was argued that the explanation of creativity must necessarily involve a balance between the two. Along a continuum between realists and constructivists, novelty and usefulness point in opposite directions, as do subjective processes vs. objective structures, and 'finding' vs. 'creating' novel and useful products. Creativity does not create 'ex nihilo', but it does not simply 'pick up' novel products either. A synthesis between realist and constructivist approaches to the creative process is needed – an approach that needs to include objective reality in the analysis. Such an ecological approach to creativity was sought in the remainder of the thesis.

Two dilemmas facing an ecological framework for creativity were discussed. First, it was discussed how something at the same time can be novel, and come from somewhere, as it is seemingly necessary in creative search. The solution was to argue that possibilities and impossibilities are part of objective reality. They are objective, although non-existing, qualities of this world. The second dilemma discussed was how you can search for something that you do not know what is, and which doesn't even exist. Searching for the non-existing was (with Davydov & Zinchenko, 1980) termed 'paradoxal search', and it was argued that when search is viewed as an activity, the *object of search* is implied in the activity of search (what Engelsted called the non-object). As such it is not necessary to 'know' what (in particular) you are searching for, in order to search, just as it is not necessary for the object of search to exist before the search. One might say that where goals have primacy and spark of the search in the IP theories, the opposite is true in the present approach. Here creative search is primary, and the goals follow.

Having overcome these two dilemmas, it was argued Neisser's (1976) model of perception constitute a close match with the specifications derived from the above discussions on creativity (e.g., the inclusion of the real-world; creativity as active being in the world; a synthesis between realist and constructivist models). Therefore Neisser's perceptual cycle was

chosen as a base analog for the explanation of the creative process. Using Neisser's perceptual cycle, a model termed the creative cycle was made that had the basic properties needed for a framework for creativity. Neisser's model was changed by including the extended view of ontology and search argued for above. Creativity is thus viewed as searching processes going from the actual world into it's possibilities and impossibilities, and back to the actual. Further, it was argued that as Neisser's model was primarily generated to explain perception and the acquisition of knowledge, his theory of cognition and schemata needed to be changed somewhat for a theory of creativity.

Four extensive discussions concerning creative cognition were then carried out. The first question concerned the distinction between 'inner' and 'outer' processes in creativity. Here it was argued that creative thinking should be viewed as simulation of objective reality (including possibilities and impossibilities), rather than as detached from it. Such a view enables a theoretical distinction between simulation and actualization, where both processes connect a subject with the world through action. Simulating variations of the actual world becomes central to understanding creativity. The second question concerned the processes involved in creative cognition. Through a brief review of two models of creativity, it was concluded that creative cognition involves three categories of processes: generation; exploration and modification; evaluation and selection. The third question concerned the structure of knowledge in creativity. Knowledge must be organized in a way that makes it possible to simulate variations, and anticipate novelty. The cognitive science explanation of this was briefly looked at, and it was found that cognitive science explains the generation of novelty in the same terms as ordinary categorization (i.e., as constrained by what is similar, typical and frequent). This explanation was discussed, and found wanting a theoretical framework that could ground thinking in the real-world, as well as incorporate individuals. Two theories were then reviewed to overcome this limitation: Mammen's (1983) theory of the human sense, and Barsalou's (1999) theory of perceptual symbol systems. Taken together these two theories can ground simulation of variations in real-world individuals and events, and extend the mainstream cognitive science explanation of concepts. Having concepts is viewed as having the ability to simulate it's referents and variations thereof competently in their absence. Further it was argued that knowledge is anticipatory is a number of different ways. One way is what Seifert et al. (1995) has called opportunistic assimilation. Another way is the expectations of how (in what way) variations can be actualized. These are generated through simulation of varia-

tions. Finally, the discussions on cognition was concluded by looking at what constrains the generation of simulated variations. A range of different constraints were shown to be operating in the creative cycle, including purpose, availability, uncertainty, search strategy and situational constraints. These four questions taken together provide an attempt to specify how cognition could be functioning in the creative cycle. However, this section is somewhat speculative, and most of these questions and suggestions remain to be specified further and tested empirically.

In the final section, I attempted to show that the creative cycle can indeed explain key elements and characteristics of the creative process. This was done by looking at how the creative cycle would explain the four stages in the creative process that have traditionally been thought to constitute the creative process (preparation-incubation-illumination-verification). The creative cycle here explained key characteristics, such as the impasse phenomenon, the function of incubation, the existence of sudden and surprising affect (such as insight), as well as preparatory and elaboration processes.

In conclusion, although this thesis has tried to formulate an ecological cognitive framework for creativity, and although it is my contention, that the creative cycle constitutes such a framework, it is probably clear that the present thesis has not been able to completely satisfy all problems with such an approach. Some of the arguments remain somewhat sketchy, and much remain to be tested empirically. But, however sketchy this model may seem, I believe it is an improvement over the predominant existing view of the creative process as sudden flashes of insight or random unconscious idea recombinations occurring inside the head of the creator – detached from the world. It is my hope that the creative cycle will help put objective reality back into theories of creativity.

As this thesis has been of an exploratory nature, trying to develop a new understanding of the creative process, many of the points and theoretical suggestions made in this thesis are yet to be fully developed and tested empirically. Below I will point in a few directions to some experiments I believe could benefit from further research.

1) I have argued that creativity is a form of paradoxal search, not limited to creative problem solving. Problem finding, solution testing and perhaps other types of conation are operating in the creative process as well. This extension of the understanding of the object of creative search

calls for new ways to examine the creative process. Rather than simply focussing on the so-called 'insight' tasks, future research should include hypothesis generation and problem finding, as well as implementation and hypothesis testing in their methodology. Creativity is not limited to insight. An approach to the study of hypothesis generation in science has actually been employed by Fredericksen, Evans & Ward (1975; see also Hoover & Feldhausen, 1990). They designed a test (the Formulating Hypothesis test) to measure one aspect of scientific creativity: the interpretation of data, i.e., the ability to conceive of hypotheses that might account for research findings. An interesting experiment in connection with such a test would be to analyze it as the creative process occurs in real-time. By linking hypotheses generation to cues from the real-world (e.g., through a cuing methodology where facts are presented on a timed basis, or through eye movement studies), it may be possible to decipher how a subject directs his exploration of data, samples information and modifies his mental structures accordingly. It would be interesting to see if a creative search for hypotheses follows the same paths, as do insight problems.

Such an experiment could be further extended to incorporate the measurement of physiological reactions (e.g., arousal measured through heart rate, or EEG measurements) to outside cues. Insight has been linked to a sudden increase in arousal (e.g., Jausovec & Bakrasevic, 1995) whereas the incubation stage is characterized by lower levels of arousal in insight tasks. It would be interesting to see if the same characteristics applies to an active creative search for hypotheses.

As can be seen, the creative cycle not only points to different units of analysis (i.e., WHAT to study: objective cues, and the subject in active search in the real-world), but also points to HOW the study should proceed (i.e., process analysis, linking the subject to the real-world)[53].

2) A hypothesis of the present thesis is that incubation effects should be primarily explained as a result of a prepared mind that interacts with objective reality, rather than as a mental search occurring detached from the world. As such it is hypothesized that exposure to stimulus from the real-world during the incubation stage is extremely important for the creative process to proceed from impasse to insight (although variations can arise both as a result of cuing from the outside world and as a result of the simulation of variations in the creative cycle). However, this hypothesis should be properly tested on different domains, as there may be domain differences (e.g., perhaps mathematics and theoretical physics rely more on

self-generated variations, than does more 'tangible' domains such as biology and medicine). It is also conceivable that there are individual differences in whether a subject primarily draws inspiration from the environment or from self-generated simulation processes.

3) A research area suggested by the creative cycle is the study of how knowledge of possibilities and impossibilities of this world (of what might be, and what cannot be) is structured and affects the creative process. I have only made a few tentative suggestions as to how this could be studied. By suggesting that having concepts implies having the ability to simulate its referents and variations thereof competently in their absence, I opened up for extending research on categorization to include what can and cannot be as well. Much research remains on this account. Knowing how something can (or cannot) come to be something else through creative processes so far remains something of a mystery to the scientific study of creativity.

