10 *Creative Cognition*

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It will come as no surprise to readers of this volume that humans are an enormously creative species. In a relatively short span of time, geologically speaking, we have gone from fashioning rocks into our first primitive tools to building spacecraft that allow us to retrieve rocks from other planets. Many other species use implements, and some even modify found objects to improve their utility, but as far as we can determine, none other than humans have built upon those tool-making skills to reach beyond the grip of Earth's gravity. There really is something uniquely generative about human cognition.

A question that naturally arises in considering human accomplishment is the extent to which it springs from the singular efforts of a few individuals whose minds work in special and mysterious ways versus the more distributed efforts of the vast bulk of humanity whose minds all work in roughly the same, plainly generative ways. Is cumulative creative progress the province of a small set of geniuses or should the glory be spread more broadly?

We do not pretend to have the answer to this question in its grandest sense, but we do have the perspective that the capacity for creative thought is the rule rather than the exception in human cognitive functioning. We claim that (a) the hallmark of *normative* human cognition is its generative capacity to move beyond discrete stored experiences, (b) the processes that underlie this generativity are open to rigorous experimental investigation, and (c) creative accomplishments, from the most mundane to the most extraordinary, are based on those ordinary mental processes that, at least in principle, are observable. These assumptions form the cornerstone of the *creative cognition* approach to understanding human creativity (Finke, Ward, & Smith, 1992; Smith, Ward, & Finke, 1995), which is the focus of the present chapter.

Creative cognition is a natural extension of its parent discipline, cognitive psychology, and it has two major goals. The first is to advance the scientific understanding of creativity by adapting the concepts, theories, methods, and frameworks of mainstream cognitive psychology to the rigorous study and precise characterization of the fundamental cognitive operations that produce creative and noncreative thought. Given the striking generativity of the human mind, there is an equally striking dearth of exactly these sorts of research efforts. Creative cognition seeks to fill the void.

The second goal is to extend the scientific understanding of cognition in general by conducting experimental observations of the cognitive processes that operate when people are engaged in plainly generative tasks. Most research in cognition has examined performance in largely receptive tasks rather than explicitly generative situations, and since generative activities comprise a major portion of human mental functioning, we are missing crucial pieces of the cognitive puzzle.

In the sections that follow we highlight the striking generativity of ordinary human cognition, elaborate on the creative cognition approach, and give representative examples of research that further the goals of creative cognition. We conclude with some observations about how creative cognition can help to resolve some long-standing controversies concerning creativity.

THE NORMATIVE NATURE OF HUMAN CREATIVITY

A commonly held belief about creativity is that it is limited to a certain class of gifted or specially talented people. By this view, only a minority are capable of genuine creative thinking (i.e., "creative geniuses"), and thus creativity has little bearing on the everyday cognitive activities of the general population. A corollary of this argument is that geniuses use cognitive processes that are radically different from those employed by most individuals and that may not be accessible to the methods of cognitive science (e.g., Hershman & Lieb, 1988).

In contrast, creative cognition emphasizes the idea that creative capacity is an essential property of normative human cognition and that the relevant processes are open to investigation. Though they are not always recognized as such, examples of the fundamental nature of human generativity abound. Beyond the obvious examples of artistic, scientific, and technological advancement that are usually listed as instances of creativity, there is the subtler, but equally compelling generativity associated with everyday thought. One of the most widely noted examples of the latter is our undeniably flexible use of language through which we craft an infinite variety of novel constructions using a relatively small set of rules (Chomsky, 1972; Pinker, 1984), but there are many other examples as well. For instance, the mere fact that we readily construct a vast array of concrete and abstract concepts from an ongoing stream of otherwise discrete experiences implies a striking generative ability; concepts are creations. Further, our concepts need not be built up gradually from multiple exposures. We seem able to create goal-derived categories as we need them to satisfy the requirements of the immediate situation (Barsalou, 1983, 1991), and we can readily modify the ordinary typicality structure of concepts by adopting different perspectives (Barsalou, 1987). We also have the capacity to combine concepts to generate more complex ones, to map properties analogically across domains, to comprehend and produce figurative language, and to perform many other functions that go well beyond the information as directly and literally given.

Far from being unusual, these generative cognitive processes are commonplace and normative. They are part of the normative operating characteristics of ordinary minds. Further, because the novel outcomes produced by these generative processes serve important purposes, they satisfy the twin criteria of creative products: novelty and utility. More significantly, it is not just that these processes are, in themselves, creative; by the creative cognition view these processes also underlie creativity in all its forms, from the most prosaic to the most exalted, from the young child who refers to cold symptoms as a "soggy nose" to the development of the theory of relativity. Hence, to understand creativity fully, we must understand these processes fully.

To be sure, all is not flexibility. People, even those who achieve notable creative accomplishments, seem to have an equally pervasive tendency to be trapped by prior experiences and to carry over knowledge that would be better left behind (Ward, Finke, & Smith, 1995). Thus, an important goal of creative cognition is to specify the factors and processes that determine how much and which portions of existing knowledge will be applied to new situations, and the precise ways in which such information can either facilitate or inhibit creative functioning.

By noting that generativity is a salient aspect of normative cognitive functioning, we are not arguing against the existence of individual differences in creativity. There is no doubt that some individuals produce more creative outcomes than others, and a limited few achieve extreme levels of accomplishment (see, e.g., Eysenck, 1995; Simonton, 1994). How-

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ever, a central tenet of creative cognition is that those differences are understandable in terms of variations in the use of specifiable processes or combinations of processes, the intensity of application of such processes, the richness or flexibility of stored cognitive structures to which the processes are applied, the capacity of memory systems (such as working memory), and other known and observable fundamental cognitive principles (see Simonton, 1997; and Ward, Smith, & Vaid, 1997, for a counterpoint). Creative cognition explicitly rejects the notion that extraordinary forms of creativity are the products of minds that operate according to principles that are fundamentally different than those associated with normative cognition, and that are largely mysterious and unobservable. Creative cognition, being rooted in experimental cognitive psychology, makes heavy use of basic laboratory studies of "normative creativity" (see Ward et al., 1997), but with the firm belief in the continuity of cognitive functioning between mundane and extraordinary creative performance.

Creative cognition also acknowledges that a range of factors other than cognitive processes contribute to the likelihood of any individual generating a tangible product that would be judged to be "creative." These would include factors such as intrinsic motivation, situational contingencies, the timeliness of an idea, the value that different cultures place on innovation, and so on (see, e.g., Amabile, 1983; Basala, 1988; Lubart & Sternberg, 1995; Runco & Chand, 1995; Sternberg & Lubart, 1991). Nevertheless, we concentrate on mental operations largely because we assume that many noncognitive factors achieve their impacts by way of their influence on cognitive functioning. For instance, an individual who is intrinsically motivated to solve some difficult problem might be more likely than a less motivated individual to craft an ingenious solution, but the solution itself would emerge from the cognitive processes applied. Increased motivation would influence the tendency to engage in the rigorous application of analogical reasoning, mental model simulation, conceptual combination, or other basic processes, but it would be the variations in the processes themselves that would be the proximal cause of the difference in the quality of ideas that different thinkers would produce.

A HEURISTIC MODEL

An early general framework for the creative cognition approach was the Geneplore model of creative functioning (Finke et al., 1992), which was intended as a broadly descriptive, heuristic model rather than an explanatory theory of creativity. The central proposal was that many creative activities can be described in terms of an initial generation of candidate ideas or solutions followed by extensive exploration of those ideas. The initial ideas are sometimes described as "preinventive" in the sense that they are not complete plans for some new product, tested solutions to vexing problems, or accurate answers to difficult puzzles. Rather they may be an untested proposal or even a mere germ of an idea, but they hold some promise of yielding outcomes bearing the crucial birthmarks of creativity: originality and appropriateness. The Geneplore model assumes that, in most cases, one would alternate between generative and exploratory processes, refining the structures according to the demands or constraints of the particular task.

