Creativity and Knowledge: A Challenge to Theories

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An important component of research in creativity has been the development of theories concerning the mechanisms underlying creative thinking. Modern theories of creative thinking have been advanced from many different viewpoints, ranging from Guilford’s pioneering psychometric theory (e.g., 1950; see also Runco, 1991) to those developing out of clinical interests, broadly conceived (e.g., Eysenck, 1965). Other theories have developed out of Gestalt psychology (e.g., Wertheimer, 1923), traditional associationist experimental psychology (e.g., Mednick, 1962), Darwinian theory (e.g., Campbell, 1960; Simonton, 1988, 1995); social-psychological perspectives (e.g., Amabile, 1983), and modern cognitive science (e.g., Martindale, 1985). In this chapter, I examine one critical issue confronting all such theories: the role of knowledge in creativity.

Although various theoretical views proposed by psychologists appear on the surface to be very different, there is among many of them, including all those just cited, one critical assumption concerning the relationship between knowledge and creativity. Since creative thinking by definition goes beyond knowledge, there is implicitly or explicitly assumed to be a tension between knowledge and creativity. Knowledge may provide the basic elements, the building blocks out of which are constructed new ideas, but in order for these building blocks to be available, the mortar holding the old ideas together must not be too strong. Thus, while it is universally acknowledged that one must have knowledge of a field if one hopes to produce something novel within it, it is also widely assumed that too much experience can leave one in rut, so that one cannot go beyond stereotyped responding. The relationship between knowledge and creativity is assumed, therefore, to be shaped like an inverted U, with maximal creativity occurring with some middle range of knowledge.

The notion that the relationship between knowledge and creativity is one of tension has a long history in psychology. Indeed, that general idea has been presented so often, in such a broad range of contexts, that it can be looked upon as a cliche (Frensch & Sternberg, 1989). However, although the “tension” view is the dominant one in modern theory, there has been presented another view of the relationship between knowledge and creativity. A number of researchers have argued the opposite of the tension view, that is, that knowledge is positively related to creativity. Rather than breaking out of the old to produce the new, creative thinking builds on knowledge (Bailin, 1988; Gruber, 1981; Hayes, 1989; Kulkarni & Simon, 1988; Weisberg, 1986, 1988, 1993, 1995b). This view can be called the “foundation” view.

The purpose of the present chapter is to discuss these contradictory approaches to the relationship between creativity and knowledge. The chapter will first briefly summarize the tension view of the role of knowledge in creativity and briefly examine research that has been taken to support it. I will then review research that has examined the relation between knowledge and creativity. Research relevant to this question comes from several related areas. A set of quantitative studies investigating this issue centers on the “10-year rule” in development of master-level work in creative fields (e.g., Hayes, 1989). It has been found consistently that creative individuals have required an extensive amount of time between their initial exposure to the field and production of their first significant work. Such results indicate, indirectly at least, that the ability to do creative work depends on deep knowledge of one’s chosen field. Furthermore, there have been a number of qualitative case studies that have examined the career development of eminent individuals in a number of creative fields (e.g., Csikszentmihalyi, 1996; Gardner, 1993; Gruber, 1981). These studies have all found evidence that deep immersion in one’s chosen field is necessary before innovation is produced.

The next question concerns what occurs during those years of development. Research has demonstrated the role of extensive amounts of deliberate practice, entailing thousands of hours spent over many years, in the acquisition of master levels of complex skills (e.g., Bloom, 1985; Ericsson, Krampe, & Clemen, 1993). Furthermore, there is evidence that developing masters practice at close to the maximal level.

The basic conclusion from this review is that extensive domain-specific knowledge is a prerequisite for creative functioning. Accommodating these findings will require a change in the way in which we conceptualize the relationship between creativity and knowledge. In the final section of the chapter, I discuss an alternative conception of the role of knowledge in creative thinking.

The Tension Between Knowledge and Creativity

In an early discussion of the relationship between knowledge and creativity, James (1880), described the thinking patterns of “the highest order of minds” as having the following characteristics:

Instead of thoughts of concrete things patiently following one another in a beaten track of habitual suggestion, we have the most rarely abstracted abstractions and discriminations, the most unheard of combinations of elements, the subtlest associations of analogies; in a word, we seem suddenly introduced into a seething cauldron of ideas, where everything is fizzling and bubbling about in a state of bewilderment activity, where partnerships can be joined or loosened in an instant, treadmill routine is unknown, and the unexpected seems only law. (p. 456)

James here makes several important claims. First, “partnerships” of ideas can be joined or loosened in an instant, which indicates that any given combination of ideas is as probable as any other. This leads to the conclusion that specific past experience is not influencing the combinations that occur. A similar inference follows from James’s statement that the thoughts processes of these “highest order of minds” bring about the “most unheard of” combinations, presumably unheard of to thinker as well as to the audience. This again is a claim for the independence of creative thought from knowledge. Similarly, James’s observation that “treadmill routine is unknown” points to the independence of this thought from ordinary knowledge. In a later writing, James (1908) carried this reasoning further and explicitly emphasizes the negative influence of habit on thinking:

The force of habit, the grip of convention, hold us down on the Trivial Plane; we are unaware of our bondage because the bonds are invisible, their restraints acting below the level of awareness. They are the collective standards of value, codes of behavior, matrices with built in axioms which determine the rules of the game, and make most of us run, most of the time, in the grooves of habit—reducing us to the status of skilled automata which Behaviorism proclaims to be the only condition of man. (p. 64)

James’s view could be looked upon as a relatively radical claim concerning the role of knowledge in creative thinking. He is saying that knowledge is only in the very loosest sense related to true creativity, and may be detrimental to it.
A similar position was advocated by the Gestalt psychologists (e.g., Scheerer, 1963; Wertheimer, 1982; for further discussion, see Weisberg, 1995a), who proposed the well-known distinction between reproductive and productive thought. The former, which depended on reproduction of previously successful behaviors, involved staying in old thought habits and would fail when something truly novel was demanded. Productive thought was the basis for insight and true novelty of thinking. The crucial issue for the productive or insightful thinker was to be able to use past experience on a general level, while still being able to deal with each new problem situation on its own terms. In this way, one does not become fixated, that is, trapped by attempting to apply specific knowledge to situations in which it turns out not to be relevant (Scheerer, 1963; Wertheimer, 1982). Such behavior would be a reduction to James’s (1908) “skilled automatism.”

Guilford (1950), in his pioneering analysis of creative thinking, emphasized the role of “divergent” thinking in the development of new ideas. This mode of thought enables the thinker to produce new ideas by breaking away, or diverging, from previously established ideas. DeBono (1968), perhaps the most well-known industrial consultant on creativity training, voices the same opinion. “Too much experience within a field may restrict creativity because you know so well how things should be done that you are unable to escape to come up with new ideas” (p. 228).