4) The difference between simulation and actualization needs exploring further. Here an analysis of the evolutionary development from mere physical tinkering to human simulation processes is needed, and could be made in the framework of Activity Theory. How did the steps from the forms of activities taking place in actualization develop to the complex simulation activities we see people make today in invention and science? Further, it could be hypothesized that the development from actualization to simulation occurs ontogenetically as well. Is the ability to simulate the environment developed and internalized in the first years of the child and if so, what steps occur in the process?

5) If environmental cues can help the creative process proceed from impasse to insight, then are there different types of cues, and are there differences in how helpful they can be to the creative process? Research on analogical transfer has pointed out that one should distinguish between so-called structural similarities and surface features, in that structural similarities secures the possibility of transfer, and is more frequently employed by experts. If one could further analyze what these 'structural similarities' are, and how they can be utilized in the creative process, perhaps tools and methods for creativity can be developed that can increase likelihood of creative analogy. So, I would call for the study of the *objective* aspects of analogical transfer, rather than merely subjective requirements. The distinction between different types of cues and the development of cuing methodologies could be the result.

6) I have pointed to a number of constraints operating on the generation of simulated variations. Some of these are more or less well established empirically in the creativity literature (what I called search strategy, situation, purpose and availability constraints). But the type of constraint that I hypothesized was directing creative search towards variations with *uncertain outcomes*, and where it is uncertain whether the result will prove itself possible or impossible, has not been tested empirically. Whether the creative search actually is directed towards uncertainty (rather than e.g., variations with clear outcomes, or where the outcomes are easily deducible) remains to be established empirically.

7) I briefly hypothesized that several different kinds of sudden and surprising affect (besides insight) could be operating in the creative process (comprehension, serendipitous discovery, and confusion). I further hypothesized that they could be operating from the same principles as 'insight' (anticipatory knowledge structures that are activated through cuing). But perhaps these types of affect operate in different stages of the creative process? All these hypotheses should be examined further.

These and other research questions could help establish or disprove the ecological cognitive framework to the study of the creative process I have called the creative cycle.

[1] A third criterion for creative products is sometimes included in the definition of creativity: that the product must be carried to a final, effective, or elaborate completion (e.g., O'Quin & Besemer, 1999; Cropley, 1999).

[2] In creativity research 'novel' is often assumed to be opposed to 'common', because this is convenient in psychometrical analysis. In other words the concepts of 'rare' or 'infrequent' are considered the same as 'novel', although this strictly speaking is somewhat problematic.

[3] As Boden explains: "If we take seriously the dictionary definition of creation, 'to bring into being or form out of nothing', creativity seems to be not only beyond any scientific understanding, but even impossible." (Boden, 1998, p. 22).

[4] We are dealing with the well known phenomenon of reification; the tendency of well-known products to afford only standard functions, rather than their historical threads in time or the alternative functions the product could also afford. The awe of the finished product does not reveal the countless variations attempted, the work process behind it. The simplicity of order seen in many products often leaves the spectator pondering : 'Now, why didn't I think of that?'. The elements so seemingly well-known, only put together in this novel way, can seem familiar, even though the particular connection is a stranger.

[5] Activity Theory researchers similarily talk of allowing objects to be generalized in society (in Danish: 'almengørelse'), and hence spread.

[6] Misjudgements in expert a priori evaluations of the potential for adaptive spread of a novel product are quite common (see Runco, 1999). Indeed, Carl Rogers suggested such an evaluation was impossible: "No contemporary mortal can satisfactorily evaluate a creative product at the time it is formed, and this statement is increasingly true the greater the novelty of the creative product" (Rogers quoted in Runco, 1999, p. 237). This suggests that expert evaluation of potential for adaptive spread can only occur well after the creation has come into being.

Discrepancies between experts a priori subjective measures of 'potential for spread' and the objectively post hoc measure of 'actual spread' occur often. Often the experts are in the wrong, but sometime they are in the right, as the terms 'overrecognition' and 'underrecognition' indicate. Below is a sketch of some thoughts on how disagreement between subjective a priori and objective post hoc evaluations of 'spread' can be interpreted.

	Expert evaluation a priori Large potential for adaptive spread	**Expert evaluation a priori** Small potential for adaptive spread
Actual objective measure of spread post hoc Large adaptive spread	A very adaptable and useful product	The experts were probably wrong, and the potential was there. The experts may rebut that it is an 'over-recognition' (e.g.,'old wine in new bottles'). The experts may have faced a very difficult task of estimation, perhaps due to radical novelty, making potentiality estimates almost impossible.
Actual objective measure of spread post hoc Small adaptive spread	Either : the experts are wrong, and there was in fact not a potential for adaptive spread; or experts were right, and there were a potential for adaptive spread, that just did not occur, perhaps due to lack of commercialism, lack of further development, lack of communication.	Not a very adaptable or useful product

[7] The Zone of Proximal Development is defined as:
"It is the distance between the actual developmental level as determined by independent problem solving and the level of potential problem solving as determined through problem solving under adult guidance or in collaboration with more capable peers." (Vygotsky, 1978, p. 86).

[8]Simonton, (1988) has suggested a fifth P – Persuasion to highlight the important role of impressing others with one's creativity – especially in the domain of leadership.

[9] The domains of discovery and invention can seem quite distinct, and opposed to each other. As Carl Mitcham is quoted for saying 'invention causes things to come into existence from ideas, makes the world conform to thought; whereas science by deriving ideas from observation, makes thought conform to existence' (Mitchum quoted in Hertz, 1999, p. 96-97). This, although true at a macro level (sociogenesis), is not true when viewed in the micro processes of creative action. As we will see in the later sections, the creative processes for invention and discovery are very similar.

[10] Creative problem solving (as a research area) is not to be confused with Creative Problem Solving (CPS), which is a particular model (consisting of specific techniques and methods) for solving creative problems. Creative Problem Solving (CPS) originally sprung out of Alex Osborn's research on (among other things) brainstorming (see Osborn, 1963).

[11] See Jausovec (1994) for a more extensive discussion of different classification systems for problem types.

[12] The word 'insight' has two different meanings, which are sometimes contradictory (Schooler, Fallshore & Fiore, 1995; Smith, 1995a). One is insight used to represent a state of *understanding*, to gain insight into something. The other is the sudden emergence of an idea into conscious awareness. Insight, as it is used here as part of the creative process, refers to the second usage.

[13] Definition of Fixation: 'A persistent block or impediment to succesful problem solving' (Dodds & Smith, 1999, p. 725).

[14] Definition of Mental Set: 'Persistently using an unsuccessful method of problem solving' (Dodds & Smith, 1999, p. 725).

[15] Definition of Functional Fixedness: 'Biased perception of an object that blocks the ability to use it in unusual ways' (Dodds & Smith, 1999, p. 725).

[16] After a symposium on invention Perkins (1994) concluded:
"Although the image of the creative leap dominates much of everyday thinking about creativity [...], we saw no cases of inventions resulting from a single leap plus working out the details" (Perkins, 1994, p. 131).

[17] Activity Theory is a psychological tradition putting emphasis on the evolutionary development of the psyche and the mediation of activity between subject and object. It is a Russian approach developed in the 1920's in the works of Vygotsky (e.g., 1978) and Leontjev (e.g., 1977) and others.

[18] Translated from the Danish: "Det nye forhold, der kommer til verden med den spontane aktivitet, er præcis det omvendte af reaktivitetens O->S, nemlig S->O, der udtrykker, at organismen i kraft af sin spontane eller selvinitierede (det betyder det samme) aktivitet bringer sig i kontakt med føden." (Engelsted, 1989, II, p. 54)

[19] As Engelsted writes concerning striving: "It is something that characterizes the organism an sich – not für sich. We are not talking about anything 'internal to the psyche' or 'internal' in any sense whatsoever." (Engelsted, 1989, II, p. 54, own translation).

[20] The concept of 'Activity' is translated from the Danish 'Virksomhed'.

[21] Translated from the Danish: "Det er den spontane kinesis i sig selv, der 'sætter' det fraværende objekt som logisk kategori." (Engelsted, 1989, II, p. 67).

[22] The concept of 'the psychical' is a translation of the Danish 'det psykiske'

[23] The concept of 'Action' is translated from the Danish 'handling'.