Processes, Structures, and Constraints

Examples of some common types of generative processes include the retrieval of existing structures from memory (Perkins, 1981; Smith, 1995; Ward, 1994, 1995), the formation of simple associations among those structures (Mednick, 1962) or combinations of them (Baughman & Mumford, 1995; Hampton, 1987; Murphy, 1988), the mental synthesis of new structures (Thompson & Klatzky, 1978), the mental transformation of existing structures into new forms (Shepard & Feng, 1972), analogical transfer of information from one domain to another (Gentner, 1989; Holyoak & Thagard, 1995; Novick, 1988), and categorical reduction, in which existing structures are conceptually reduced to more primitive constituents (Finke et al., 1992).

Exploratory processes can include the search for novel or desired attributes in the mental structures (Finke & Slayton, 1988), the search for metaphorical implications of the structures (Ortony, 1979), the search for potential functions of the structures (Finke, 1990), the evaluation of structures from different perspectives or within different contexts (Barsalou, 1987; Smith, 1979), the interpretation of structures as representing possible solutions to problems (Shepard, 1978), and the search for various practical or conceptual limitations that are suggested by the structures (Finke et al., 1992).

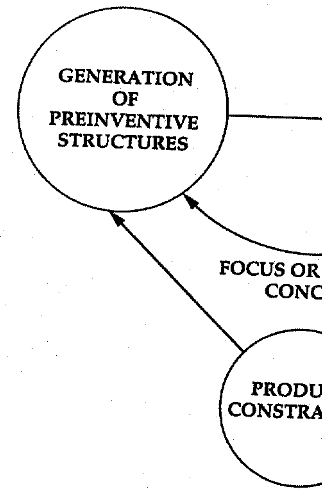
Creative thinking can thus be characterized in terms of how these various processes are employed or combined. For example, a writer might generate the beginnings of a new plot line by mentally combining familiar and exotic concepts, and then explore the ramifications of their combination in fleshing out the details of the story (see, e.g., Donaldson, 1992; Ward et al., 1995). Similarly, a scientist might generate candidate analogies designed to understand one domain in terms of another, and then rigorously scrutinize those analogies to test their descriptive or explanatory utility (e.g., Gentner et al., 1997). An inventor might mentally synthesize the parts of different objects, and then explore how the structure might be interpreted as representing a new invention or concept (Finke, 1990). Thus, by considering various types of generative and exploratory processes and their interactions, one can study diverse aspects of creativity within a broad, cognitive framework.

The Geneplore model also makes a distinction between the cognitive processes that are used in creative cognition and the types of mental structures on which they operate. For instance, Finke et al. (1992) proposed that a particular class of mental structures, called *preinventive structures,* play an important role in creative exploration and discovery. These structures can be thought of as internal precursors to the final, externalized products of a creative act. They can be generated with a particular goal in mind or simply as a vehicle for open-ended discovery. They can be complex and conceptually focused or simple and relatively ambiguous, depending on the situation or the requirements of the task.

Examples of preinventive structures include symbolic visual patterns and diagrams (Finke & Slayton, 1988), representations of three-dimensional objects and forms (Finke, 1990), mental blends of basic concepts (Hampton, 1987; Murphy, 1988), exemplars of novel or hypothetical categories (Ward, 1994, 1995), mental models representing physical or conceptual systems (Johnson-Laird, 1983), and verbal combinations that give rise to new associations and insights (Mednick, 1962). Which type of preinventive structure is most appropriate would depend on the nature of the task or problem.

The Geneplore model also assumes that constraints on the final product can be imposed on either the generative or exploratory phases at any time. This allows the model to be applied to many different types of situations and restrictions. For example, constraints on resources might limit the types of structures that could be generated, whereas constraints on practicality might limit the types of interpretations that are allowable. The ideal time for imposing these constraints is an empirical question that can be addressed in creative cognition research.

The relationship among generative processes, exploratory processes, preinventive structures, and constraints is presented in Figure 10.1. As depicted, the model assumes that the two distinct processing stages, generation and exploration, are used in most instances of creative cognition. In the generative stage, processes such as mental synthesis, mental transformation, and exemplar retrieval give rise to preinventive structures, which are then used or interpreted in the exploratory stage by examining their emergent properties and consid-



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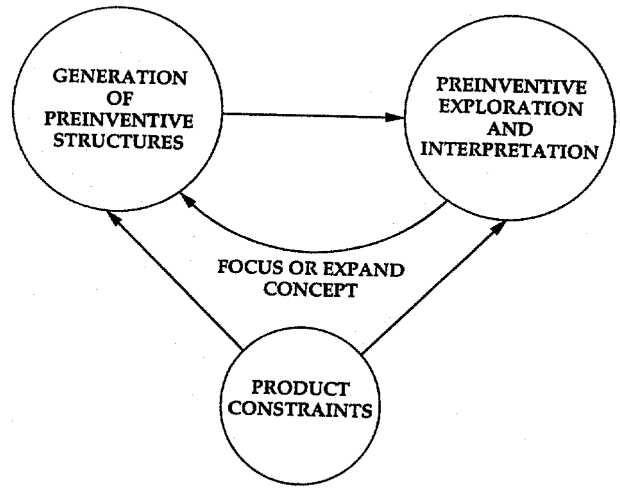


Figure 10.1. The basic structure of the Geneplore model. Preinventive structures are constructed during an initial, generative phase, and are interpreted during an exploratory phase. The resulting creative insights can then be focused on specific issues or problems, or expanded conceptually, by modifying the preinventive structures and repeating the cycle. Constraints on the final product can be imposed at any time during the generative or exploratory phase. From Finke, Ward, and Smith (1992).

ering their implications. As discussed, these preinventive structures might consist of imagined three-dimensional forms, mental models and designs, and exemplars for novel or hypothetical categories. After the exploratory stage is completed, the preinventive structures can then be refined or regenerated in light of the discoveries and insights that might have occurred. The process can then be repeated, until the preinventive structures result in a final, creative idea or product.

Family Resemblance in Creative Cognition

In our approach to creative cognition, we avoid trying to define creativity in any absolute way or by using a single set of cognitive processes or properties. Instead, we prefer to adopt a "family resemblance" view of creative cognition, similar to that used to characterize category membership (e.g., Rosch & Mervis, 1975). That is, we regard creative thinking as involving various subsets of generative and exploratory processes, and types of preinventive structures, where no one particular process or structure must necessarily be present. Accordingly, most instances of creative cognition will display at least some of these processes and structures, and there are no sharp boundaries between creative and noncreative thinking.

One advantage of this characterization is that, in addition to recognizing that everyday and extraordinary forms of creativity are linked by a common set of processes, creative and noncreative thinking can also be seen as lying along a continuum. The extent to which generative processes, exploratory processes, and preinventive structures are involved and give rise to emergent features merely increases the likelihood that a creative idea or product will result. There is thus considerable overlap between creative and noncreative cognition. This is another reason why we prefer to base the study of creative cognition on traditional concepts in cognitive science, rather than trying to propose a distinct class of processes and structures specifically tailored to creative thinking.

EXAMPLES OF THE CREATIVE COGNITION APPROACH

The creative cognition approach is relatively new, but it has already made enormous strides. Here we focus on some examples of the types of investigations that have been carried out under the general framework of creative cognition. We will consider creative cognition approaches to the traditional creativity topics of insight and incubation, as well as the issues of conceptual expansion, recently encountered information, conceptual combination, and creative imagery.

Although it may be the case that some of the cognitive processes we examine tend to be more prevalent during initial generation of proto-ideas, whereas others are more evident during exploration, the Geneplore model also explicitly describes creative functioning as a continual iteration of generative and exploratory steps, as novel ideas are brought to fruition. Thus, it is not always certain whether a particular process should be thought of as being exclusively involved in generation as opposed to exploration. In the sections that follow, we describe a wide range of processes that are crucial to creativity without necessarily attempting to classify them as primarily generative or exploratory.