Koestler’s (1964) often-cited discussion of creativity also emphasizes the necessity for creative thinking to break out of the boundaries set by knowledge, in the form of habit:

Habit is thus second nature . . . at any rate as regards its importance in adult life; for the acquired habits of our training have by that time inhibited or strangled most of the natural impulsive tendencies which were originally there. Ninety-nine hundredths or, possibly, nine hundred and ninety-nine thousandths of our activity is pure and automatic and habitual. (p. 365)

Amabile (1989, pp. 48-49) summarizes her views on creativity in the context of a discussion of how to increase the chances of raising children who can think creatively. She presents the following as some of the thinking styles that are often observed in creative adults and children: (1) Breaking set, that is, breaking out of your old patterns of thinking about something; (2) breaking out of scripts, which is much the same thing; and (3) perceiving freshly, that is, changing one’s old ways.

A number of researchers have stated explicitly that the belief that situations which demand creative thinking are so novel that one’s past experience cannot be applied to them without large-scale modification. Another way of saying the same thing is to propose that “true” creative thinking produces results of such novelty that they are unrelated to what came before. For example, Hausman (1984) claims that there is a break between the creative product and the past. The novelty inherent in creativity means that the creative product is not comprehensible or analyzable in terms of what was known before. Concomitantly, he also assumes that the creative product must have developed independently of the creator’s knowledge or past experience:

[A] created object exhibits a complex structure that is new and is unprecedented and un-predicted. It appears to be unaccounted for by its antecedents and available knowledge, and it is thus disconnected with its past. In this sense, it occurs in the midst of discontinuity. (p. 9)

Campbell (1960) makes a similar point in an influential paper that proposed a Darwinian perspective on creative thinking. Such a perspective assumes that creative ideas, like the mutations that provide the raw material on which natural selection operates, are the results of a “blind” process. This is necessary, according to Campbell, to bring about true advances in knowledge:

Between a modern experimental physicist and some virus-type ancestor there has been a tremendous gain in knowledge about the environment. . . . It has represented repeated “breakouts” from the limits of available wisdom, for if such expansions had represented only wise anticipations, they would have been exploiting full or partial knowledge already achieved. Instead, real gains must have been the products of explorations going beyond the limits of foresight and prescience, and in this sense blind. In the instances of such real gains, the successful explorations were in origin as blind as those which failed. (pp. 380-381)

A similar point is made by Simonton (1995), who has taken Campbell’s basic view and elaborated it into a wide-ranging theory of creative development and creative process:

For the kinds of problems on which historical creators stake their reputations, the possibilities seem endless, and the odds of attaining the solution appear nearly hopeless. At this point, problem solving becomes more nearly a random process, in the sense that the free-associative procedure must come into play. Only by falling back on this less disciplined resource can the creator arrive at insights that are genuinely profound. (pp. 472-473)

We see here a consistency of opinion concerning the need for creative thinking to go beyond the bounds of knowledge in order to produce true advances. This is seen as necessary for true creativity because it is assumed that changes in the environment demand it. I will now very briefly examine selected research that provides support for the tension view, which will demonstrate how researchers have approached the relevant issues. It has been shown that the relation between education and creative achievement is curvilinear, as the tension view assumes; and it has been shown that past experience can interfere with effective adjustment to novel situations. That is, using one’s past experience results in negative transfer in new situations.

The U-Shaped Relation Between Education and Creativity

Simonton (1984, chap. 4) has analyzed the relationship between outstanding creative accomplishment and level of formal education. He examined the lives of more than 300 eminent individuals, born between 1450 and 1590, who had been included in an earlier study of the roots of genius. Some of the individuals included in the study were Leonardo, Galileo, Mozart, Rembrandt, and Beethoven. Simonton determined the level of formal education that each individual had achieved, and also scored the level of eminence the person had attained, based on an archival measure: the amount of space devoted to the individual in several standard reference works.

When eminence was plotted as a function of level of education, it was found that the relationship was curvilinear, an inverted U, with the peak of eminence occurring at about midway through undergraduate training. Fewer or more years of training (including postgraduate training) were associated with lower levels of eminence. Thus, one could argue that higher levels of knowledge (presumably brought about by graduate training) had a negative effect on creativity.

Past Experience and Negative Transfer

Well-known studies by Luchins and Luchins on problem-solving set (e.g., 1959) have shown that individuals can easily be induced to perform inefficiently in problem-solving situations, as a result of success with one specific solution. Experimental participants were sometimes so fixated on “blindly” applying that previously successful solution to new problems that simpler solutions would be overlooked. The new problem might not even be solved by the experienced problem solvers, although naive participants solved it with no difficulty. Thus, past
success had trapped the knowledgeable participants into habitual modes of thought, and when the world changed, so that the previously successful solution did not work, they were incapable of adapting.

This perspective has recently been carried forth by Frensch and Sternberg (e.g., 1989), who showed that experts in bridge were less able than were novices to adjust to changes in the rules of the game. Two sorts of changes were made by Frensch and Sternberg. Surface changes involved changes in the names and order of suits; deep or conceptual change involved having the player who lost the last trick, rather than the winner, lead the next one. Both novices and experts were tested on the two types of changes. Experts were particularly affected by the deep changes and had a harder time adjusting to them than did the novices. Once again, knowledge made for less flexible thinking in adjusting to changes in the world. In this study, as in those by Luchins and Luchins (1959), the experts would have been better off knowing nothing.

**Conclusions**

This brief discussion has served to introduce the tension view and research presented in its support. The next section investigates more directly the question of the relation between knowledge and creativity. Two related sets of studies will be examined. The first is research that has examined career development of acknowledged masters in several domains and has found that a large amount of time in the discipline is required before one makes a significant contribution (the 10-year rule). Second, there is evidence that much of this time is spent in internalizing what has already been done in the discipline; master-level performance only comes after years of extensive deliberate practice. Further, there is evidence that individuals who achieve master-level ability may practice more extensively to the human maximum, rather than at some intermediate level, as the tension view would lead one to expect.

**DEVELOPMENT OF MASTER-LEVEL PERFORMANCE IN CREATIVE FIELDS: THE 10-YEAR RULE**

Hayes (1989) carried out a study of the role of what he called preparation in creative production. The basic question that Hayes investigated was the time needed to reach master-level performance. He examined career development in several fields requiring creative thinking, such as musical composition, painting, and poetry. The results, which were consistent across fields, showed that even the most noteworthy and "talented" individuals required many years of preparation before they began to produce the work on which their reputations were built.

**Composers**

To examine the development of skill in musical composition, Hayes examined the biographies of 76 composers, listed in a standard reference work (Schoenberg, 1970), for whom enough information was available to determine when they began the study of music. Hayes calculated the length of time between the beginning of each composer's career, as defined by introduction to musical instruction, and production of the individual's first "notable" work or "masterwork." In defining such a work, Hayes used an "archival" measure: the number of recordings of the work available.

Based on this criterion, Hayes identified over 500 notable works produced by his sample of composers throughout their careers. Of these works, only 3 were composed before year

**Poets**

Wishbow (1988, as cited by Hayes, 1989) carried out a biographical study of 66 eminent poets. A notable poem was defined as one included in a major anthology of poetry. We once again find the same pattern of career development: no notable poem was written earlier than 5 years into the poet's career. Furthermore, of the 66 poets examined, 55 required 10 years until production of their first notable work.