[24] For theories of creativity in *human* prehistory, see e.g., Klix (1980, 1983); Mithen (1998).

[25] It should be noted that Newell and Simon disagreed with my contention that the creative process and problem solving are distinct phenomena although they have an overlapping set. They regarded (at least at the time) creative activity as being a special class (i.e., a subset) of problem solving activity (Newell, Shaw & Simon, 1962, p. 66).

[26] Heuristics means 'rules of thumb'.

[27] Cryptarithmetic is a problem like the following:
DONALD (D=5)
+ GERALD
= ROBERT
Each letter stands for a digit from 0-9.

[28] The IP theories of Ohlsson (1992) and Knoblich, Ohlsson, Haider & Rhenius (1999) are further examples of creativity theories following Newell and Simon's problem-space theory. They will not be discussed here. Klahr & Dunbar (1988) has also developed a theory of scientific reasoning as a search in two problem spaces: an hypothesis space and an experiment space. By focussing on scientific discovery as a dual search this theory avoids viewing scientific discovery as a purely mental search, and thus escapes some of the criticism that can be directed against most IP theories. It will also not be discussed here.

[29] Becker (1994) argues that this difference between 'finding' and 'creating' something should be analyzed into two paradigmatic different kinds of creativity he calls 'discovery' and 'creation'.

[30] For a selection of philosophical views on the relation between the possible and the actual, see Loux (1979).

[31] For example, one of the most utilized creativity tests, the Torrance Test of Creative Thinking (Torrance, 1977, 1988), includes a subscale asking the subject to 'just suppose…' that something happens, and then list what could or would come next. This subscale obviously asks the subject to stretch his or hers knowledge of the world into the future, into a space of possibilities, to see what would happen if… Other subscales of the TTCT asks the subject to list possible product improvements, provide unusual uses for objects, ask unusual questions of objects, or guess causes etc. All these subscales have elements of asking the subject to list possible alternative states to the present one.

[32] By arguing that objects exist over time, and that possible properties are 'objective, although not-yet-existing', my position is close to the Activity Theory position of Leontjev (1977). Leontjev placed a heavy emphasis on the objectivity of the history of objects. Indeed, societal meanings of objects are viewed as forms of praxis that are an objective part of objects in the world (although they have to be appropriated through other human beings). But whereas Leontjev focussed on what the prior history has been, and how this is an objective part of objects, I focus on what could have been, and could be in the future, thereby extending the ontology of objects to include it's possibilities.

[33] The difference between fantasy and creativity is thus determined by whether the process is directed at distinguishing accurately between the possible and the impossible, in order to make a possible product. It is not, as certain theorists have argued, a difference that can be accounted for merely by *the number* of constraints upheld or dropped in the process. For example Glenberg (1997) writes:

"Once we have managed to suppress the environments control over conceptualization, a type of tradeoff will determine whether our thoughts are viewed as childish daydreaming or creative. The tradeoff is between suppression and maintenance of important constraints on action. Suppressing all constraints on action leads to childlike or dreamlike thoughts, such as contemplating the possibility of flying or moving back through time. Because many physical constraints cannot be overcome in reality, these thought have little practical import." (Glenberg, 1997, p. 518).

Although Glenberg is quite right in arguing that many physical constraints cannot be overcome in reality, he is not right in arguing that it is the *number of constraints* dropped that determine whether thoughts are fantasy or creative. Rather it is the intention of creating (by including in the process an evaluation of whether or not the result is possible or impossible), and whether the dropping of constraints increase the adequacy of the subjective representation of the objective possibilities and impossibilities.

[34] It is quite interesting to note the consequences of the fact that impossibilities are usually acting as ground in our thinking about the world. One of the consequences is that once we have found a possible exemplar of a kind, we tend to forget the specifics that makes the exemplar possible. We then regard the entire kind as being possible, instead of including the specifics in the kind, so as to say, that the kind needs to include such and such specifics in order to be possible. For example the possibility of 'a flying machine that can carry people in it': Today we call them airplanes and helicopters and know for a fact that they are possible – even though most people would have deemed them impossible 150 yeas ago. The problem with looking at it this way is that it seemingly ignores all the problems with making airplanes, and the impossible exemplars built that could not fly! Obviously a flying machine needs to be of a very specific kind, otherwise it will not fly! But in making the general statement that 'flying machines are possible' the needed specifics of the kind are ignored, and the entire kind is deemed possible. Well, the kind *is* possible under certain conditions, but the kind is just as certainly *impossible* under a different and insufficient set of specifics. The initially failing exemplars of airplanes built by the Wright brothers would fail today as well, even though we regard the kind 'flying machines' as possible. Perhaps this tendency to as-

cribe 'possible' to the entire kind, without regards of the needed specifics is a tendency derived from optimism about the future. In 1962 the science fiction writer Arthur C. Clarke expressed it this way: "When a distinguished but elderly scientist states that something is possible, he is almost certainly right. When he states that something is impossible, he is very probably wrong". Clarke here clearly makes the common sensical mistake of regarding an entire kind as possible, when just one exemplar proves to be possible, while forgetting that the exemplar may have had a whole range of needed specifics to work! Clearly the correct way to put it would be to regard the kind as possible under certain conditions and specifics, but impossible under others. What Clarke is trying to say is, however, that we create and get smarter, and an initial overgeneralization of what can and cannot be done, can be qualified by later research, so as to specify the conditions under which something is possible and impossible. Laying bare the boundary between the possible and the impossible is what creativity is most essentially about.

[35] Here we see clearly the distinction between the kind of realism used in the present thesis, opposed to the naive realism used by e.g., Gibson (1979/1986). As Mammen (1994) has argued: Gibson is a positivist in the original meaning of the term, i.e., that he reduces knowing to the positively present, while ignoring thinking about that which is not positively present. Here my position is closer to Hegel, in that I also regard what is *not* positively present (i.e., the negative aspect of thinking), in recognizing that possibilities and impossibilities are objective, although not-yet-existing. The explanation of creativity requires the acknowledgement of the human ability to think in terms of objective although not-yet-existing possibilities and impossibilities.

[36] Translated from the Danish: "Sker der nu det, at eleven går i stå (og det ses minsandten meget tit), kan eleven få den tanke, at der mangler informationer, og give sig til at opsøge informationer, som kan vise sig at være nyttige. Når denne process starter, ved eleven endnu ikke præcist, hvilke informationer det er relevant at søge efter. Det forhindrer dog ikke søgningen, og eleven er således *spontant* intentionelt rettet mod materiale, som endnu ikke er tilgængeligt i situationen. Eleven tilvejebringer (søger efter) ikke-percipertbart materiale. […] Eleven søger efter noget uden at vide hvad det er, der søges efter. Alligevel er det muligt at finde det, man ikke vidste hvad var." (Bang, 2000, p. 31).

[37] As the reader will recall, a difference between learning and the kind of creativity I am dealing with (i.e., 'level 4 creativity' – see part II), is that the subject has to stretch beyond, not only his own skills, but also the skills of all others to be creative (and, thus, cannot be creative *within* the Zone of Proximal Development, as defined by Vygotsky, 1978).

[38] Although Neisser writes that we are still able to pick up unanticipated information, he also writes: "Perceivers pick up only what they have schemata for, and nilly-willy ignore the rest." (Neisser, 1976, p. 80). However, this last quote is in connection with his arguments on anticipation, where he argues that attention is a positive process (i.e., positively picking, rather than negatively filtering out of information). As such, this last quote, it seems, should be seen in connection with the physiological limitations of humans (i.e., what humans as a species are prepared to direct attention towards), rather

than individual differences, and where the individual can direct his or her attention. So if the human (qua universal human being) is prepared to pick up a certain kind of information, then this information may be unanticipated (and even unattended to) and can still be picked up by the individual human (qua individual).