Insight

A telling example of the creative cognition approach is Schooler and Melcher's (1995) investigation of insight, a topic of long-standing interest in creativity circles, but one that until recently has received little experimental attention from cognitive psychologists. Schooler and Melcher point out that mainstream cognitive psychology may have ignored insight as a topic of investigation, at least in part because anecdotal accounts of dramatic insights and nonexperimental observations of such phenomena tend to highlight the unconscious aspects of insightful solutions. For example, the chemist Kekule supposedly had his key insight into the molecular structure of benzene after having dreamed of coiled snakes that represented ring-shaped structures. The mathematician Poincaré reported having made his sudden discovery of a new expression for Fuchsian functions while stepping onto a bus. Indeed, Koestler (1964) suggested that conscious thought, especially in the form of language, might actually inhibit the unconscious forming of connections that underlies insightful leaps. If creative insights occur in sudden, unpredictable ways and if conscious thought might inhibit insights, how could they ever be studied under controlled laboratory conditions?

It is understandable that experimental cognitive psychologists might shy away from such notions, because on the surface they seem to imply a type of process that may not yield to experimental observation. However, Schooler and Melcher went on to describe an ingenious set of studies that shed light on the phenomenon. They reasoned that, if conscious verbalization inhibits the unconscious processes needed for achieving insights, then requiring subjects to engage in concurrent verbalization should disrupt performance on insight problems, and this is exactly the pattern observed. They also noted that performance on analytic, noninsight problems was not disrupted by concurrent verbalization, which indicates that the effect is not a generalized decline in problem-solving ability. Rather it seems to be a specific deficit in insight problem solving associated with engaging in conscious verbalization.

Schooler and Melcher also went on to summarize other findings that related various individual differences – such as perceptual-restructuring ability and field dependence – to performance on insight problems, thereby providing suggestive evidence for various proposed unconscious elements of insight. Overall then, Schooler and Melcher's work demonstrates clearly that the approaches of cognitive psychology can be applied to study even the most mysterious-seeming of creativity topics, such as insightful leaps.

Other recent work on insight has also begun to relate basic cognitive processing issues to creative thinking. For instance, studies have examined whether new insights occur rapidly and without much warning, in a manner similar to perceptual restructuring (e.g., Metcalfe, 1986; Metcalfe & Weibe, 1987) or whether they occur in predictable increments based on identifiable properties of prior knowledge (e.g., Weisberg, 1995; Weisberg & Alba, 1981). One approach to this issue has used an on-line metacognitive-monitoring technique for investigating insight problem solving (Metcalfe, 1986; Metcalfe & Weibe, 1987). While working on problems, subjects tell, every 10 seconds, how "warm" or "cold" they feel, that is, how near to a solution they feel from moment to moment. Metcalfe's studies show that when people solve noninsight problems, their feelings of warmth increase incrementally until the solution is reached, but when they solve insight problems their sense of finding an impending solution is very sudden, coming on with little warning. These experiments provide empirical evidence of insight, as opposed to naturalistic cases that retrospectively examine historically important insight experiences, such as Poincaré's mathematical insights, or Mullis's unintentional discovery of the polymerase chain reaction (see Ward et al., 1995). Although the rarity of historical insights may seem to place such phenomena beyond the reach of empirical science, these studies demonstrate creative ways of evoking and studying the remarkable phenomenon of insight.

Extending Concepts

As noted, the mere fact that we build extensive and elaborate conceptual structures is an indicator of the essential generative power of the human mind. Further, the fact that those structures serve important functions such as classification, understanding, and prediction indicates that they possess utility, an important criterion for creative products. Hence, at its core, human conceptual functioning is a creative phenomenon. Nevertheless, even within this realm of generativity certain aspects of conceptualization are particularly central to creative cognition and we highlight some of them here.

One of the most common creative uses of concepts is to extend them in the service of developing new ideas, an activity that Ward et al. (1997) referred to as conceptual expansion. Consider for instance, what a fiction writer, an architect, and a chef might have in common. Each might begin with a familiar concept, such as "unlikely hero," "single-family dwelling," or "fish stew," and create something new from that base. In so doing, each would extend the boundaries of the existing concept, and each would craft a product bearing critical resemblances to prior instances of the concept.

Anecdotal and historical accounts from real-world settings highlight the fact that new ideas, even highly creative ones, often develop as minor extensions of familiar concepts. Sometimes this mapping of old to new can facilitate progress, as in the case of many well-known inventions (see Basala, 1988), and sometimes it can inhibit, as in the case of lost productivity due to reliance on outmoded organizational structures (e.g., Hammer & Champy, 1993). Because the properties of existing concepts can have positive and negative effects on the form of new ideas, it is important to understand the processes involved in conceptual expansion in all its forms.

By way of its ties to the extensive cognitive literature on the nature and structure of concepts, creative cognition provides a framework for understanding these important varieties of human creativity. A number of recent studies, for example, have attempted to characterize how the central properties of known concepts or recent experiences influence the development of new ideas (e.g., Cacciari, Levorato, & Cicogna, 1997; Jansson & Smith, 1991; Marsh, Landau, & Hicks, 1996; Smith, Ward, & Schumacher, 1993; Ward, 1994).

As an example of this approach to conceptual expansion, Ward (1994) gave subjects the task of imagining an animal that lived on another planet. The subjects provided drawings depicting what the imaginary animal might look like, and raters assessed the presence of familiar properties such as bilateral symmetry, sensory organs, arms, and legs, which are characteristic attributes of most Earth animals (e.g., Ashcraft, 1987; Tversky & Hemenway, 1984).

The vast majority of these novel creatures displayed many features in common with those of typical Earth animals. In particular, most of the exemplars were bilaterally symmetric and possessed two eyes, two ears, and two or four legs (see Figure 10.2 for examples of creatures). This was true even though the planet was described as being very different from Earth. Further, the same pattern obtains even when people are encouraged to develop aliens that are "wildly different" from Earth animals and when they are released from the expectation that what they imagine must be something that can be drawn (Ward & Sifonis, 1997). Such findings suggest that people's knowledge about the typical features of familiar categories structures their imaginative creations, even for unfamiliar or unusual categories. Knowing the categories that are being drawn upon can allow one to predict many of the properties of imaginative creations.

Significantly, these structuring effects generalize to different conceptual domains and to different age and ability groups. Sifonis (1995), for example, asked subjects to design restaurants for a novel birdlike species of aliens. She asked some subjects to design locales where the creatures might get a quick bite to eat and others to design establishments where they might acquire a leisurely meal, and she found that their creations embodied many of the central properties of fast-food and fine dining restaurants, respectively.

Sifonis's work is also important in that it highlights a distinction between the initial generation of an idea and extended exploration of that idea. In one sense, the task of designing a restaurant for birdlike aliens is one of conceptual combination. That is, one must find a way to combine or integrate the concept of restaurant with that of bird.

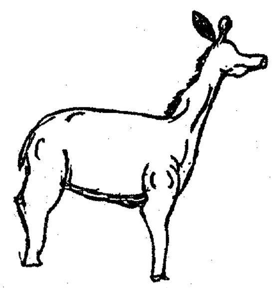
Much research on conceptual combination examines the initial interpretations that people generate for novel pairings of concepts (see later). For instance, given the combination "bird restaurant" out of context, people might use generative processes to produce candidate interpretations such as "a restaurant for birds," "a restaurant where one can only eat chicken or other bird-based dishes," or even "a restaurant shaped like a bird."

In contrast, Sifonis supplied subjects with the initial interpretation of a "restaurant for birds," thereby eliminating the need for them to use comprehension processes to generate preinventive candidate interpretations. Thus, she primarily examined the exploratory processing by which people fleshed out the mapping of known restaurant properties to their novel creations.

Cacciari et al. (1997) extended the observation of structuring effects to younger age groups. They had 5- and 10-year-old children draw animals and houses that did not exist and found at least as much conceptual structuring in the younger age group as in the older one. As in the case of the college students tested by Ward (1994), children in both age groups produced symmetric imaginary creatures that were highly likely to possess standard sense organs and appendages. Interestingly, the younger children were less likely than the older ones to cross conceptual boundaries (e.g., to put animate features, such as eyes, on their imaginary houses), a finding consistent with an earlier report by Karmiloff-Smith (1990).