**Conclusions**

Hayes (1989), following Chase and Simon (1973), proposed that preparation, in the sense of immersion in a discipline, is required for creative achievement. Composers, painters, and poets, like the chess masters studied by Chase and Simon, require significant periods of time to acquire sufficient knowledge and skills to perform in their fields at world-class levels. It
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for such an immersion. The interview studies of Bloom and co-workers (Bloom, 1985), to be
discussed further shortly, also support this conclusion. Quantitative information on what
occurs during this period comes from recent work by Ericsson and his colleagues (e.g.,
Ericsson & Charness, 1994; Ericsson, Krampé, & Clemens, 1993), who have examined the
role of what they call deliberate practice in the development of master-level skills.

Deliberate Practice and the Development of Expert Performance

Deliberate practice consists of a set of activities specifically designed to improve performance in some skill (Ericsson et al., 1993). Among these are: application of structured methods, rather than haphazard working; involvement of a tutor or coach, although not usually in every practice session; feedback to the student; and repeated chance for the student to attend to the critical aspects of the situation and his or her performance. That is, the individual is able to go over again and again, under the eye of the coach, the specific parts of the skill that require improvement, and then work further alone.

Deliberate practice is contrasted with two other forms of activity: play and work. Play is, of course, carrying out some activity for its own sake. Many individuals report that as children they began some activity as play, but then they changed to practice as they became more serious about a possible career in that discipline. Play does not have the structure of deliberate practice, and so cannot bring about systematic improvement. Work involves performance or competition, for external reward, and the performer is expected to be at his or her best. Work therefore usually would not provide the opportunity for deliberate practice, since problematic aspects of the skill cannot be isolated and repeated. Indeed, problematic aspects of the skill would probably be actively avoided at such times.

In Ericsson’s view, there is essentially no limit to the level of performance an individual can reach in any skill (Ericsson et al., 1993; see also Bloom, 1985). Some broad limits are set by genetic factors, but if the person is capable of carrying out the activity, then, with sufficient deliberate practice, he or she can reach the highest level of performance. However, this practice must extend over years, and it requires extensive resources on the part of the individual. The person must be well versed in the practices and his or her support group (usually the family; see Bloom, 1985, and Feldman, 1986). Resources involve time and energy, as well as access to teachers. Deliberate practice demands a high degree of effort on the part of the learner, because he or she must commit full attention for the entire session for the practice to be effective. This limits the length of sessions; deliberate practice therefore can only be carried out for a limited amount of time per day. In order to maintain a practice schedule, the learner must be able to recover from one session before the next is scheduled. Studies that have varied the length of practice sessions from 1 to 8 hours have found that maximal improvement occurred with sessions of 2 to 4 hours in length (Ericsson et al., 1993, p. 370), and teachers of music recommend shorter sessions, separated by breaks.

In order to examine the role of deliberate practice in the development of master-level skills, Ericsson et al. (1993) studied musicians of different levels of skill and assessed the amount of practice and other activities they engaged in. The sample consisted of a group of elite professional violinists, and three groups of student violinists at a prestigious music school. The elite violinists were members of one of two world-class symphony orchestras. In order to obtain student violinists of different levels of skill, indirect criteria were used. The professors at the school were asked to identify the students who had the best chance of achieving careers as international soloists; the professors also nominated “good” violinists from the same department. Finally, a group of violin students were identified who planned careers in music education. These students were presumably at a level of skill lower than the others.
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These four groups of violinists were interviewed concerning their activities, musical and otherwise, and the groups of students were asked to keep diaries of their activities over a week. The interviews involved rating various activities as to their career relevance, the effort they entailed, and how enjoyable they were. In their ratings, the violinists differentiated among musical activities, with deliberate practice being rated as most relevant, but also highly effortful, and not enjoyable. Playing with others was rated more enjoyable and less effortful than deliberate practice, but also less relevant. These results supported the framework of Ericsson et al. which assumed that deliberate practice is most important for the development of skill, but at a cost of much effort. It was also found that the more elite violinists spent more time practicing, and also more time sleeping. This supported the idea that practice was effortful and necessitated sleep for recovery from the effort expended.

Based on the interviews, Ericsson et al. determined that the better violinists had begun study of the violin earlier in life and had practiced more throughout their careers. The interviews plus the diaries allowed an estimate of the amount of practice the groups of violinists had engaged in, from the time they had begun study until the age of 20. The groups were reliably different in this regard: the best violinists were each estimated as having accumulated more than 10,000 hours of practice, compared with approximately 8,000 hours for the good violinists and 4,000 hours for the music teachers.

In addition, based on information concerning the length of typical practice sessions and the extra time spent in sleep by the best violinists, Ericsson et al. concluded that the best violinists were practicing close to the maximum that they could sustain. A second study, of high-level pianists, supported the conclusions from the study of violinists. Furthermore, studies cited by Ericsson et al. (e.g., of writers) also indicate that the capacity to sustain deliberate effortful work is limited and that individuals at the highest levels of accomplishment work at close to their limit.

These results are an indication that “too much practice” does not seem to stifle accomplishment. In the domains studied by Ericsson et al., the relationship between practice and achievement seems to be a positive and monotonic function of practice, not the inverted U postulated by the tension view. The contradiction between this conclusion and Simonton’s (1984) study of the relationship between education and creative accomplishment will be examined later.

The same conclusion can be drawn from the interview studies conducted by Bloom and co-workers (Bloom, 1985). These researchers interviewed more than 20 individuals in each of several fields who had achieved high levels of success, including athletics (tennis players ranked in the top ten worldwide and Olympic swimmers), music (award-winning piano soloists), artists (award-winning sculptors), and scientists (neurologists and mathematicians who had been recognized for excellence in early career development). In all these fields, attainment of excellence was foreshadowed by years of immersion in the activity, accompanied by strong support by a network of individuals, including parents and coaches. Furthermore, although some of the fields investigated might more obviously require creativity (e.g., sculpture, neurology, and mathematics versus tennis, swimming, and playing the piano), the pattern of years of preparation was found in the former as well as the latter.

The Question of Creativity

One might object that the research on deliberate practice is not relevant to the study of creativity, because such fields as musical performance or athletics may require minimal creativity. However, as just indicated, several of the fields investigated by Bloom and co-workers (1985), albeit on only a qualitative level, undoubtedly involve creativity (sculpture, neurology, mathematics). Furthermore, it can be argued that musical performance and athletics can involve creativity. The highest level of instrumentalists, those who have achieved careers as soloists, are selected presumably because of the personal interpretations that they apply to the pieces they play. That is, they are capable of communicating emotion to their listeners.