[39] There is a noteworthy exception to this where Neisser tries to extend his notion of the perceptual cycle to include what had been termed 'cognitive maps'. In a figure, where cognitive maps are incorporated into the perceptual cycle, Neisser includes in the extended *schemata* concept, the "…cognitive maps of the world *and its possibilities*" (Neisser, 1976, p. 112, my bold). However, it is extremely unclear exactly what these possibilities are, as it is not a point elaborated on in the chapter. Neisser does not seem to incorporate the possibility concept into any of his thoughts on schemata and the cognitive maps. And further, it is noteworthy that it is under the heading of the *schemata* concept that 'possibilities' are included, rather than under the 'actual world'. Here it could be argued that Neisser is repeating the IP theories view of possibilities as being a completely internal phenomenon.

[40] Mammen (1989) refers to this distinction as 'real-abstraction' vs. 'thought abstraction'

[41] It could be hypothesized that the ability to perform simulations (such as those in creative thinking) are derived and developed from physical action in phylogeny. This follows the Activity Theory tradition in assuming an evolutionary development of action (e.g., Leontjev, 1977). The function of separating simulations from physical actions could have been to increase effectiveness of the actions (e.g., number of variations) or reduce risk with performing actions on the actual world. A similar development (from physical action to simulation) may occur in ontogeny (Barsalou, 1999; Vygotsky, 1978). I will not pursue these hypotheses any further in this thesis, as they are not the main focus hereof.

[42] Primary Darwinism refers to Darwin's original theory of biological evolution, along with the many scientific developments extending from this theory to explain the diverse features of living organisms (e.g., sexual selection and sociobiology). The secondary form of Darwinism, in contrast, has to do with the explanation of other phenomena not directly related to biological evolution. Darwinian theory provides the bases for describing analogous processes that operate outside the sphere of biological evolution proper (e.g., various cultural, behavioral and biological phenomena). (Simonton, 1999c, pp. 8-20).

[43] The notion of the 'blindness' or 'randomness' of the variations has become subject of a major dispute in the creativity research domain. While some argue for 'sighted' or 'intelligent' variations, Campbell and Simonton argue that they are blind or random. For further discussions see e.g., the discussions in Psychological Inquiry (Simonton, 1999), or the discussion in Journal of Creative Behavior (Simonton, 1998; Sternberg, 1998; Perkins, 1998; Cziko, 1998).

[44] At a theoretical level Finke (1995) called for the study of *creative realism*, implying a *structural connectedness* between a variation and it's antecedents. He argued that the future of creative cognition lies in discovering the connective paths between variations, and where they came from, along with other questions that secure a creative realism (i.e., ideas that show imaginative divergence, while being structurally connected to realistic issues and concepts). Creative realism should be seen in opposition to other kinds of variations (conservative realism; creative idealism; conservative idealism). Finke's (1995) two dimensions (creative-conservative and realistic-idealistic) closely resemble the two criteria I have argued for in the definition of creativity (novelty and usefulness), and in arguing that creative realism rather than the others kinds of variations should be studied in creativity research, his theory seems to be in accord with the present thesis.

[45] Translated from the Danish: "Enkelttingens identitet med sig selv og de genetiske forbindelser angiver nogle objektive realiteter, en objektiv struktur af ubrudte forbindelseslinier over tiden, som ikke kan reduceres til identitet af en nok så lang opremsning af nok så specielle eller særegne egenskaber. 'Det enkelte' som filosofisk kategori kan ikke opløses i et produkt af almenheder eller særheder "(Mammen, 1983, p. 193).

[46] Translated from the Danish: "Den første er en kategorial betingelse: Nemlig overhovedet at erkende forskellen mellem en genstands identitet med sig selv (numerisk eller materiel identitet) og dens identitet med andre genstande i en eller flere henseender (kvalitativ identitet, formel identitet, lighed eller ækvivalens).
Den anden betingelse er en praktisk betingelse: Nemlig at råde over de tilstrækkelige kognitive midler til i praksis at træffe korrekte afgørelser vedrørende genstandens (numeriske) identitet." (Mammen, 1983, pp. 268-269).

[47] Translated from the Danish: "…en forståelse af, at tingene ikke blot er defineret ved deres allerede erkendte universelle egenskaber, men er bestemt også derudover. Der kan derved dannes begreb om en genstands endnu ikke erkendte egenskaber, og et begreb om en genstands forandring under forandrede omstændigheder.
Genstanden kan nu i tanken løsrives relativt fra enhver af sine almene, begrebslige bestemmelser og anskues under andre bestemmelser uden derved at miste sin identitet, og uden at tanken mister sin mulighed for at vende tilbage til udgangspunktet.
Ved at forstås som konkret kan genstanden også i tanken løsrives relativt fra enhver af sine forbindelser, abstraheres fra sin samfundsmæssige betydning, for dernæst at blive genindsat i sine forbindelser." (Mammen, 1983, p. 271).

[48] Translated from the Danish: "Vores begreber er subjektive genspejlinger af klasser af genstande, der både genspejler dem som konkrete enkeltting, i deres forbindelser og ligheder.
Vi ved altså, at begrebernes indhold og omfang er gensidigt betingede, og at det ene ikke i absolut forstand går forud for det andet.
I vores gradvise vidensmæssige tilegnelse af naturens og samfundets mangfoldighed og lovmæssigheder, er vi også nødt til hele tiden at lade vores afgrænsninger af indhold og omfang vekselvirke. En forøget indsigt i indhold og i den lovmæssige sammenhæng mellem fællestræk fører til nye afgrænsninger af omfang; og nyskabelser, opdagelser

eller inddragelse af nye eksempler fører til justeringer af klassernes indhold." (Mammen, 1983, p. 128).

[49] Simulating a concept's referent need not be done only in their absence, but is an inherent part of thinking about them in their presence as well. In the presence of a referent which a subject wishes to turn into something else, he will simulate variations of that present referent. This is a notion that has extensive implication for cognitive research. In so far as eye-movements is related to simulations, the notion is supported by some eye-movement studies that have shown that subjects asked to imagine or recall objects performs saccades similar to saccades performed, had the object been present (Brandt & Stark, 1997). Spivey & Geng (2001) found that subjects asked to imagine objects performed oculomotor search of the external (blank) space, which could easily be interpreted as mental simulation. Similarly, it could be argued that chess players' eye-movements on the present chess board can be seen as simulations of future chess positions, rather than simply the examination of the present state.

[50] The philosophical reader may recoqnize a critique of the principle of induction in psychology. David Hume argued that there are two problems with induction: a logical and a psychological one.
"(a) The logical problem: *Are we rationally justified in reasoning from repeated instances of which we have had experience to instances of which we have had no experience?* Hume's unrelenting answer is: No, we are not justified, however great the number of repetitions may be. And he added that it did not make the slightest difference if, in this problem, we ask for the justification not of *certain* belief, but of *probable* belief. Instances of which we have had experience do not allow us to reason or argue about the *probability* of instances of which we have had no experience, any more than to the *certainty*, of such instances.
(b) The following psychological question:
How is it that nevertheless all reasonable people expect and believe that instances of which they have had no experience will conform to those of which they have had experience? Or in other words, why do we all have *expectations*, and why do we hold on to them with such great *confidence*, or such strong belief?" (Popper, 1974, p. 1018).

Hume's reply to the psychological problem was that we are conditioned by repetition, by custom or habit. Much of cognitive psychology still revolves around documenting ways subjects performs inductions from typical or similar cases to new cases, as we have seen above. However, such thinking will only tell us (however illogical and unreasonable and uncertain as it may be) of the probable and likely events and entities of the world. This is only a small proportion of the possibilities of the world. I am interested in how we know about the BROAD spectrum of possibilities. Of events that have not yet happened or entities not yet created. The knowledge of that kind of possibility requires something more than mere induction from similarities and association. Here we need to learn and generalize and simulate on the basis of the single (a-typical and even unlikely) case – despite the uncertainties in doing so.
What we can learn from the a-typical and unlikely event is that such an event is in fact objectively POSSIBLE (rather than impossible), and it is that knowledge we (however uncertain and unreasonable) use in our creative attempts to re-combine and simulate

variations of the world. It is knowledge of the possibility or impossibility of the singular (and not so much the probability of the common) we need to generate useful novelty. This 'context of discovery' must then be followed by a 'context of justification' where we test, falsify and attempt to realize our simulated variation – much as Popper argued.