Even professional science fiction writers tend to develop suspiciously Earth-like extraterrestrials, as a cursory viewing of the bulk of contemporary science fiction movies and TV shows will reveal. Content analyses of science fiction collections confirm that structuring that uses symmetry, eyes, and legs is the norm rather than the exception (Ward, 1994).

The structuring exhibited by science fiction writers also helps to illustrate the role of constraints in the Geneplore model. Although a writer might be able to envision a creature bear-



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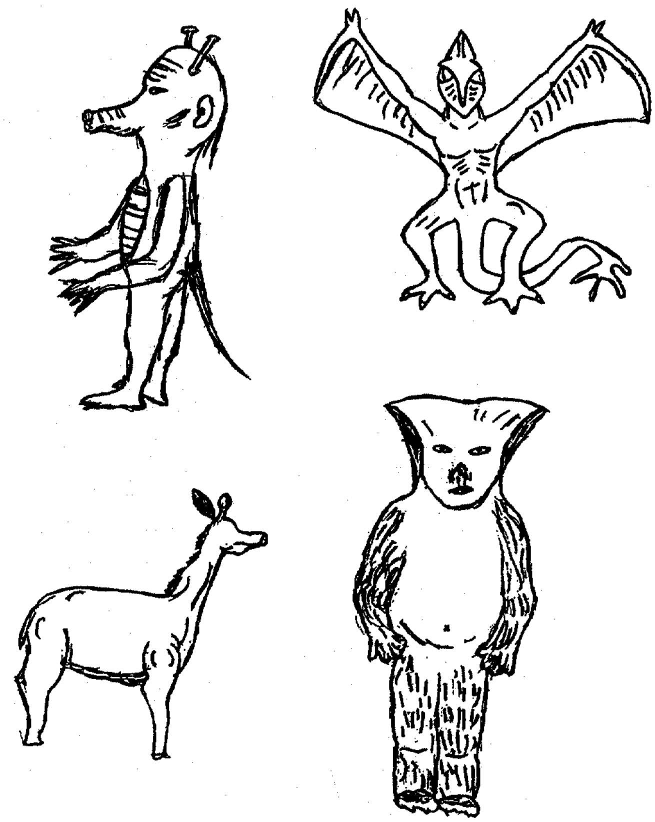

Figure 10.2. Examples of what a creature on another planet might look like, generated in experiments on structured imagination. Adapted from Ward (1994).

ing no resemblance whatever to Earth animals, he or she would also be constrained by the need to communicate with a potential audience and to relate any novel ideas to what is already familiar (see, e.g., Ward et al., 1995). Thus, the very practical goals of selling books or attracting moviegoers might constrain a writer from deviating too far from existing Earth animal properties.

Subsequent studies have also revealed the impact of several different aspects of conceptual structures. For example, Ward (1994) explored the influence of correlated attributes as a structuring principle in creative imagination. Traditional studies on categorization have shown that certain groups of features tend to occur together in natural, real-world categories (e.g., Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976). For instance, in animal categories, the feature "wings" tends to occur more often with "feathers" than with "fur." To determine whether similar types of feature correlations would occur in the generation of creative exemplars, Ward had subjects imagine and draw animals from a planet described as being completely different from Earth, and different groups were either told that the creatures had feathers, scales, or fur or were given no information about their attributes.

The subjects in the "feather" condition were significantly more likely to include wings and beaks as additional features, whereas those in the "scales" condition were significantly more likely to include fins and gills, relative to those in the "fur" or control conditions. Self-reports collected after subjects created their animals indicated that they tended to base them on particular instances of known birds, fish, or mammals, in the feather, scales, and fur conditions, respectively. Thus, the different instructions led to the retrieval of different instances of Earth animals, whose properties were then projected onto the novel entities. Figure 10.3 presents examples of creatures generated in these conditions.

We are not suggesting that existing knowledge will always reduce the creative potential of new ideas. In fact, it is the human capacity to accumulate knowledge and to build new ideas on what has come before that underlies our enormous generativity and makes creativity possible. However, there may be times when certain central properties of existing concepts are better left behind, and the creative cognition approach provides a way of considering how this might be accomplished.

Ward (1994) proposed that structuring effects can be attributed to creators being led down a path of least resistance. When instantiating the problem of developing a new idea, they are drawn to retrieve typical, specific instances of a known concept and then to project the properties of those instances to the empty frame of the novel idea. Because properties at more abstract levels of representation will necessarily be less specific and constraining than those tied to specific instances, an important implication of this view is that encouraging people to move to more abstract problem characterizations will lead to more innovation.

Additional exemplar generation studies have in fact revealed that accessing knowledge at very abstract levels does lead to a greater potential for innovation. For example, Ward (1993) found that when subjects were instructed to consider the environment of the imagined planet and what attributes the creature would have to have in order to survive there, they developed more innovative creatures, in terms of deviations from the characteristic features of Earth animals. In a more applied domain, Condoor, Brock, and Burger (1993) have suggested that mechanical engineers are more likely to develop innovative products if they begin by considering a highly abstract characterization of the problem than if they begin by considering specific solutions to earlier problems.

At the same time, research on creative cognition is nicely convergent with evidence from more traditional approaches to creativity, such as case studies. For instance, anecdotal observations about real-world invention have also stressed the role of abstraction in leading to important innovations (e.g., Rossman, 1964). These case studies can provide a check on the ecological validity of the general principles, whereas the laboratory findings of creative cognition can provide empirical confirmation of the role those principles supposedly play.

Recently Activated Knowledge

The studies described thus far were largely concerned with the impact of long-term existing knowledge structures. However, the mainstream cognitive psychological focus of the creative cognition approach leads naturally to a distinction between such effects and those due to priming or activation of knowledge by recent experiences. Thus, a related topic that has been addressed in recent studies is the extent to which creative products can be influenced by features that are depicted in previously seen examples. Smith et al. (1993) devised a task in which subjects were to generate new designs for toys. Smith et al. varied whether or not the subjects were shown examples of possible designs, which contained certain key features. As shown in Figure 10.4, each example toy included a ball as part of the design, involved a high level of physical activity, and used electronic devices. This example depicts a game called "tether tennis," in which a person bounces a ball between two rackets, with an electronic counter that automatically records the number of successful hits.

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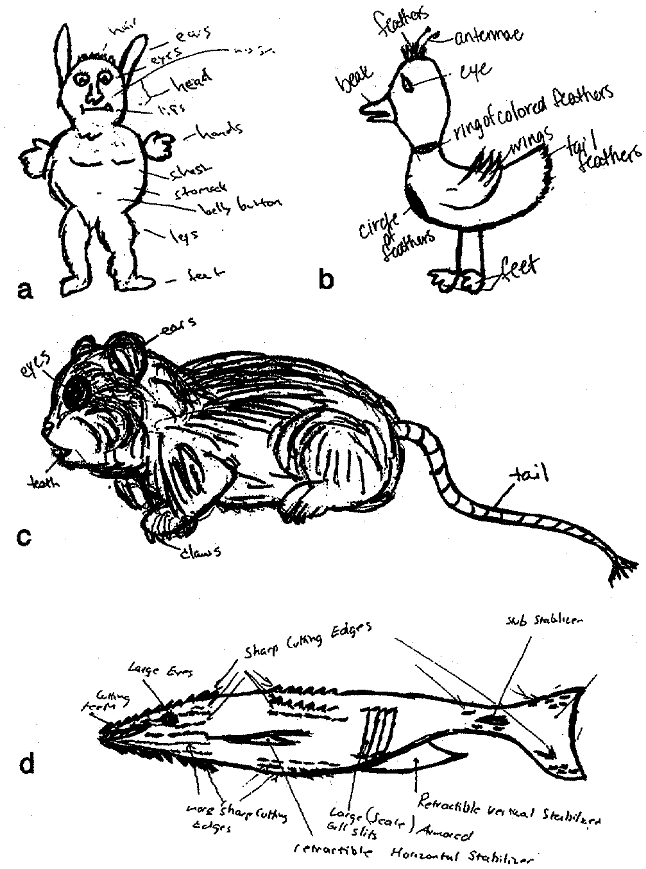


Figure 10.3. Examples of imaginary creatures generated in experiments on structured imagination, under either (a) control instructions or the the constraints that it had to possess: (b) feathers, (c) fur, and (d) scales. From Ward (1994).

designs, the group that had seen the examples were much more likely to include the kinds of features that were depicted in those examples in their own designs. This was true even when the subjects were explicitly told to make their designs as different as possible from the examples. Subsequent work by Marsh et al. (1996) has confirmed and extended these findings.