This communication of emotion presumably indicates that the player learns something more than a well-rehearsed series of unchanging movements, since not all performers are able to communicate emotion to the same high degree. The pianists interviewed by Bloom and his colleagues (Bloom, 1985) reported that the final stage of their training entailed study with what could be called a “master teacher,” an individual who in most cases had achieved international acclaim as a soloist. Such teachers accepted as students only those young people who demonstrated high levels of potential in auditions and who were recommended by highly respected lower-level teachers. The students reported that the master teachers were not interested in perfecting piano technique. Rather, they were concerned with the student’s developing a personal style of communicating the emotion in the music. Thus, each developing soloist must “create” his or her own style of playing, and performing music can be looked upon as a creative activity.

Athletic skills at the highest level also have creative components. In such sports as tennis, basketball, and hockey, to name a few, the basic activity is unstructured, and therefore requires constant improvisation. The outstanding athlete in such domains has therefore learned more than how to repeat a set of moves in the same way each time. Thus, the results from studies of musical performers and athletes have relevance to the understanding of creative thinking. In addition, as noted earlier, studies of the development of artists and scientists by Bloom and his co-workers present results concerning practice and immersion in the discipline that parallel the findings with musicians and athletes (Bloom, 1985).

The potential importance of the findings of Bloom and co-workers and of Ericsson et al. points to the necessity of examining the careers of individuals in other fields that unquestionably entail creative thinking. The next section presents evidence concerning the importance of practice and development of knowledge in musical composition (including composition “on-line,” i.e., jazz improvisation), unquestionably a creative skill. No relatively direct assessment of patterns of practice and other activities is possible in the case of such individuals as Mozart. However, indirect evidence supports the findings from the studies of Bloom and co-workers (Bloom, 1985) and of Ericsson et al. (1993); that is, immersion in the discipline is a prerequisite for creative accomplishment.

PRACTICE AND CREATIVITY IN MUSICAL COMPOSITION

Who Wrote Mozart’s First Seven Piano Concertos?

Evidence that deliberate practice is important in the development of musical composition comes from a consideration of Mozart’s production of concertos for piano and orchestra. As mentioned earlier, Mozart’s first masterwork as identified by Hayes (1986) was the Piano Concerto no. 9, K. 271. This piece was composed more than 10 years into Mozart’s career, when he was 21 years old. Mozart’s first four piano concertos (K. 37, 39, 40, 41) were produced in June–July, 1773; Mozart’s age was 21. However, calling these works piano concertos by Mozart is misleading, since they contain no original music by him; they were constructed out of works of five other composers.

The next three works of this type (K. 107, nos. 1–3) were written in 1772, when Mozart was 16. These works too contain no original music by Mozart: They were works of Johann Christian Bach (the youngest son of J. S. Bach), who had become an important composer in his own right; they were merely arranged by Mozart for a new combination of instruments.
They can play them back effortlessly (often a whole repertoire of solos and “licks”), and this forms the basis for the development of the ability to go beyond what they have learned and to create new music. The new music may be related to the models that have “internalized,” in the sense that often one can tell who has influenced a given player, but the new music will go beyond the music of the model, sometimes in relatively radical ways. Here again, one might have expected that these aspiring jazz players were doing themselves to a lifetime of repetition of the works of others, but that is not what necessarily happens.

Analysis of performances of jazz musicians of the highest rank has provided some specifics concerning the way in which improvisational skills depend on knowledge. Owens (1995) has analyzed the recorded solos of Charlie Parker (1920–1955), who is recognized as the greatest improviser in modern jazz. Parker is the individual most responsible, along with Dizzy Gillespie, for the transition from the swing of the 1930s to the bebop and modern jazz of the 1940s and early 1950s. Parker was legendary for playing fluently at incredible speed, with some of his solos recorded at tempos of 400+ beats per minute. (It is difficult for a listener to even beat one’s foot in time with such tempos.) He was also recognized for never repeating himself.

Perhaps surprisingly, given Parker’s reputation, Owens (1995) has reported that Parker can be characterized as a “formulistic” improviser. Over his career, Parker acquired a large repertoire of formulas – patterns of notes, ranging from two- or three-note clusters to strings encompassing perhaps a dozen notes – which he used in his solos. A significant proportion of even Parker’s greatest solos were constructed from these formulas, some of which might be repeated every eight or nine measures.

Parker’s formulas were developed in several ways. Some can be traced to specific musicians in the previous swing generation, about whom Parker was very knowledgeable. He was, at least once, heard in his nightclub dressing room, between shows, playing from memory a solo of Lester Young, a swing musician of great renown. Excerpts from the recorded solos of Young and other swing musicians (e.g., Coleman Hawkins) can be heard in Parker’s recorded solos. Other formulas were what could be called “common currency” among Parker’s peers, in that the same formulas were used by many of them. Finally, other formulas were developed by Parker himself, during his practice and playing sessions.

Thus, Parker’s ability to play fluently and without repetition is attributed by analysts to his large and well-learned repertoire of formulas (Kernfeld, 1995; Owens, 1995). At the speeds at which Parker played, it is argued, it would have been impossible to compose new music truly from scratch; one must have precomposed pieces to use. The more of these formulas one has mastery over, the less chance of repeating oneself.

Johnson-Laird (e.g., 1988) has recently developed a computer model of jazz improvisation, based on heuristics, that is, a set of rules of thumb that can be used to produce improvisations. Johnson-Laird begins with the fact that jazz musicians begin by imitating the work of others. In Johnson-Laird’s analysis, a crucial aspect of the development of the jazz musician is that on the basis of this imitation, the jazz musician must develop a skill of improvisation that can run efficiently in real time, since there is no revision possible in jazz. In Johnson-Laird’s view, these skills involve the musician’s abstraction of principles of improvisation from the internalized models. The principles are used to choose notes to be played at a given point in the performance, based in part on the harmonic structure of the piece being played and in part on what the performer has just played.

Johnson-Laird’s model, for example, is one where the player chooses notes that fit the present chord or that can be used to link one chord with another. (2) The model also tries to vary the structure of the solo, so that, for example, if he or she has played a series of small steps in a scale, a larger
Learning to Write Hits: The Beatles

As a further example of the role of practice in creative development, we can consider the career of the Beatles. The first hit single written by John Lennon and Paul McCartney was "Love Me Do," which was recorded in 1962 and reached the no. 17 slot in the British hit parade in December of that year. It was followed in 1963 by "Please Please Me" (released January 17, reached no. 1 February 22; this was their first no. 1 hit); "From Me to You" (released April 11, reached no. 1 after two weeks); "She Loves You" (released August 23, no. 1 for four months); and "I Want to Hold Your Hand" (released November 29, no. 1 in a week, displacing "She Loves You"). What had preceded this outburst of creative activity? The answer is the same as we have seen for Mozart and jazz musicians: practice, practice, practice (Davies, 1958; Lewisohn, 1952).