[51] As Csikszentmihalvyi (1988;1990) has noted, and as I argued in part II, knowledge about what the evaluative criteria used by the field in estimating the level of creativity in products can constrain the simulated variations, just as can knowledge of the domain itself. Expectations about what external evaluators will deem novel and useful can thus constrain simulated variations.

[52] Inspiration to such an examination of the objective aspects of 'structural similarities' may come from TRIZ. TRIZ is the Russian acronym for 'Theory of Inventive Problem Solving', and is a Russian approach to invention by analogy (see Altshuller, 1994; Terninko, Zusman & Zlotin, 1998). Genrich Altshuller studied patents primarily taken out in the domains of chemistry and mechanics, and selected a large number (exceeding 40.000) which he considered to be the most effective solutions. These he further structured, so that for any new inventive problem encountered, analogous solutions could be readily accessed through TRIZ.

[53] Such a methodology is has recently been developed by Kevin Dunbar and his associates (e.g., Dunbar, 2000; Dunbar, 2001b). The methodology is termed the in vivo-in vitro approach, which refers to the fact that the methodology seeks to examine the same cognitive phenomenon both in the cognitive laboratory, and in ecologically valid studies in the real-world. The studies examine cognitive processes as they occur 'live' in the real-world and the laboratory. Dunbar has used this novel approach to study the cognitive mechanisms operating in scientific discovery (in particular molecular biology), for example analogy (Blanchette & Dunbar, 2000; Dunbar, 1995; 1997; Dunbar & Blanchette, 2001; Schunn & Dunbar, 1996); attention to and use of unexpected scientific findings (Dunbar, 2000); and distributed reasoning. Extending this methodology to other areas of creativity is likely to uncover some of the cognitive mechanisms operating during creative search, and shows great promise.

REFERENCE LIST

Altshuller, G. (1994). *And suddenly the inventor appeared*. Worcester, MA: Technical Innovation Center, Inc.

Amabile, T. M., Conti, R., Coon, H., Lazenby, J., & Herron, M. (1996). Assessing the work environment for creativity. *Academy of Management Journal, 39(5),* 1154-1184.

Bang, J. (2000). Et økologisk begreb om tænkning. *Bulletin fra Forum for Antropologisk Psykologi*, *8,* 6-42. Aarhus: Psykologisk Institut, Aarhus Universitet.

Barsalou, L. W. & Prinz, J. J. (1997). Mundane creativity in perceptual symbol systems. In T. B. Ward, S. M. Smith, & J. Vaid (eds.), *Creative thought: An investigation of conceptual structures and processes*. Washington D. C.: American Psychological Association.

Barsalou, L. W. (1999). Perceptual symbol systems. *Behavioral and Brain Sciences*, *22*, 577-660.

Barsalou, L. W., Huttenlocher, J., & Lamberts, K. (1998). Basing categorization on individuals and events. *Cognitive Psychology*, *36,* 203-272.

Becker, G. M. (1994). Making it or finding it. In M. P. Shaw & M. A. Runco (eds.), *Creativity and affect*. Norwood, N. J.: Ablex Publishing Corporation.

Blanchette, I. & Dunbar, K. (2000). How analogies are generated: The roles of structural and superficial similarity. *Memory and Cognition, 28:* 108-124.

Boden, M. A. (1991). *The creative mind: Myths and mechanisms*. London: Basicbooks.

Boden, M. A. (1994a). What is creativity? In M. A. Boden (ed.), *Dimensions of creativity*. London: Bradford Book.

Boden, M. A. (1994b). Précis of the creative mind: Myths and mechanisms. *Behavioral and Brain Sciences, 17*, 519-570.

Boden, M. A. (1999). Computer models of creativity. In R. J. Sternberg (1999), *Handbook of creativity*. Cambridge: Cambridge University Press.

Boden, M. A. (2000). Computer models and creativity. *American Psychologist, 13(2)*, 72-76.

Bowers, K. S., Farvolden, P., & Mermigis, L. (1995). Intuitive antecedents of insight. In S. M. Smith, T. B. Ward & R. A. Finke (eds.), *The creative cognition approach*. Cambridge, MA: MIT Press.

Bowers, K. S., Regher, G., Balthazard, C., & Parker, K. (1990). Intuition in the context of discovery. *Cognitive Psychology, 22*, 72-110.

Brandt, S. A. & Stark, L. W. (1997). Spontaneous eye movements during visual imagery reflect the content of the visual scene. *Journal of Cognitive Neuroscience, 9:* 27-38.

Cacciari, C., Levorato, M. C., & Cicogna, P. (1997). Imagination at work: Conceptual and linguistic creativity in children. In T. B. Ward, S. M. Smith, & J. Vaid (eds.), *Creative thought: An investigation of conceptual structures and processes*. Washington D. C.: American Psychological Association.

Campbell, D. T. (1960). Blind variation and selective retention in creative thought as in other knowledge processes. *Psychological Review, 67*, 380-400.

Cheng, P. C. H. & Simon, H. A. (1995). Scientific discovery and creative reasoning with diagrams. In S. M. Smith, T. B. Ward & R. A. Finke (eds.), *The creative cognition approach*. Cambridge, Massachusetts: MIT Press.

Christensen, B. T. (1998). *Muligheden og umuligheden af kreativitet og fantasi i virksomhedsteorien*. [The possibility and impossibility of creativity and fantasy in Activity Theory]. Unpublished Bachelors Thesis. Available online at http://www.virksom.dk.

Cohen, L. M. & Ambrose, D. (1999). Adaptation and creativity. In M. A. Runco & S. R. Pritzker (eds.), *Encyclopedia of creativity*. San Diego: Academic Press.

Cohen, L. M. (1989). A continuum of adaptive creative behaviors. *Creativity Research Journal, 2*, 169-183

Cropley, A. J. (1999). Definitions of creativity. In M. A. Runco & S. R. Pritzker (eds.), *Encyclopedia of creativity*. San Diego: Academic Press.

Csikszentmihalyi, M (1988). Society, culture, and person: A systems view of creativity. In R. J. Sternberg (ed.), *The nature of creativity*. Cambridge: Cambridge University Press.

Csikszentmihalyi, M. (1990). The domain of creativity. In M. A. Runco & R. S. Albert (eds.), *Theories of creativity*. Newbury Park, CA: Sage Publ..

Csikszentmihalyi, M. (1996). *Creativity: Flow and the psychology of discovery and invention.* NY: Harper Perennial.

Csikszentmihalyi, M. & Sawyer, K. (1995). Creative insight: The social dimension of a solitary moment. In R. J. Sternberg & J. E. Davidson (eds.), *The nature of insight*. Massachusetts: Bradford Book.

Cziko, G. A. (1998). From blind to creative: In defense of Donald Campbell's selectionist theory of human creativity. *Journal of Creative Behavior, 38(3),* 192-209.

Davis, G. A. (1999). *Creativity is forever*. Fourth edition, revised printing. Dubuque, Iowa, USA: Kendall/Hunt Publishing Company.

Davydov, V. V. & Zinchenko, V. P. (1980). The principle of development in psychology. *Soviet Psychology, 20 (1),* 22-46.

Dawkins, R. (1989). *The selfish gene*. Oxford: Oxford University Press. (Original: 1976).

Dodds, R. & Smith, S. M. (1999). Fixation. In M. A. Runco & S. R. Pritzker (eds.), *Encyclopedia of creativity*. San Diego: Academic Press.

Dreistadt, R. (1969). The use of analogies and incubation in obtaining insights in creative problem solving. *Journal of Psychology, 71*, 159-175.

Dunbar, K. (1995). How scientists really reason: Scientific reasoning in real-world laboratories. In R.J.Sternberg & J. E. Davidson (Eds.), *The nature of insight.* (pp. 365-395). Cambridge, MA, US: The MIT Press.

Dunbar, K. (1997). How scientists think: On-line creativity and conceptual change in science. In T.B.Ward, S. M. Smith, & J. Vaid (Eds.), *Creative thought: An investigation of conceptual structures and processes.* (pp. 461-493). Washington, DC, US: American Psychological Association.

Dunbar, K. (2000). How scientists think in the real world: Implications for science education. *Journal of Applied Developmental Psychology, 21,* 49-58.