Figure 10.5 presents the design of one subject who had viewed the example shown in Figure 10.4. This subject had conceived of an "auto pitcher," in which a person can practice hitting a baseball that is electronically guided along a particular path. All three of the key features that had been depicted in the previous example were incorporated into this design. In contrast, a typical design from a subject who had not seen that example is shown in Figure 10.6. This was a design for "water jets," a toy that is attached to a faucet and launches small airplanes at regular intervals. The design shows little resemblance to those in the preceding figures. In related work, Jansson and Smith (1991) have demonstrated a similar influence of design fixation among professional engineers, implying that previous exemplars can influence the content of imaginative creations even in the case of design experts.

These findings point to the need for special care when relying on examples to solve prob-

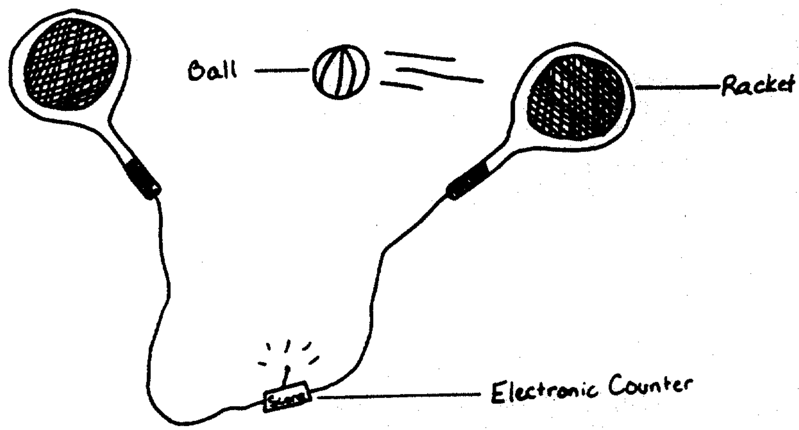


Figure 10.4. Example of a novel toy shown to subjects in studies on fixation in creative idea generation. All example toys contained electronic devices, used a ball, and involved a high degree of physical activity. In this particular toy, called "tether tennis," a person bounces the ball between the rackets, and the number of successful hits is automatically recorded by an electronic counter. From Smith, Ward, and Schumacher (1993).

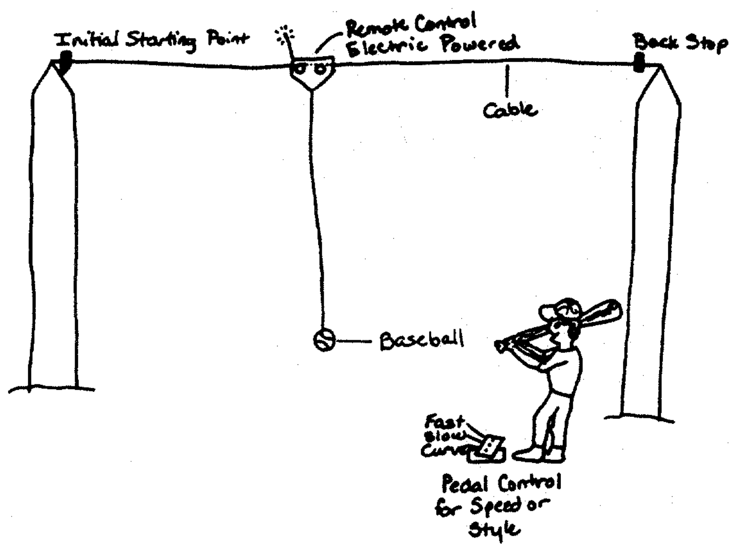
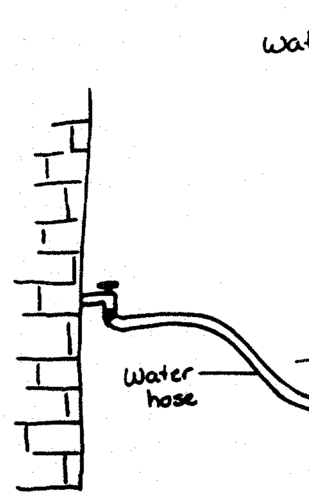


Figure 10.5. Example of a toy generated by a subject after having viewed the example shown in Figure 10.4. This toy, called an "auto pitcher," allows one to practice hitting a baseball, which is guided electronically along a cable. Note that the design contains all three of the major features depicted in the previous example. From Smith, Ward, and Schumacher (1993).

lems. Ordinarily, examples are regarded as beneficial aids in performing a given task. However, it is clear that they can also hinder innovation. Accordingly, further work in creative cognition can help to identify when such examples would help and when they would hurt.

Studies of memory blocking have also begun to provide new insights into the nature of creative thinking. For example, studies on interference and inhibition suggest ways in which



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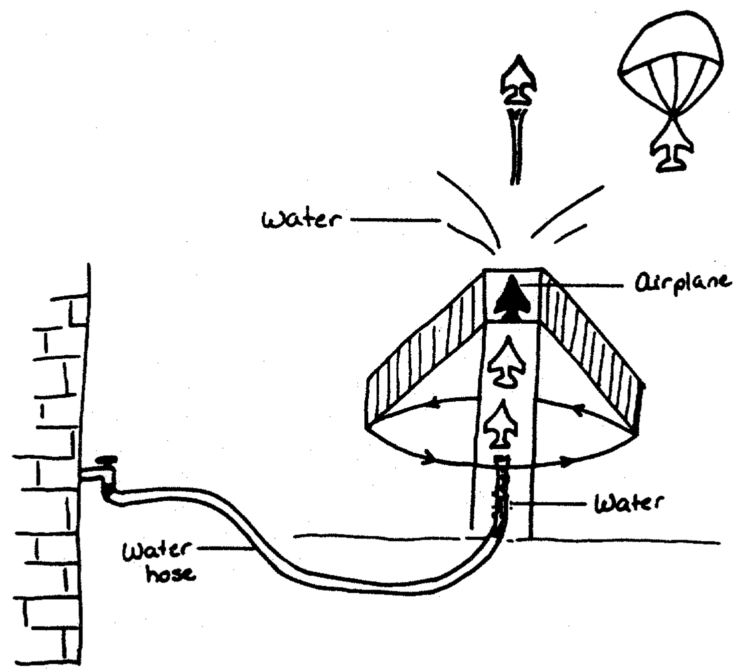

Figure 10.6. Example of a toy generated by a subject who was not shown any example toys. In using this toy, called "water jets," one hooks the hose to a faucet, and toy airplanes are launched at regular intervals. Note that this design bears little resemblance to that shown in Figure 10.4. From Smith, Ward, and Schumacher (1993).

creative thinking might be facilitated (Smith, 1995; Smith & Blankenship, 1991; Smith et al., 1993). Such studies have also begun to reveal the cognitive processes that underlie incubation (Smith & Vela, 1991), intuition (Bowers, Regehr, Balthazard, & Parker, 1990), and other phenomena that have traditionally been regarded as unresearchable.