The Beatles developed out of the Quarry Men, a musical group formed by Lennon in March 1957 at age 17, soon after he received his first guitar. Lennon had earlier been taught the rudiments of music by his mother. In July, McCartney saw them perform at a dance. McCartney's father was a musician, and Paul had some experience with the trumpet and guitar. After the dance, he met the group and played for them. He also showed them how to tune a guitar, something that the Quarry Men had not yet mastered. Later in July, McCartney was asked to join the group. In March 1958, George Harrison (just turned 15) joined the group. Ringo Starr was the last to join, in 1962, although he had played with the group in public a number of times before that. By that time, the group had gone through several name changes, and their musical style had changed from "skiffle," a British- and African-influenced music to U.S. folk music, to U.S. popular music - rhythm and blues, country and western, rockabilly, and rock and roll. The Beatles, like Mozart and many jazz musicians, were both performers and composers. At the time Lennon and McCartney began writing songs, however, relatively few pop musicians wrote their own songs. Elvis Presley, one of their early idols, did not, although Buddy Holly, Chuck Berry, and Little Richard, also favorites of theirs, did.

No detailed information is available on the Beatles' actual practice regimen, but one can get a feeling for the activities they engaged in by considering their public performances. Although Ericson et al. (1993) distinguish between performance (as work) and deliberate practice, this distinction may not be particularly sharp in the case of the Beatles. They seemed to have used their early performances as opportunities to hone their craft, in addition to whatever deliberate practice and rehearsal they carried out at other times (Lewisohn, 1992, p. 23). They played the same songs repeatedly over these performances, which gave them chances to work out problems in playing as a group, as well as to improve their indi-
sions are very close imitations of the originals. Any novelty that occurs is almost exclusively the result of them forgetting or misinterpreting the words.

In contrast, from 1963 to 1966, over 80% of the 39 songs entering the Beatles' performance repertoire were their own. During these later years, they produced a large number of their own songs and used them in their performances; almost everything new that they sang had been written by them. Thus, Lennon and McCartney learned very well the works of others before they produced a significant number of works.

In one respect, the results in Figure 12.2 are not particularly impressive. Of course the Beatles sang the songs of others before producing many of their own: What else would one expect? Early in their career they simply had not had enough time to write many songs, so that is why they sang songs by others. From this perspective, the only difference between the early and late Beatles' songs is their quantity. The years of practice might have had no effect other than giving Lennon and McCartney time to write more songs.

However, there is evidence that in addition to being relatively few in number, early Lennon-McCartney songs were judged to be of lower quality than later ones, which supports the claim that over the years of immersion, Lennon and McCartney were learning their craft. One can adopt Hayes's (1989) method to investigate this and examine the release of Beatles' songs on records. Whether or not a song is released on record is presumably the result of judgments concerning its quality.

First, let us limit the analysis to songs that were actually performed at some point during the Beatles' 10-year performing career. Some songs that they wrote, especially early songs, never were performed in public, which could be taken as an early elimination of weaker songs. Thus, the relatively few Lennon-McCartney songs performed in the early years had undergone a selection process for quality. However, even if we restrict the analysis to songs that were performed, we still find that many were not released on recordings. Figure 12.3 shows the proportion of Beatles' songs composed in each half of their performance career that were released on records at any time during their recording career, which extended until 1970. There was a much higher proportion of late songs released, providing support for the claim that the Beatles had to learn their trade as songwriters. The difference in recording frequencies shown in the figure is significant ($\chi^2(1) = 26.43, p < .0001$).

One might argue that the reason the early songs were not recorded was because the decision makers at their recording company did not want to take a chance on them. Once the Beatles established themselves, on the other hand, then anything they produced was probably considered worth recording. Thus, the quality of the songs might not have changed; rather, the criteria were less strict once the Beatles were established. However, many of the early songs were ignored even after the group was established, when early work must have been given new scrutiny. Even this new scrutiny was not enough to produce strong interest in many early songs. It is only in recent years, with the production of exhaustive anthologies of Beatles' material, that a significant number of these early songs has been released.

In addition, one can also examine the amount of innovation involved in various Beatles songs, in this case by considering critics' and historians' assessments of various works. Based on this criterion, there is little doubt that the Beatles' unique contribution to popular music occurred in the period 1965-1967, beginning with the production of the albums Rubber Soul and Revolver; and reaching a high point with Sergeant Pepper's Lonely Hearts Club Band (e.g., Lewisohn, 1992). Thus, the Beatles' innovations occurred in what one could designate as the third stage of their career, the three being (1) cover versions of others' works, (2) production of their own works, but within the existing styles, and (3) significant innovation.

In conclusion, development of the Beatles parallels that of Mozart and the jazz musicians just discussed, as well as that of the groups studied by Bloom and co-workers (Bloom, 1985) and Ericsson et al. (1993) and the individuals studied by Gardner (1993). All these cases have indicated that years of immersion in a discipline is a precursor for the capacity to produce novel work.

The Question of the Control Group

A question can be raised concerning the interpretation of data on cumulative practice and their relation to creativity. One could argue that the Beatles' data by themselves tell us nothing about the development of creative skills. If one wishes to conclude that the years of practice were causally related to the Beatles' creative output, then, so it could be argued, it is necessary to compare the Beatles with unsuccessful rock groups, to show that the Beatles worked harder than the latter did.

However, the hypothesis under consideration is that a large amount of domain-specific practice is necessary for the development of the skills that underlie creative accomplishment, not that practice is sufficient for creative accomplishment. Production of masterworks
requires not only a large amount of practice, but also the coming together of a number of different sorts of external factors, many of which are independent of the amount of study and practice put in by a given individual. One’s works must be accepted by the professional decision makers and the audience before they become masterworks, that is, before they are put into books that survey the history of a field, where they will be found by cognitive psychologists looking for evidence of creative accomplishment. If, for example, George Martin at Parlophone records had not responded positively to the Beatles’ demonstration recordings that their manager played for him, then all their practice would have been wasted. These issues are discussed in more detail in Weisberg (1986, 1993; see also Csikszentmihalyi, 1988, 1996).

Thus, the strongest version of the hypothesis being examined here is that one will never find an individual who has made a significant contribution to a creative discipline without first having deep initial immersion in that discipline. If one can show that the Beatles spent close to the maximum amount of available time honing their skills, then one does not need to examine unsuccessful groups, because the relevant data come from successful individuals. Furthermore, although there may still be a question of whether playing the violin is a creative activity, Ericsson et al. (1993) did carry out an analysis that included control groups, in the sense that they assessed the amount of practice engaged in by violinists of different levels of accomplishment, and found that the higher-achieving violinists had practiced more.

Reexamination of Empirical Support for Tension View

Earlier in the chapter I briefly reviewed two pieces of evidence that seem to provide strong support for the tension view: the inverted-U-shaped relationship between formal education and creative accomplishment (Simonton, 1984), and laboratory studies of problem-solving set, that is, negative transfer when previously successful methods must be modified in response to changes in the situation (Frensch & Sternberg, 1989; Luchins & Luchins, 1959). Since those results are in conflict with the conclusion that, in creative work, practice makes perfect, it would be of value to consider them once again. These studies are only a small sample of evidence supporting the tension view. However, since they are obviously contradictory of the present conclusions, they are worth examining here, if only to demonstrate that support of the tension view is not as solid as it might seem.