Dunbar, K. (2001a). The analogical paradox: Why analogy is so easy in naturalistic settings yet so difficult in the psychological laboratory. In D.Gentner, K. J. Holyoak, & B. N. Kokinov (Eds.), *The analogical mind: Perspectives from cognitive science.* (pp. 313-334). Cambridge, MA, US: The MIT Press.

Dunbar, K. (2001b). What scientific thinking reveals about the nature of cognition. In K.Crowley, C. D. Schunn, & T. Okada (Eds.), *Designing for science: Implications from everyday, classroom, and professional settings.* (pp. 115-140). Mahwah, N.J., US: Lawrence Erlbaum Associates,Inc.,Publishers.

Dunbar, K. & Blanchette, I. (2001). The invivo/invitro approach to cognition: the case of analogy. *Trends in Cognitive Sciences, 5,* 334-339.

Dunker, K. (1972). *On problem-solving*. (Orig: 1945).Westport, Connetticut, USA: Greenwood Press.

Ekvall, G. (1996). Organizational climate for creativity and innovation. *European Journal of Work and Organizational Psychology, 5*, 105-123.

Engelsted, N. (1989). *Personlighedens almene grundlag: En teoretisk ekskursion i psykens historie*. Aarhus: Aarhus Universitetsforlag.

Engelsted, N. (1994). Floden og svømmeren eller hvad psykologi egentlig drejer sig om? In J. Mammen & M. Hedegaard (eds.), *Virksomhedsteori i udvikling*. *Psykologisk skriftserie, 19 (1)*. Aarhus: Psykologisk Institut, Aarhus Universitet.

Engeström, Y. (1998). Den nærmeste udviklingszone som den basale kategori i pædagogisk psykologi. In M. Hermansen (ed.), *Fra Læringens Horisont - en antologi*. Århus: Klim. [Reprinted from: Engeström, Y. (1986). The Zone of Proximal Development as the Basic Category of Educational Psychology. *The Quarterly Newsletter of the Laboratory of Comparative Human Cognition, 8(1)*.]

Eysenck, M. W. & Keane, M. T. (1995). *Cognitive psychology. A student's handbook*. Hillsdale, USA: Lawrence Erlbaum Associates, Publ.

Feldman, D. H., Csikszentmihalyi, M., & Gardner, H. (1994). *Changing the world: A framework for the study of creativity*. Westport, CT, US: Praeger Publishers/Greenwood Publishing Group, Inc.

Fetzer, J. H. (1994). Creative thinking presupposes the capacity for thought. [Comment on: Boden, M. A. (1994b). Précis of the creative mind: Myths and mechanisms. Behavioral and Brain Sciences, 17, 519-531.] *Behavioral and Brain Sciences, 17*, 539-540.

Finke, R. A. (1995). Creative realism. In S. M. Smith, T. B. Ward, & R. A. Finke (eds.), *The creative cognition approach*. Cambridge, MA.: MIT Press.

Finke, R. A. (1997). Mental imagery and visual creativity. In M. A. Runco (ed.), *The creativity research handbook, vol. 1*. Cresskill, NJ: Hampton Press.

Finke, R. A., Ward, T. B. & Smith, S. M. (1992). *Creative cognition: Theory, research, and applications*. London: Bradford Book.

Frederickson, N., Evans, F. R. & Ward, W. C. (1975). Development of provinsional criteria for the study of scientific creativity. *Gifted Child Quarterly, 19*, 60-65

Freska, C. Barkowsky, T., & Klippel, A. (1999). Spatial symbol systems and spatial cognition: A computer science perspective on perception-based symbol processing. [Comment on: Barsalou, L. W. (1999): Perceptual symbol systems]. *Behavioral and Brain Sciences, vol. 22*, 616-17.

Gardner, H. (1987). *The mind's new science*. USA: Basicbooks

Gardner, H. (1999). Was Darwin's creativity Darwinian? *Psychological Inquiry, 10(4),* 338-339.

Getzels, J. W. & Csikszentmihalyi, M. (1976). *The creative vision*. New York: Wiley.

Ghiselin, B. (1952). *The creative process. A symposium*. New York: Mentor Books.

Gibson, J. J. (1986). *The ecological approach to visual perception*. (orig. 1979). Hillsdale, N. J. : Lawrence Erlbaum Assiciates, Inc., Publ.

Gick, M. L. & Lockhart, R. S. (1995). Cognitive and affective components of insight. In Sternberg, R. J. & Davidson, J. E. (eds.), *The nature of insight*. London: Bradford Book.

Glenberg, A. M. (1997). Mental models, space, and embodied cognition. In T. B. Ward, S. M. Smith, & J. Vaid (eds.), *Creative thought: An investigation of conceptual structures and processes*. Washington D. C.: American Psychological Association.

Goldstone, R. L. & Barsalou, L. W. (1998). Reuniting perception and conception. *Cognition, 65*, 231-262.

Gruber, H. E. (1995). Insight and affect in the history of science. In R. J. Sternberg & J. E. Davidson (eds.), *The nature of insight*. Massachusetts: Bradford Book.

Guildford, J. P. (1962). Creativity: Its measurement and development. In S. J. Parnes & H. F. Harding (eds.), *A source book for creative thinking.* New York: Charles Scribner's Sons.

Harrington, D. M. (1990). The ecology of human creativity: A psychological perspective. In M. A. Runco & R. S. Albert (eds.), *Theories of creativity*. London: Sage

Hausman, C. R. (1984). *A discourse on novelty and creation*. Albany, N. Y., USA: State University of New York Press.

Hertz, M. (1999). Invention. In M. A. Runco & S. R. Pritzker (eds.), *Encyclopedia of creativity*. San Diego: Academic Press.

Holyoak, K. J. & Thagard, P. (1995). *Mental leaps. Analogy in creative thought*. Cambridge, MA: MIT Press.

Hoover, S. M. & Feldhausen, J. F. (1990). The scientific hypothesis formulation ability of gifted ninth-grade students. *Journal of Educational Psychology, 82*, 838-848

Isaak, M. I. & Just, M. A. (1995). Constraints on thinking in insight and invention. In R. J. Sternberg & J. E. Davidson (eds.), *The nature of insight*. London: Bradford Book.

Jausovec, N. (1994). *Flexible thinking: An explanation for individual differences in ability*. Cresskil, N. J.: Hampton Press.

Jausovec, N. & Bakracevic, K. (1995). What can heart rate tell us about the creative process? *Creativity Research Journal, 8(1),* 11-24

Jay, E. S. & Perkins, D. N. (1997). Problem finding: The search for mechanisms. In M. A. Runco (ed.), *The creativity research handbook, vol 1*. Cresskill, NJ: Hampton Press.

Johannessen, J.-A., Olsen, B., & Lumpkin, G. T. (2001). Innovation as newness: What is new, how new, and new to whom? *European Journal of Innovation Management, 4,* 20-31.

Kaplan, C. A., & Simon, H. A. (1990). In search of insight. *Cognitive psychology, 22*, 374-419.

Keane, M. T. (1988). *Analogical problem solving*. Chichester, England: Ellis Horwood LTD.

Klahr, D. & Dunbar, K. (1988). Dual space search during scientific reasoning. *Cognitive Science, 12,* 1-48.

Klix, F. (1980). *Erwachendes denken. Eine entwicklungsgeschichte der menschenliche Intelligenz*. Berlin: VEB Deutscher Verlag der Wissenshaften.

Klix, F. (1983). An evolutionary approach to cognitive processes and creativity in human being. In R. Groner, M. Groner & W. F. Bischof (eds.), *Methods of heuristics*. Hillsdale, N.J.: Lawrence Erlbaum Associates, Publ.

Knoblich, G., Ohlsson, S., Haider, H., & Rhenius, D. (1999). Constraint relaxation and chunk decomposition in insight problem solving. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 25:* 1534-1555.

Knoblich, G., Ohlsson, S. & Raney, G. (1999). Resolving impasses in problem solving: An eye movement study. In M. Hahn & S. C. Stoness (eds.), *Proceedings of the twenty first annual conference of the cognitive science society*. Mahwah, N.J.: Lawrence Erlbaum Associates, Publ.

Koestler, A. (1964). *The act of creation*. London: Penguin Group.