One phenomenon that has been studied is the involuntary or unavoidable nature of certain mental blocks that can impede or constrain creative thinking. Can people avoid or escape traps in problem solving and creative idea generation? In some cases researchers have found that a simple warning is enough to avoid a mental set. Luchins and Luchins (1959), for example, described how a mental set (aka, *Einstellung*) brought about by repeated use of a single solution could be avoided if subjects were given warnings in advance. Other studies, however, give a different picture. An extensive set of experiments by Smith and Tindell (1997) studied involuntary mental blocks caused by negative priming in a word fragment completion task. After seeing the negative prime ANALOGY, subjects have great difficulty solving the word fragment A_L_ _GY. This block occurs even if subjects are warned in advance that thinking about the negative primes will obstruct their ability to solve word fragments. Involuntary blocking has also been demonstrated by Smith et al. (1993), Marsh et al. (1996), and Ward and Sifonis (1997), all of whom have shown that conformity effects in creative idea generation are not diminished when subjects are urged to give ideas very different from the examples they view. Likewise, Jansson and Smith (1991) found that engineering design students who were instructed to avoid certain negative features of an example they had seen nonetheless incorporated those negative features in their creative designs. Future studies in this area must delimit the circumstances in which mental blocks are likely to be unavoidable, as well as investigate methods for recognizing and overcoming involuntary blocks to problem solving and creative thinking.

Conceptual Combination

Several keen observers of the creative process have identified the synthesis or merging of previously separate concepts as being crucial to human creativity (e.g., Baughman & Mumford, 1995; Koestler, 1964; Mobley, Doares, & Mumford, 1992; Rothenberg, 1979), and creators themselves regularly comment on the generative power inherent in considering novel combinations of concepts (see, e.g., Donaldson, 1992, Freeman, 1993). Donaldson, for instance, developed the underpinnings of his fantasy series on Thomas Covenant, The Unbeliever, by merging the concept of "an unwillingness to accept the possibility of fantasy worlds" with that of "leprosy." He crafted a character who was unwilling to believe in the apparent reality of an otherwise pleasant fantasy world for fear of abandoning the rigorous self-inspection procedures that had helped him avoid serious health problems as a leprosy sufferer in the real world.

On a more mundane level, a plethora of everyday examples suggests that producing and comprehending even simple combinations could be appropriately labeled as creative, if only in the sense that new mental structures are brought into being or elaborated. Where before there were just the separate, well-known concepts of "soccer" and "mom," the 1996 presidential election saw the birth of "soccer moms," whose votes were vigorously courted by the major contenders. It is reasonable to suppose that, prior to encountering the term, most people did not have a coherent mental representation for such a subset of the voting population, but developed it in the service of understanding the phrase. The ease with which such novel mental representations are formed gives evidence of the generative power of conceptual combination. As it turns out, soccer moms also resulted in the emergent property of "political clout," which is not generally attributed to soccer or moms separately. Again it appears that mundane and extraordinary forms of creativity may be endpoints on a continuum, with conceptual combination being one of the important underlying causal processes they share.

Somewhat separate from these historical and anecdotal accounts, experimentally oriented psycholinguists and cognitive psychologists have intensely scrutinized the basic processes involved in comprehending combinations of concepts (see Wisniewski, 1996, 1997). Although such studies have been motivated largely by issues relevant to language comprehension, rather than creativity itself, a clearly established finding from these investigations is that properties often emerge in a combination that were not evident in any of its constituents (e.g., Hampton, 1987; Murphy, 1988; Wilkenfeld, 1995). Because these emergent properties are a source of novelty, they confirm the speculation that conceptual combination can contribute to creative functioning, and they highlight the fact that well-controlled laboratory studies can examine such functioning.

A variety of models have been developed to account for how people comprehend combinations of concepts (e.g., Cohen & Murphy, 1984; Gagne & Shoben, 1997; Hampton, 1987; Murphy, 1988; Rips, 1995; Smith & Osherson, 1984; Thagard, 1997), and a growing body of empirical studies attests to the continued interest in this topic. Here we simply highlight some of this work that, consistent with the creative cognition approach, provides a rigorous look at the fundamental nature of a process that is crucial to creativity.

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properties are most likely to be observed in a combination, and he has highlighted different processes that might produce emergence. He notes that emergent attributes are relatively uncommon for reasonably familiar conjunctions, such as "birds that are also pets," and that those that are found tend to result from retrieving knowledge about specific known instances of the conjunction. For example, "talking" is not generally true of most pets or most birds, but may be regarded as an important attribute of their conjunction, pet birds. Presumably "talking" emerges from the combination because people retrieve familiar instances of pet birds that do talk (e.g., parrots). Hampton thus concludes that there is little evidence for creative emergence for these types of familiar combinations.

In contrast, emergent attributes occur much more commonly for combinations that result in imaginary objects, and those that do occur tend to be based on elaborate problem solving or on scenario construction. For example, when faced with the task of imagining fruit that was also furniture, subjects introduced properties such as "regenerates itself." Presumably the property emerged as a solution to the basic incompatibility between the durability of furniture and the perishable nature of fruit.

Hampton's (1987) attribute inheritance model provides a way of conceptualizing the need for such elaborate processing. The model states that any attribute that is necessary for either constituent of a conjunction will be inherited by the conjunction and that any attribute that is impossible for either constituent will not be inherited. Because furniture ought to be durable and fruit is perishable, these principles of inheritance drive a conflict that forces the comprehender to reason from aspects of world knowledge that go well beyond the boundaries of the individual concepts, and hence result in emergence. What this illustrates is that models designed to account for basic cognitive functioning can have important implications for our understanding of when and how creative outcomes will be observed.

Wilkenfeld (1995) has also provided evidence from laboratory studies of conceptual combination that can enhance our understanding of creative functioning. She attempted to test the proposition that concepts which are more discrepant will result in more creative outcomes than those that are more compatible (see, e.g., Rothenberg, 1979, 1995). Wilkenfeld asked subjects to provide two different definitions for combinations of similar (e.g., guitar harp) and dissimilar concepts (e.g., motorcycle carpet) and to list attributes of the separate and combined concepts. She found that dissimilar pairs resulted in more emergence, but only on the first definition.

Wilkenfeld interpreted the result using Markman and Gentner's (1993) model of structural alignment. Similar pairs have compatible structures that allow the comprehender to merge them easily, and consequently they evoke little emergence from information outside the parent concepts. Dissimilar pairs are less readily aligned and foster a search beyond the parent concepts to resolve the conflicts in their structures. Once the easy initial alignment for similar pairs is exhausted in the service of producing the first definition, they behave more like dissimilar pairs, requiring a search outside the ordinary bounds of the component concepts to conceive a new definition. As in the case of Hampton's analysis then, Wilkenfeld's work reveals how laboratory studies based on theories about fundamental cognitive processes can shed light on issues of long-standing interest in the world of creativity.

Other recent studies also highlight how the similarity of the concepts in a combination can influence processing. Wisniewski (1996, 1997) has identified three strategies by which people interpret combinations: finding some relation to link them, constructing a property of one in the other, and forming a hybrid or blend of the two. For instance, a skunk bird might be a bird that eats skunks, a bird that smells bad, or some novel creature that might result if a skunk and bird could breed. Wisniewski has shown that relation linking is more common with dissimilar pairs, whereas property construction and hybridization are more common with similar pairs.

Wisniewski is also quite explicit that property interpretations are not simply the copying of an attribute from one concept to another. A zebra clam might well be striped, but the stripes are not a mere copy of a zebra's stripes. They are modified in whatever way is needed to make them compatible with what we know about clams. Thus, even a conceptual combination strategy that does not seem, on the surface, to be very creative, nevertheless reveals important generative properties.

Finally, Thagard (1997) presented a coherence-based account of the role of conceptual combination in creativity. This model makes use of the notion of multiple constraint satisfaction; each of the components places constraints on the possible interpretations of the combination. The cognitive system searches for the interpretation that provides the most coherent account given all of the constraints. If the most coherent interpretation available is still not deemed to be sufficiently coherent, other processes can come into play that open the possibility for more creative outcomes. Thagard's focus on assessing the coherence of initial candidate interpretations is thus consistent with the Geneplore model's suggestion of a split between generative processes that produce preinventive structures, and exploratory processes that test their viability and modify them as needed.