Formal Education and Creative Accomplishment

Simonton’s (1984) study on its face provides strong support for the tension view, but a question remains. Simonton examined the relation between formal education and creative accomplishment over a lifetime, but that does not directly examine the relationship between knowledge and creativity. We do not know what the relationship is in creative individuals between formal education and knowledge in their fields. Formal education and knowledge might not be directly related, which would mean that Simonton’s results might not in actuality be contradictory to the present view.

It is informative to consider some of the cases included in the sample studied by Simonton. Darwin, for example, did not go beyond a bachelor’s degree. However, by the time he returned from the voyage of the Beagle, he probably had more first-hand knowledge about the development of species than anyone else in the world (Gruber, 1981). So although his formal education might have ended with the baccalaureate, his acquisition of knowledge did not. By the time he had created the theory of evolution through natural selection, he had been working on the problem for years. As another example, Faraday left school at age 14 to begin an apprenticeship to a bookbinder (Tweney, 1989). However, he had an interest in reading the books that he was binding, and over the next several years carried out a program of self-education. At the age of 23, he was able to obtain the post of assistant to Humphrey Davy, a scientist who served as his mentor in the development of his career, although Faraday soon went beyond Davy in accomplishment. However, Faraday’s accomplishment was based on deep knowledge of the scientific work of the day. Similarly, although Mozart had little in the way of formal education, his musical training began at a very early age and extended over a significant period of time before he made his mark.

One significant aspect of Simonton’s study is that he used a sample of eminent individuals born between 1450 and 1850. Knowledge changed significantly over that long stretch of time, and it is difficult to extrapolate to modern education based on conclusions drawn from educational levels of past centuries. For example, since scientific fields especially changed drastically over that time, it is not clear that someone obtaining a bachelor’s degree at the end of the nineteenth century had “the same amount” of education in his or her chosen field as did an individual who received a bachelor’s degree 300 years ago. That is, the earlier bachelor’s degree may have been closer to a modern-day Ph.D., as concerns knowledge about one’s field. It should also be noted that in the investigations of present-day neurologists and mathematicians by Bloom and co-workers (Bloom, 1985), all the participants had obtained the Ph.D.

Thus, although the relationship between formal education and creative accomplishment may be an inverted U, that does not necessarily contradict the view that the relation between knowledge and creativity is positive. Formal education and knowledge in one’s field can be independent.

Knowledge, Rigidity, and Creativity: Positive Transfer in Creative Thinking

There is no doubt that negative transfer in problem solving can be demonstrated in laboratory situations (Frensch & Sternberg, 1989; Luchins & Luchins, 1959). Participants experience difficulty when “deep” changes in a problem-solving situation demand that the thinker modify previously successful responses in a significant way. Furthermore, the degree of negative transfer seems to be a function of the amount of past experience in the situation; in such modified situations, expertise turns out to be a disadvantage.

There is, however, an important assumption that must be considered before we conclude that those laboratory demonstrations support the general claim that expertise is detrimental to creative thinking. Laboratory demonstrations of negative transfer are of interest because they are assumed to be microcosms of real-world situations. We are thus led to ask if creative thinking in the real world is in fact demanded by situations in which there have been “deep” changes, which would make one’s past experience detrimental. Or, when creative thinking occurs in the real world, are the situations only different on the surface from past situations, in which case past experience would be an asset? Or might some mixed circumstance hold?

If there are connections between present and past situations (i.e., if past and present situations differ only in surface attributes), then it would be useful for the thinker to use the past as the basis for responding to the present. Even if one’s knowledge is not totally applicable to the present situation, because the present is indeed different than the past, one’s knowledge would still be a reasonable place to begin. Furthermore, modifying one’s past experience to make it fit the unique aspects of the present situation would also be reasonable. Recent analyses indicate that, contrary to the assumption of “deep” change which underlies the tension view, many situations in which significant creative advances occurred were similar enough to old situations that knowledge from the old situation was usable (Weisberg, 1993, 1995b).
We can consider first the development of two of Picasso's most important paintings, Les Demoiselles d'Avignon and Guernica. In both cases, Picasso's initial sketches for the new work were based closely on earlier work, his own and that of other artists. The ideas in the sketches were then elaborated and extended, in one case radically, as Picasso worked further on the paintings. The radical change was in response to the work of other artists. However, in the present context, the important point is that the creation of these new works of art did not begin with a rejection of what had come before. Rather, the new work could be looked upon as an elaboration of what had come before. As well, Calder's development of mobiles (nonrepresentational moving sculpture, driven by the wind) was based on work he had done earlier, again elaborated as the result of his exposure to work by others.

Similar processes are seen in Edison's development of the electrical lighting system, to make his lightbulb practical as an in-home device. He used an extant system, that for natural gas lighting, as the basis for his new system. The Wright brothers' flying machine was also based on extant work, although in this case, that work was much more useful. The Wrights were therefore forced to rely on themselves to a large degree, and to work out many problems, large and small, that plagued their work. However, in this case too one does not find examples of free-associative thinking and the whole-hearted rejection of the past. The development of the steam engine and the cotton gin follow the same path.

These examples are but a few of many that could be cited to support the conclusion that creative thinking is firmly rooted in the past. Positive transfer of past experience can occur because many real-world situations that require creative thinking are not like a bridge game in which the low card from the last trick now leads (Frensch & Sternberg, 1995). However, some situations do involve deep changes, and are particularly informative in the present context.

A situation in which there turned out to be deep changes was the development by Watson and Crick of the double-helix model of DNA (Olby, 1974; Watson, 1968). Watson and Crick decided first of all that the structure of DNA might be a helix of some sort, based on earlier work by Linus Pauling, who long before had proposed that the structure of the protein alpha-keratin was helical. This decision served to focus Watson and Crick's investigation on specific questions of the structure, but the initial direction of their work came about through the adoption of Pauling's orientation. A straightforward extension of past work provided the basis for the creation of something new.

However, this discovery also involved negative transfer, which provides a case study of what happens in the real world when there has been a deep change in the situation. The double helix of DNA is formed by two phosphate-sugar "backbones" linked together in a structure similar to a spiral staircase, with the runs constructed out of pairs of nitrogen-rich bases (adenine, thymine, cytosine, and guanine). Before ultimately determining the correct base pairings (adenine with thymine, cytosine with guanine), Watson spent time considering the possibility of "like-with-like" pairings — adenine with adenine, thymine with thymine, and so on. One reason for Watson's interest in this possibility may have been his past experience with such structures in graduate school (Olby, 1974). Watson spent time attempting to work with the like-with-like scheme before it was rejected and the correct pairings were worked out, essentially by trial and error (Watson, 1968).

Several important points come from this example. First, there was negative transfer at the specific level of base pairings, but there was undoubtedly positive transfer overall. That is, without Watson and Crick's initial assumption that the molecule was a helix, which was positive transfer from Pauling's work, little or no progress would have been made. It is not possible in such a case to quantify the amount of positive versus negative transfer, but some relevant information can be gleaned from the behavior at the same time of Rosalind Franklin, another investigator who was studying the structure of DNA. According to several sources...