Kristjansen, N., Lunøe, N. & Visholm, S. (1979). *Det forsvundne subjekt - til kritikken af sovjetpsykologiens pædagogik*. København: Eget forlag.

Leontjev, A. N. (1977). *Problemer i det psykiskes udvikling*. København: Rhodos.

Loux, M. J. (ed.) (1979). *The possible and the actual: Readings in the metaphysics of modality*. Itchaca, N. Y: Cornell University Press.

Maier, N. R. F. (1931). Reasoning in humans: II. The solution of a problem and its appearance in consciousnes. *Journal of Comparative and Physiological Psychology, 12,* 181-194.

Mammen, J. (1983). *Den menneskelige sans - et essay om psykologiens genstandsområde*. København: Dansk Psykologisk Forlag

Mammen, J. (1986). Erkendelsen som Objektrelation. *Psyke & Logos, 7*, 178-202.

Mammen, J. (1989). The Relationship between subject and object from the perspective of Activity Theory. In N. Engelsted, L. Hem & J. Mam-

men (eds.), *Essays in general psychology. Seven danish contributions*. Århus: Aarhus University Press.

Mammen, J. (1993). The elements of psychology. In N. Engelsted, M. Hedegaard, B. Karpatschof & A. Mortensen (eds.), *The societal subject*. Århus: Aarhus University Press.

Mammen, J. (1994). En realistisk begrebsteori: Om forholdet mellem Virksomhedsteori og den Økologiske Kognitive psykologi. In J. Mammen & M. Hedegaard (eds), *Virksomhedsteori i udvikling. Psykologisk skriftserie, 19 (1).* Aarhus: Psykologisk Institut, Aarhus Universitet.

Mammen, J. (1998). Udvalgskategorier og logik eller Oberst Danckwardts og harens sørgelige skæbner. *Bulletin fra Forum for Antropologisk Psykologi, 4*, 44-62.

Mandel, D. R. & Lehman, D. R. (1996). Counterfactual Thinking and ascriptions of cause and preventability. *Journal of Personality and Social Psychology, 71 (3),* 450-463.

Martindale, C. (1999). Darwinian, Lamarckian, and rational creativity. *Psychological Inquiry, 10(4),* 340-342.

Mayer, R. E. (1995). The search for insight: Grappling with Gestallt psychology's unanswered questions. In R.J. Sternberg & J. E. Davidson (eds.), *The nature of insight*. London: Bradford Book.

Mayer, R. E. (1999a). Fifty years of creativity research. In R. J. Sternberg (ed.), *Handbook of creativity*. New York: Cambridge University Press.

Mayer, R. E. (1999b). Problem solving. In M. A. Runco & S. R. Pritzker (eds.), *Encyclopedia of creativity*. San Diego: Academic Press.

Mednick, S. A. (1962). The associative basis of the creative process. *Psychological Review, 69*, 220-232.

Melcalfe, J. & Wiebe, D. (1987). Intuition in insight and noninsight problem solving. *Memory & Cognition, 15(3),* 238-246.

Metcalfe, J. (1986a). Feeling of knowing in memory and problem solving. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 12(2),* 288-294.

Metcalfe, J. (1986b). Premonitions of insight predict impending error. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 12(4)*, 623-634.

Mithen, S. (ed.) (1998). *Creativity in human evolution and prehistory*. London: Routledge.

Mooney, R. L. (1963). A conceptual model for integrating four approaches to the identification of creative talent. In C. W. Taylor & F. Barron (eds.), *Scientific creativity: Its recognition and development.* New York: Wiley & Sons.

Moore, M. T. (1994). The ecology of problem finding and teaching. In M. A. Runco (ed.), *Problem finding, problem solving, and creativity*. Norwood, N. J.: Ablex Publ. Company.

Neisser, U. (1976). *Cognition and reality*. New York: W. H. Freeman and Company.

Neisser, U. (1994). Multiple systems: A new approach to cognitive theory. *European Journal of Cognitive Psychology, 6(3),* 225-241.

Newell, A. & Simon, H. (1972). *Human problem solving*. Englewood Cliffe, NJ: Prentice Hall.

Newell, A., Shaw, J. C. & Simon, H. A. (1962). The process of creative thinking. In H. E. Gruber, G. Terrell & M. Wertheimer (eds.), *Contemporary approaches to creative thinking*. New York: Atherton Press.

Novick, L. R. (1988). Analogical transfer, problem similarity and expertise. *Journal of Experimental Psychology: Learning, Memory and Cognition, 14 (3),* 510-520.

Novick, L. R. (1990). Representational transfer in problem solving. *Psychological Science, 1(2),* 128-132.

O'Quin, K. & Besemer, S. P. (1999). The development, reliability, and validity of the revised Creative Product Semantic Scale. In G. J. Puccio & M. C. Murdock (eds.), *Creativity assessment – readings and resources*. N.Y. : Creative Education Foundation Press. [Adapted with permission from Creativity Research Journal, 1989, 2, 267-278]

Ohlsson, S. (1992). Information-processing explanations of insight and related phenomena. In M. Keane & K. Gilhooley (eds.), *Advances in the psychology of thinking*. London: Harvester Wheatsheaf.

Osborn, A. F. (1963). *Applied Imagination* (3rd ed.). New York: Scribners.

Patalano, A. L. & Seifert, C. M. (1994). Memory for impasses during problem solving. *Memory and Cognition, 22(2),* 234-242.

Patalano, A. L. & Seifert, C. M. (1997). Opportunistic planning: Being reminded of pending goals. *Cognitive Psychology, 34*, 1-36.

Perkins, D. N. (1981). *The mind's best work*. Cambridge: Harvard University Press.

Perkins, D. N. (1988). The possibility of invention. In R. J. Sternberg (ed.), *The nature of creativity*. Cambridge University Press.

Perkins, D. N. (1994). Creativity: Beyond the Darwinian paradigm. In M. A. Boden (ed.), *Dimensions of creativity*. London: Bradford Book.

Perkins, D. N. (1998). In the country of the blind. An appreciation of Donald Campbell's vision of creative thought. *Journal of Creative Behavior, 38(3),* 177-191.

Perkins, D. N. (2000). *Archimedies' bathtub. The art and logic of breakthrough thinking*. New York: WW. Norton Company.

Policastro, E. (1995). Creative intuitions: An integrative review. *Creativity Research Journal, 8*, 99-113.

Policastro, E. (1999). Intuition. In M. A. Runco & S. R. Pritzker (eds.), *Encyclopedia of creativity*. San Diego: Academic Press.

Popper, K. (1974). Replies to my critics. In P.A.Schilpp (Ed.), *The Philosophy of Karl Popper* (pp. 961-1200). La Salle, Ill, US: Open Court.

Posner, M. I. (1973). *Cognition: An introduction*. Glenview, Ilinois, US: Scott, Foresman & Co.

Reber, A. S. (1995). *Penguin Dictionary of Psychology* (2nd ed.). London: Penguin Books.

Reeves, L. M. & Weisberg, R. W. (1994). The role of content and abstract information in analogical transfer. *Psychological Bulletin, 115(3)*, 381-400.

Reitman, W. R. (1965). *Cognition and thought: An Information-Processing approach*. New York: John Wiley & Sons.

Rhodes, M. (1961). Analysis of creativity. *Phi Delta Kappan, 42*, 305-310.

Rochhausen, R. & Ilgenfritz, G. (1975). 'Schöpfertum' als Form der Wiederspiegelung. [Creation as a form of reflection]. *Deutsche Zeitschrift für Philosophie, 23 (2)*, 262-276.

Roese, N. J. & Olson, J. M. (1995). Counterfactual thinking: a critical overview. In N. J. Roese & J. M. Olson (eds.), *What might have been. The social psychology of counterfactual thinking*. Mahwah, N.J.: Lawrence Erlbaum Associates, Publ.

Roese, N. J. (1997). Counterfactual thinking. *Psychological Bulletin, 121(1),* 133-148.

Rogers, C. F. (1970). Towards a theory of creativity. In P. E. Vernon (ed.), *Creativity*. Middlesex, England: Penguin. [Reprinted from Rogers, C. F. (1954). Towards a theory of creativity. In ETC: A review of general semantics, vol. 11, pp. 249-260]

Rosch, E. (1978). Principles of categorization. In E. Rosch & B. B. Lloyd (eds.), *Cognition and categorization*. Hillsdale, N. J., USA: Lawrence Erlbaum Associates, Publ.