Creative Imagery

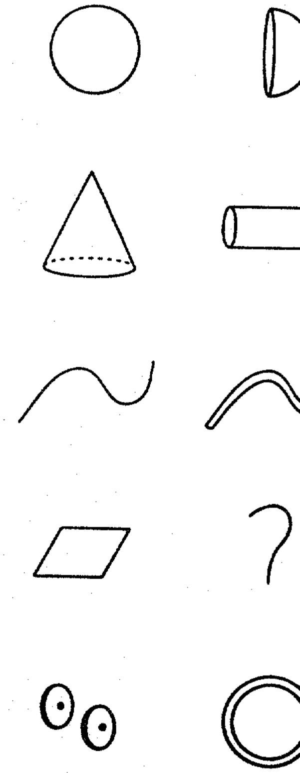
There is little doubt from historical and anecdotal accounts that imagery plays a central role in creative functioning, and research in creative cognition has provided experimental evidence on this important phenomenon. Finke (1990) developed a novel procedure for exploring the discovery of creative inventions under laboratory conditions. Subjects were asked to imagine forms that could be obtained by merging a randomly determined set of three parts selected from the larger set depicted in Figure 10.7. Their basic task was then to interpret the forms as representing a practical object or design.

In one condition, the subjects were free to choose the interpretive category in advance. The allowable categories consisted of furniture, personal items, vehicles, scientific instruments, appliances, tools and utensils, weapons, and toys and games. In a second condition, the category was specified in advance by the experimenter and was chosen at random. In a third condition, the interpretive category was also chosen randomly, but was specified only after the subjects had constructed their imagined forms. The resulting inventions were rated for originality and practicality and were classified into creative and noncreative categories using consensual agreement among judges.

The greatest number of creative inventions were obtained when the interpretive categories were specified only after the subjects had completed their forms, whereas the fewest number of creative inventions were obtained when the subjects were free to choose the interpretive categories at any time. These findings suggest that delaying the search for creative interpretations until after the preinventive structures are initially completed may enhance creative discovery.

Apparently, innovation can be fostered by developing preinventive structures that are relatively uncontaminated by knowledge of the specific goal or task. This suggests that in addition to the clearly valuable approach of letting the form of an idea be derived from the function it must satisfy, another valuable approach may be to let the form itself suggest new and potentially useful functions (Getzels & Csikszentmihalyi, 1976; Perkins, 1981).

Examples of objects that were classified as creative inventions in these experiments are shown in the next two figures. The preinventive structure shown in Figure 10.8 was inter-



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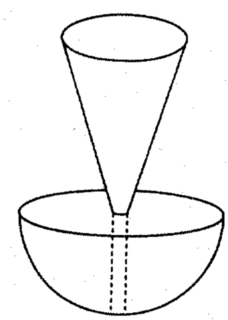

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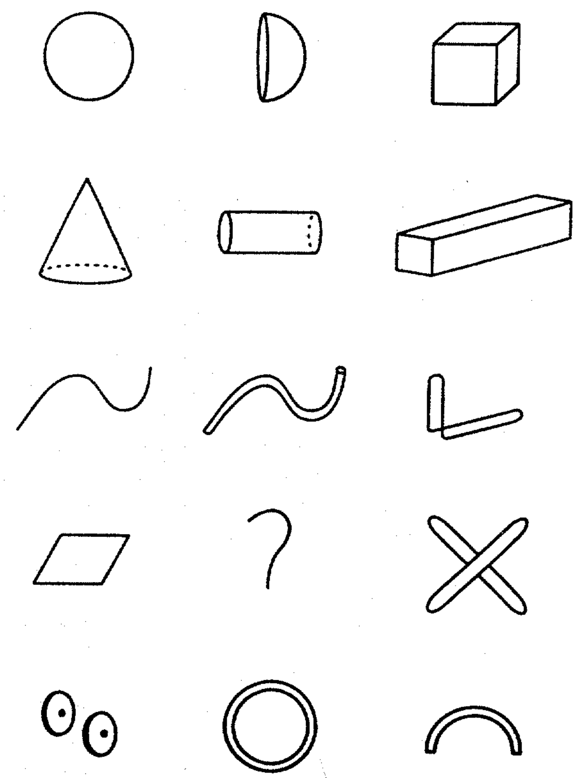


Figure 10.7. Set of parts from which three were chosen at random for creative imagery task.

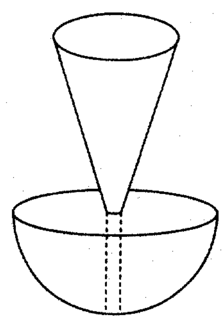


Figure 10.8. The "contact lens remover," an example of a creative invention obtained in studies on creative mental synthesis, constructed using a half sphere, cone, and tube. One places the rubber cone against the contact lens, covers the back of the tube with a finger, lifts the contact off the eye, and then removes the contact from the cone by releasing the finger from the tube. From Finke (1990).

preted as a "contact lens remover," which works by placing the rubber cone against the contact lens, covering the hole at the back, and then moving the device away from the eye. Figure 10.9 shows an invention called the "universal reacher," which can be used to retrieve keys and other items that fall into hard-to-reach places. The wire is drawn out of the spherical housing and can be bent as needed to reach the lost item.

It is important to note, however, that these ideas should not be viewed as representing

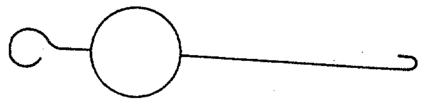


Figure 10.9. The "universal reacher," another example of a creative invention, constructed using a hook, sphere, and wire. The wire is drawn out of the sphere and can be shaped and bent to retrieve things that fall into hard-to-reach places, while the hook allows the device to be secured so that both hands can be used to guide the wire. From Finke (1990).

final, workable inventions, but rather as invention prototypes. In most cases, these designs would require further refinement or modification in order to actually work as conceived.

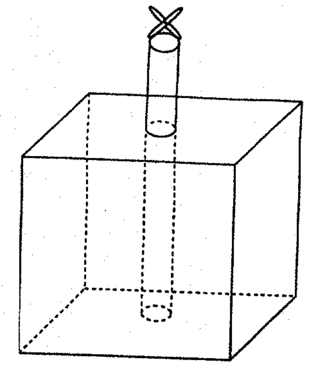
These methods for generating creative inventions have been extended to examine more abstract types of interpretations of preinventive structures (Finke, 1990). The subjects were instructed to interpret their forms as representing an abstract idea or concept within a particular subject category, rather than as a concrete object or invention. The allowable categories consisted of architecture, physics and astronomy, biology, medicine, psychology, literature, music, and political science. After the subjects had generated their forms, they were either given one of the categories, selected at random, or were allowed to choose the category themselves. The resulting concepts were then rated according to their originality and sensibility and were again classified into creative and noncreative categories.

As with creative inventions, subjects were more likely to discover a creative concept when the interpretive categories were specified randomly than when they were freely chosen. The use of unexpected categories evidently encourages the exploration of interpretive possibilities that were not considered when the preinventive structures were initially generated, which thereby enhances creative discovery.

An example of a creative concept obtained in these experiments is presented in Figure 10.10. This is the concept of "viral cancellation," which was discovered by one subject after having generated a preinventive form and having been given the category "medicine." The basic idea represented by the structure is that two viruses attempting to invade the same cell might possibly cancel one another, curing or preventing the disease. Many of the conceptual discoveries obtained in this study resembled those reported in some of the earlier, anecdotal accounts of creative insight, except that they had now been elicited in the context of a controlled experiment.

Of course, experts are normally much better than novices at developing interpretations of a given structure that would be judged by others in the field as being both novel and sensible. For example, Kekule's famous image of a snake would not have meant the same thing to someone who knew nothing about chemistry. Thus, although expert knowledge may be profitably suspended during the generation of preinventive structures, it is certainly useful when those structures are subsequently explored.