Creativity and Knowledge: A Challenge to Theories

(e.g., Olby, 1974; Watson, 1968), Franklin claimed that she was attempting to determine the structure with the fewest assumptions possible. That is, she may have been attempting to analyze the structure from the bottom up, without assuming anything about it as a working hypothesis. It may be significant that Franklin was not able to determine the structure of DNA before Watson and Crick. So, although this is obviously not an experimental study with a true control group, the results are consistent with the conclusion that positive transfer from similar situations involving analysis of organic macromolecules was on the whole helpful to Watson and Crick.

In addition, although there may have been negative transfer at one point in Watson and Crick's formulation of the double helix, it must be emphasized that the correct model was ultimately worked out. That is, any negative transfer was overcome. Watson did not respond like the participants in a water-jar-set experiment, who, through previous successes with problems with a complex solution, become incapable of solving a simple problem. When Watson was repeatedly unsuccessful in constructing a model with like-with-like pairings that could account for the relevant data, he (with input from Crick and others) rejected the like-with-like structure. Thus, the "blindness" of participants in water jar studies is not analogous to what happened in this case of creative accomplishment: Any set that might have existed was overcome.

It would be interesting to examine other cases from this perspective, to determine the frequency of positive versus negative transfer and to see where success and/or failure occurred. The fact that negative transfer was overcome in the case of the double helix, does not, of course, preclude cases in which negative transfer was strong enough to interfere with the ultimate discovery. No data are available at present to address this issue. The important conclusion for the present discussion, however, is that laboratory studies of negative transfer in problem solving may have only limited relevance to the broader study of creative thinking (see also Weisberg, 1995b).

Knowledge and Heuristics in Scientific Discovery. Simon and co-workers (e.g., Kulkarni & Simon, 1988; Langley, Simon, Bradshaw, & Zytkow, 1987) have proposed that scientific discoveries can be analyzed in terms of heuristics, some of which may develop out of immersion in the discipline. As one example, Kulkarni and Simon modeled Krebs's discovery of the ornithine cycle and concluded that half the heuristics in the model were based on past experience within the relevant domain. Furthermore, the particular advantage that Krebs possessed was his facility with a technique learned during his training.

Langley et al. (1987) have also argued that some scientific discoveries are the result of very general heuristics, which are not based on deep immersion in a domain of expertise. For example, in an analysis of Kepler's discovery of the three laws of planetary motion that bear his name, Langley et al. assume that all that was required were several heuristics concerned with patterns in sets of numbers. That is, knowledge concerning planetary motion was not at all relevant to the discovery of the laws. The computer model that was developed to simulate Kepler's discovery had no information about astronomy in its database.

Similarly, Dunbar (e.g., 1995) has carried out laboratory simulations of scientific creativity, in which naive undergraduates have been able to make scientific discoveries under controlled laboratory conditions. The students are given information corresponding to the results from experiments and are able to use a computer simulation to design and carry out further experiments of their own. Dunbar reports that participants in his studies are able to replicate the Nobel Prize-winning discovery by Monod and Jacob of regulator genes, which control the activity of other genes. The students are successful even though they are chosen because they lack anything but the most superficial knowledge in the domain of genetics.
simulations of the work of Jacob and Monod (Dunbar, 1995) raise interesting issues concerning how knowledge is used in creative thinking. First of all, these findings raise the question of whether it is always necessary to have immersion in the domain. If Kepler's discovery can be simulated with a computer model or by undergraduates with no knowledge of astronomy, then did Kepler need his knowledge? Similarly, if naive undergraduates can simulate Jacob and Monod's discovery, then why did Monod and Jacob need advanced training? One possibility is that Jacob and Monod needed their knowledge to understand the problem in the first place, as it existed in the world. That is, the undergraduates in Dunbar's (1995) study were given the very end of the whole enterprise. By that time, much work had already been done in analyzing the problem and setting up the relevant experiments, which could then be used in the simulation exercise.

It is also of interest to consider whether such simulations would be possible with other scientific problems. For example, could naive undergraduates discover the double helix? The discovery of the double helix involved several different components, among which were the number and position of the backbones, the structure of the backbone, the pitch of the helix, the positions of the bases, and the pairings of the bases. For all of these except the last, undergraduates would not know even where to begin. For example, in order to determine number and position of the backbones, one would have to know how to read x-ray diffraction patterns, and one would also have to know how they are obtained. None of this would be possible without expertise. Determining the base pairings, on the other hand, is little more than working out a simple jigsaw puzzle, once the problem has been narrowed down. Thus, different scientific problems may require different types of knowledge, which is an issue worth investigating further.

Rethinking the Relationship between Creativity and Knowledge: How is Knowledge Used in Creative Thinking?

If it is concluded for the present that creativity and knowledge are positively related, we are still left with the question of specifying how knowledge is actually used in creative thinking. Since most recent theorizing concerning creative thinking has been based on the tension view, the main concern has been with understanding how the thinker can break away from knowledge. Accordingly, little has been said about how knowledge is extended to new situations. Therefore, little in the way of specific proposals can be offered here, although some speculations are possible.

Knowing the Territory

Bailin (1988) has argued that, rather than being independent of the past, as James (1880), Hausman (1984), and others have claimed, even the most radically new creative products must be tied to the past. In Bailin's view, there can be no creativity if a product is not strongly rooted in the past, because in order for the audience to even understand the product, we must have some frame of reference, and this can only be supplied by the past. Without some sort of reference to the past, there would be no coherence: The product would make no sense to us.

Bailin's argument is framed from the perspective of the audience viewing the product, but we can easily extend it to the creative person as well. When a person makes some innovation, no matter how radical, in order for that product to make sense to the creator, he or she must be able to link it to what has been done before. Therefore, in order to have produced it in the first place, the thinker must have started with something from the past. And any changes introduced, which may serve to turn the product into something radically new, were probably also based on knowledge. How else could one know how to modify something? A related view is that if one does not know the discipline, one cannot go beyond it. It is reasonable to assume that all individuals engaged in creative fields are motivated to produce something new. Therefore, if they did not know what had been done, they could not move significantly beyond it. However, this does not provide a complete understanding for why years of immersion seem to be necessary for creative accomplishment. Would not simple familiarity do as well? If one were reasonably familiar with a domain, then one would be able to tell whether or not something were familiar. So we are still left with the question of why deep immersion is necessary.

Immersion Results in Automatic Processing

A different sort of possibility is that deep immersion provides extensive opportunities for practicing any skills, such as playing the piano, required to create within the domain, which makes them automatic. Automaticity of skills may be necessary for the production of novelty, for example, improvisation of new melodies. However, this speculation does not specify how automaticity leads to novelty. Perhaps when a skill becomes automatic, one can then allocate capacity to production of novelty. One does not have to think about how to express one's ideas, one can just do it as the ideas become available. This view proposes that the value of immersion is to perfect a skill, so that carrying it out does not drain capacity.