Rothenberg, A. (1979). *The emerging goddess*. Chicago: University of Chicago Press.

Runco, M. A. & Chand, I. (1994). Problem finding, evaluative thinking, and creativity. In M. A. Runco (ed.), *Problem finding, problem solving, and creativity*. Norwood, N. J.: Ablex Publ. Company.

Runco, M. A. (1999). Misjudgement. In M. A. Runco & S. R. Pritzker (eds.), *Encyclopedia of creativity*. San Diego: Academic Press.

Russ, S. W. (1993). *Affect and creativity: The role of affect and play in the creative process*. Hillsdale, N. J.: Lawrence Erlbaum Associates, Publ.

Schooler, J. W. & Dougal, S. (1999). Why creativity is not like the proverbial typing monkey. *Psychological Inquiry, 10(4),* 351-357.

Schooler, J. W., Fallshore, M. & Fiore, S. M. (1995). Epilogue: Putting insight into perspective. In R. J. Sternberg & J. E. Davidson (eds.), *The nature of insight*. London: Bradford Book.

Schooler, J. W. & Melcher, J. (1995). The ineffability of insight. In S. M. Smith, T. B. Ward & R. A. Finke (eds.), *The creative cognition approach*. Cambridge, Mass: MIT Press.

Schunn, C. D. & Dunbar, K. (1996). Priming, Analogy, & Awareness in complex reasoning. *Memory and Cognition, 24,* 271-284.

Seelau, E. P., Seelau, S. M., Wells, G.L. & Windschitl, P. D. (1995). Counterfactual constraints. In N. J. Roese & J. M. Olson (eds.), *What might have been: The social psychology of counterfactual thinking*. Mahwah, N.J. : Lawrence Erlbaum Associates, Publ.

Seifert, C. M., Meyer, D. E., Davidson, N., Patalano, A. L. & Yaniv, I. (1995). Demystification of cognitive insight: Opportunistic Assimilation and the Prepared-mind perspective. In R. J. Sternberg & J. E. Davidson (eds.), *The nature of insight*. London: Bradford Book.

Seifert, C. M. & Patalano, A. J. (1991). Memory for interrupted tasks: The Zeigarnik effect revisited. In *Proceedings of the Thirteenth Annual Conference of the Cognitive Science Society*. Hillsdale, N.J.: Lawrence Erlbaum Publ.

Shaw, M. P. (1994). Affective components of scientific creativity. In M. P. Shaw & M. A. Runco (eds.), *Creativity and affect*. Norwood, N. J.: Ablex Publishing Corporation.

Sherman, S. J. & McConnell, A. R. (1995). Dysfunctional implications of counterfactual thinking: When alternatives to reality fail us. In N. J. Roese & J. M. Olson (eds.), *What might have been. The social psychology of counterfactual thinking*. Mahwah, N.J.: Lawrence Erlbaum Associates, Publ.

Simonton, D. K. (1988). Creativity, leadership, and chance. In R. J. Sternberg (ed.), *The nature of creativity*. Cambridge: Cambridge University Press.

Simonton, D. K. (1995). Foresight in insight? A Darwinian answer. In R. J. Sternberg & J. E. Davidson (eds.), *The nature of insight*. London: Bradford Book.

Simonton, D. K. (1998). Donald Campbell's model of the creative process: Creativity as blind variation and selective retention. *Journal of Creative Behavior, 38(3),* 153-158.

Simonton, D. K. (1999a). Creativity as blind variation and selective retention: Is the creative process Darwinian? *Psychological Inquiry, 10(4),* 309-328.

Simonton, D. K. (1999b). The continued evolution of creative Darwinism. *Psychological Inquiry, 10(4),* 362-367.

Simonton, D. K. (1999c). *Origins of genius*. New York: Oxford University Press.

Smith, G. J. W. & Amnér, G. (1997). Creativity and perception. In M. A. Runco (ed.), *The creativity research handbook, vol 1*. Cresskill, N. J.: Hampton Press.

Smith, S. M. (1995a). Getting into and out of mental ruts: A theory of fixation, incubation, and insight. In R. J. Sternberg & J. E. Davidson (eds.), *The nature of insight.* London: Bradford Book.

Smith, S. M. (1995b). Getting into and out of mental ruts: A theory of fixation, incubation, and insight. In R.J.Sternberg & J. E. Davidson (Eds.),

The nature of insight. (pp. 229-251). Cambridge, MA, US: The MIT Press.

Smith, S. M., Ward, T. B., & Finke, R. A. (1995). Principles, paradoxes and prospects for the future of creative cognition. In S. M. Smith, T. B. Ward, & R. A. Finke (eds.), *The creative cognition approach*. Cambridge: Bradford Book.

Smith, S. M. & Blankenship, S. E. (1991). Incubation and the persistence of fixation in problem solving. *American Journal of Psychology, 104,* 61-87.

Smith, S. M. & Dodds, R. (1999). Incubation. In M. A. Runco & S. R. Pritzker (eds.), *Encyclopedia of creativity*. San Diego: Academic Press.

Solomon, K. O., & Barsalou, L. W. (2001, under review). *Grounding concepts in percptual simulation: II. Evidence from property verification*. (Available online at

http://userwww.service.emory.edu/~barsalou/Publications/online.html

Spivey, M. J. & Geng, J. J. (2001). Oculomotor mechanisms activated by imagery and memory: Eye movements to absent objects. *Psychological Research/Psychologische Forschung, 65:* 235-241.

Sternberg, R. J. & Davidson, J. E. (1999). Insight. In M. A. Runco & S. R. Pritzker (eds.), *Encyclopedia of creativity*. San Diego: Academic Press.

Sternberg, R. J. (1998). Cognitive mechanisms in human creativity: Is variation blind or sighted? *Journal of Creative Behavior, 32(3),* 159-176.

Terninko, J., Zusman, A. & Zlotin, B. (1998). *Systematic Innovation: An introduction to TRIZ*. Boca Raton: St. Lucie Press.

Torrance, E. P. (1977). *Creativity in the classroom*. Washington D.C.: National Education Association.

Torrance, E. P. (1988). The nature of creativity as manifest in its testing. In R. J. Sternberg (ed.), *The nature of creativity*. New York: Cambridge University Press.

Treffinger, D. J. (1996). *Dimensions of creativity. Idea Capsule, report number 9004.* Buffalo, N .Y.: Center for Creative Learning. Unpublished.

Vygotskij, L.S. (1995). *Fantasi och kreativitet i barndomen* [Fantasy and creativity in childhood]. Göteborg: Daidalos.

Vygotsky, L. S. (1978). *Mind in society - The development of higher psychological processes*. London: Harvard University Press

Wallas, G. (1926). *The art of thought*. London: Jonathan Cape

Ward, T. B. (1994). Structured imagination: The role of category structure in exemplar generation. *Cognitive Psychology, 27*, 1-40.

Ward, T. B. (1995). What's old about new ideas? In S. M. Smith, T. B. Ward, & R. A. Finke (eds.), *The creative cognition approach*. Cambridge, MA.: MIT Press.

Ward, T. B., Smith, S. M., & Finke, R. A. (1999). Creative cognition. In R. J. Sternberg (ed.), *Handbook of creativity*. Cambridge: Cambridge University Press.

Ward, T. B., Smith, S. M., & Vaid, J. (1997). Conceptual structures and processes in creative thought. In T. B. Ward, S. M. Smith, & J. Vaid (eds.), *Creative thought: An investigation of conceptual structures and processes*. Washington D. C.: American Psychological Association.

Weisberg, R. W. (1995). Prolegomena to theories of insight in problem solving: A taxonomy of problems. In R. J. Sternberg & J. E. Davidson (eds.), *The nature of insight*. London: Bradford Book.

Wu, L. L., & Barsalou, L. W. (2001- Under review). *Grounding concepts in perceptual simulation: I. Evidence from property generation.* (Available online at

http://userwww.service.emory.edu/~barsalou/Publications/online.html)