The studies already described represent only a small sample of the kinds of studies that have been and could be conducted in creative cognition. A number of other recent studies highlight other aspects of creative cognitive processes, such as the types of emergent properties and categories that can result from metaphor comprehension (Becker, in press; Glucksberg & Keysar, 1990; Tourangeau & Rips, 1991), the role of diagrams in scientific discovery and creativity (Cheng & Simon, 1995), and the importance of both distant and near analogies in historical and contemporary scientific reasoning (Dunbar, 1997; Gentner et al., 1997). These and other recent efforts show how it is possible to study creative thinking using the general methods of cognitive science. In particular, they show that people can often make



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RESOLVING CONTROVERSIE
OF CREATIVITY

Studies on creative cognition can also he
ing the nature of creativity. In this section
they might be addressed in creative cogn

Goal-Oriented Versus Explorat

Is it better to have clear goals or proble
ideas, or is it better to generate creative i
the one hand, there is evidence that creat
on particular problems (e.g., Bowers e
hand, there is evidence that creativity
"problem-finding" attitude of trying to
Bransford & Stein, 1984; Getzels & Csik

In creative cognition, it becomes evid
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whether or not a person has already gen
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can therefore help to identify those sit
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cessful.

Domain-Specific Versus Unive

Are there general creativity skills that on
to particular tasks or domains? As menti

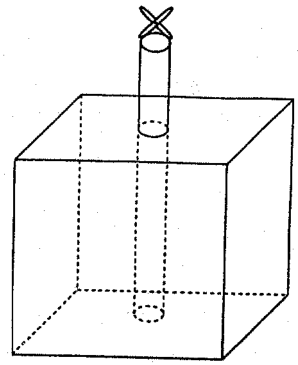

Figure 10.10. The concept of "viral cancellation," an example of conceptual interpretations of preinventive structures, represented using a tube, cross, and cube. The idea is that two viruses attempting to invade a cell may cancel one another, curing or preventing the disease. From Finke (1990).

genuine creative discoveries, under laboratory conditions, using processes and structures that have been studied in more traditional areas of cognitive science. They also suggest how traditional theories in cognitive science can be applied to creativity and how findings obtained in these more creative contexts can then raise new issues about basic cognitive processes.

RESOLVING CONTROVERSIES REGARDING THE NATURE OF CREATIVITY

Studies on creative cognition can also help to resolve some classic controversies surrounding the nature of creativity. In this section, we consider three of these controversies and how they might be addressed in creative cognition research.

Goal-Oriented Versus Exploratory Creativity

Is it better to have clear goals or problems in mind when trying to come up with creative ideas, or is it better to generate creative ideas first, and then consider their implications? On the one hand, there is evidence that creative insights normally arise when people are focused on particular problems (e.g., Bowers et al., 1990; Kaplan & Simon, 1990). On the other hand, there is evidence that creativity is enhanced when one adopts the more general, "problem-finding" attitude of trying to discover interesting issues and possibilities (e.g., Bransford & Stein, 1984; Getzels & Csikszentmihalyi, 1976).

In creative cognition, it becomes evident that this is not an either/or question. The relative merits of keeping particular goals in mind may depend on many factors, including whether or not a person has already generated a preinventive structure, whether the problem is close to being solved or is not yet fully formulated, and whether the knowledge that would be accessed in meeting the goals is abstract or specific. Studies in creative cognition can therefore help to identify those situations where goal-oriented approaches would be more successful and those where more open, exploratory approaches would be more successful.

Domain-Specific Versus Universal Creativity Skills

Are there general creativity skills that one can master, or does creativity tend to be restricted to particular tasks or domains? As mentioned previously, there is considerable evidence that creative performance is tied to expertise in a particular field, which enables the person to retrieve relevant information and to recognize when a new idea is likely to be valid or significant (e.g., Clement, 1989; Langley, Simon, Bradshaw, & Zytkow, 1987; Perkins, 1981; Weisberg, 1986). However, others have proposed that there are broad, creativity skills that can be acquired and applied across many types of problems and situations (Finke, 1990, 1995; Guilford, 1968; Koestler, 1964).

Studies of creative cognition suggest that both positions are partly right. Knowing how to efficiently explore and interpret a preinventive structure clearly depends on experience and expertise. However, as suggested by studies on creative concepts and inventions, certain broad, creativity skills very likely exist. For example, the same, general methods can be used to discover a new type of appliance, a new form of transportation, or a new concept in medicine. Expert knowledge may be most useful when applied in conjunction with general principles for generating and exploring preinventive structures.

Structured Versus Unstructured Creativity

Are creative insights normally derived from existing cognitive structures and representations, or are they chanced upon arbitrarily? Again, the field of creativity has been divided on this issue. According to one position, randomness plays an important role in creativity, leading to novel variations in thinking and allowing one to depart from conventional patterns (e.g., Bateson, 1979; Findlay & Lumsden, 1988; Johnson-Laird, 1988). According to another position, creative discovery is systematic and organized and is based on highly structured processes (e.g., Perkins, 1981; Ward, 1994; Weisberg, 1986).

Again, the creative cognition approach makes it clear that this is not an either/or question. Rather, the methods of creative cognition permit one to determine the relative roles that randomness and structure play in creative discovery. Studies on exemplar generation and design fixation show that creative imagination is a highly structured activity, and is thus not an arbitrary process or one that results simply from random associations among ideas. Random selection of components or interpretive categories can, however, enhance creativity by forcing one to abandon conventional ways of exploring and interpreting preinventive structures.

CONCLUSIONS

We have proposed that creative cognition represents a natural extension of contemporary work in cognitive science to the domain of creative thinking. The generative and exploratory processes that play key roles in creative cognition have already been investigated in many noncreative contexts, and by studying them in more creative contexts they can provide new insights into the nature of creativity, its underlying mechanisms, and how creativity can be enhanced.

In addition to helping clarify the nature of creative thinking, creative cognition also raises new, empirical questions for traditional areas of cognitive science. For instance, studies on creative imagination suggest new issues that could be explored in mental imagery and problem solving, such as the role that preinventive structures might play in representing graphic information or solving geometric problems. Findings from studies on creative exemplar generation have implications for current research on how people form new conceptual categories. Findings from studies on design fixation suggest new issues that could be explored in traditional work on information retrieval and interference. Research on creative cognition can thus make useful contributions to current studies in cognitive science and vice versa.

In conclusion, our main purpose has been to demonstrate how creativity can be studied

using the methods of cognitive science
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using the methods of cognitive science and to propose that it is now time to accept creativity as a legitimate part of this field. Just as behaviorism helped to legitimize the study of behavior, and cognitive psychology helped to legitimize the study of the mind, our hope is that creative cognition will help to legitimize the study of the creative mind.

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11 *From Case Studi Generalizations: Study of Creativi*

EMMA POLICA

TWO APPROACHES TO SOC

There are two distinct bases on whicl structed. The first can be termed the "c departure the most closely related sc researchers and attempts to build upon nomenon" approach. Here one begins v eral and attempts to construct a social-sc upon a thorough understanding of the p

The study of intelligence provides a r lative approach, researchers begin with ically through standardized tests – and t with some other variable of interest (say in some way. In the phenomenon appr example of intelligent behavior and th from. Such otherwise diverse instances stein's thinking process and de Groot's (latter approach.

These two approaches have also bee been earlier efforts to look at creative th H.A. Murray, 1938), sustained psychol Getzels and Jackson (1962), Guilford (work was strongly influenced by the p essential idea of this approach is that cr vidual who is able to produce many re (e.g., geometrical form, houehold objec creative, and this capacity is thought t intelligence. Workers in this tradition a to construct a research domain on that

While the psychometric approach to i chology's greatest success stories (Brown this cumulative approach to the study of able, their validity has never been adequ "cocktail party" variety of creative produ guish themselves in creations that societ captured in the tests seem remote fro taking stance, that emerges from the stu

As a result, a growing number of rese