Deep immersion might also lead to development of heuristics. It might be that understanding the methods in some domains, such as the sciences, requires time because of their complexity. In order to understand x-ray diffraction, for example, one needs to know many different things, several of which are built on others, and so forth. As indicated earlier, at this point, little more than speculation can be offered concerning how knowledge is used during creative thinking.

What Are the Differences Between Creative and Noncreative Thinkers?

The conclusion that knowledge plays a positive role in creative thinking leads to a different perspective concerning the question of individual differences in creative thinking. Perhaps the basic difference between a creative and noncreative thinker, assuming equivalent levels of motivation, etc., is the knowledge that they bring to the situation. A related idea is that, if one takes the perspective of the creative thinker, we should be able to understand relatively directly where any creative idea came from. That is, if we knew what the creative thinker knew, we would be able to understand how the new idea came about. As an example, consider the following situation, discussed by DeBono (1968):

For many years physiologists could not understand the purpose of the long loops in the kidney tubules, it was assumed that the loops had no special function and were a relic of the way the kidney had evolved. Then one day an engineer looked at the loops and at once recognized that they could be part of a counter-current multiplier, a well-known engineering device for increasing the concentration of liquids. In this instance, a fresh look from outside provided an answer to something that had been a puzzle for a long time. (pp. 145–149)

On the basis of this sort of example, DeBono recommends that in order to solve a recalcitrant problem, one should adopt a fresh perspective, in this case that of the engineer. That is, in a classic statement of the tension view, one is urged to break away from one's knowledge. However, from the perspective of the engineer, there was nothing new involved: He
was able to apply his knowledge relatively directly to the new situation he was presented with, because of a straightforward relationship between what he saw and what he knew. For the engineer, this response was just another example of recognizing something familiar. The engineer's behavior can be explained by theories of pattern recognition; we do not need a theory of creativity to understand what he was able to do. It is only from the perspective of the perplexed physiologist that there is anything requiring explanation in terms of creative thinking.

Thus, if we can get into the database of the creative thinker, we may be able to understand creative thinking as a process based on the direct application of knowledge. It is only when we examine the situation from outside, as an ignorant observer, that we feel the necessity to postulate basic differences between creative and noncreative individuals. That is, it may not be necessary to assume that creative individuals differ from the noncreative in any significant way, except for the knowledge they possess.

As a specific example of how we can understand creative thinking without postulating anything in the way of exotic processes, we can consider again Watson and Crick's development of the double-helix model of DNA. A number of other well-regarded researchers, including Pauling, Maurice Wilkins, and Franklin, were also working on the structure of DNA. Why was it that Watson and Crick produced the structure, and these others did not? Based on the tension view, one might be led to speculate that something about Watson and Crick's mode of thinking or personalities allowed them to break away from previous knowledge and to develop the new. However, we have already seen that a cornerstone of Watson and Crick's work was available knowledge. There may be a direct answer to the question of why Watson and Crick were successful while the others were not: If one considers various components of the ultimate model of DNA, all of them were available to only Watson and Crick (Weisberg, 1993). Therefore, they were able to construct the model while the others were not.

Nothing further is required as far as explanation is concerned; one does not have to assume that Watson and Crick were different (or better) thinkers than the others. They simply had what was needed to develop the correct model of DNA, and the others did not. Although this explanation of the achievement of Watson and Crick may leave one unsatisfied ("Surely there is more to it than that!") if on the right track, it allows us to understand how at least one creative advance came about without postulating anything in the way of extraordinary aspects of the creative individual.

A related objection to this conclusion is the hypothetical example of the deeply knowledgeable person who does not produce significant creative work. An example is the individual who writes textbooks (thereby presumably demonstrating encyclopedic knowledge), but who does not produce innovation. However, the level of expertise needed to write a textbook is not the same as that developed through deep immersion in a discipline. People who write texts are not, under the present conception of knowledge (loose though it is), deeply knowledgeable. Of course, it is still possible that a deeply knowledgeable person might never produce innovation within his or her domain or expertise. As discussed earlier, knowledge is necessary, not sufficient, for creative achievement.

CONCLUSIONS

The present chapter argues that the relation between creativity and knowledge is much more straightforward than theories of creativity typically assume: One may be able to understand creative thinking by determining the knowledge that the creative thinker brings to the situation he or she is facing. The reason that one person produced some innovation, while another person did not, may be due to nothing more than the fact that the former knew something that the latter did not. Furthermore, this knowledge may not have been of an extraordinary sort. This view, if correct, means that we do not need special theories to explain creative thinking. Rather, we simply need a complete theory of thinking. Theories of creative thinking may be theories in search of phenomena to explain.

NOTE

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REFERENCES

13 Creativity and Intelligence

ROBERT J. STERNBERG AND LINDA A. O’HARA

What is the relationship between creativity and intelligence? Creativity has often been defined as the process of bringing into being something novel and useful. Intelligence may be defined as the ability to purposively adapt to, shape, and select environments (Sternberg, 1985a). Although there are many other definitions of both intelligence (see “Intelligence and Its Measurement,” 1921; Sternberg & Detterman, 1986) and creativity (see Cross, 1989; Pollock & Gardner, Chapter 11, this volume; Rotenberg & Hausman, 1976; Sternberg, 1988), these definitions tend to share at least some elements with these consensual definitions.

What about the relationship between the two? Ochs (1990) said, “If intelligence means selecting and shaping environments, it is creativity” (p. 104). In order to select or shape the environment to suit oneself, one requires the imagination to create a vision of what the environment should be and of how this idealized environment can become a reality. On the other hand, the ability to adapt to the environment — to change oneself to suit the environment — typically involves little or no creativity, and may even require one to suppress creativity, as when one realizes that adaptation to a school or job environment means keeping one’s creative ideas to oneself, or else risking a low grade or job evaluation. According to Gatzis and Csikszentmihalyi (1972), creativity and intelligence may represent different processes and intelligence may be required in widely varying degrees in different fields of creative endeavor. For example, a great amount of intelligence may not be needed to be a creative artist but certainly would be expected in a Nobel Prize-winning physicist. One could also say that creativity is required in widely different degrees in different fields of intelligent behavior.

Are creativity and intelligence the same or not? If not, how are they related, if at all? In this chapter, we will review work that covers the five possible answers to that question: (1) Creativity is a subset of intelligence; (2) intelligence is a subset of creativity; (3) creativity and intelligence are overlapping sets; (4) creativity and intelligence are essentially the same thing (coincident sets); and (5) creativity and intelligence bear no relation at all to each other (disjoint sets). All of these relations have been proposed. The most conventional view is probably that of overlapping sets, that intelligence and creativity overlap in some respects, but not in others. But the other views deserve serious attention as well.

We shall consider each of the relations in turn, realizing that these set relations are idealizations that cannot do justice to the complexity and richness of each theory or creativity. We shall limit our consideration primarily to theories and research on human intelligence, although, of course, artificial intelligence also can provide key insights into the nature of creativity (see, e.g., Boden, 1991, 1994; Johnson-Laird, 1988; Langley, Simon, Bradshaw, & Zytkow, 1987).