The Relationship of Intrinsic Motivation, Cognitive Style and Tolerance of Ambiguity and Creativity in Scientists

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THE RELATIONSHIP OF INTRINSIC MOTIVATION, COGNITIVE STYLE AND TOLERANCE OF AMBIGUITY AND, CREATIVITY IN SCIENTISTS

BY

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2001
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DEDICATION

To my mother, Eva Katz, for teaching me the importance of drawing outside the lines and to my father, David Katz, for shaping my nature so that I would have the ferocity to do so.
ABSTRACT

THE RELATIONSHIP OF INTRINSIC MOTIVATION, COGNITIVE STYLE, AND TOLERANCE OF AMBIGUITY, AND CREATIVITY IN SCIENTISTS

The relationship between creativity among scientists and the personality characteristics of tolerance of ambiguity, intrinsic motivation, and cognitive preferential style was investigated to determine if bivariate and multivariate relationships existed. The creativity of scientists is defined in terms of the novelty, resolution, and elaboration and synthesis found in their work products (Besemer, 1998; Besemer & O’Quin, 1993; O’Quin & Besemer, 1989, 1999).

A sample of 102 scientists participated in the study. Participants were requested to provide a description of a scientific work product developed specifically for the proposed study, which was in turn evaluated by the short form of the Creative Product Semantic Scale (CPSS) (personal communication, 2000), to determine levels of creativity. Participants completed the Tolerance of Ambiguity Test adapted by Kirton (1981), the Work Preference Inventory (WPI) (Amabile, Hill, Hennessey, & Tighe, 1994), the Kirton Adaption-Innovation Inventory (Kirton, 1976, 1999) in order to measure personality characteristics. Simultaneous multiple regression and Pearson correlation were performed to determine if any significant relationships existed between the personality indicators and the creativity displayed in the submitted products.

This study was unable to establish any significant correlations between the specified personality traits and the product developed by the scientist. Implications of the findings and further research are discussed.
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CHAPTER I

Introduction

The study was designed to determine the relationship between creativity among scientists and the personality characteristics of tolerance of ambiguity, intrinsic motivation, and cognitive preferential style. Creativity has been defined as "an ability to respond adaptively to the need for new approaches and new products" (Barron, 1989, p. 79). To insure the continued prosperity of the nation, it is essential that the creativity of the scientific and engineering talent pool be augmented (Mechlin & Berg, 1988; Stein, 1963; Tierney, Farmer, & Graen, 1999). Numerous scholars have suggested that it is the task of the psychologist to identify creative individuals for recruitment into the scientific and industrial communities (Barron, 1989; Eysenck, 1994; Feist, 1999; Perkins, 1994; Sternberg & Lubart, 1999).

To date, however, it appears that psychologists have done relatively little work in this field. Sternberg and Lubart (1996) reported that during the period from 1975 through 1994 less than one-half of one percent of the articles indexed in the Psychological Abstracts were concerned with creativity. Isaksen and Murdock (1993) suggested that there appears to be considerable resistance to the study of creativity within the field, and they argued that greater attention should be paid to this area of inquiry. This study was aimed at addressing this need.

The literature consistently attributes the personality traits of tolerance of
ambiguity (Hill & Amabile, 1993; Murdock, Isaksen, & Colemen, 1993), intrinsic motivation (Amabile, 1996, 1997), and cognitive preferential style (Clapp & DeCiantis, 1989; Cohen & Ambrose, 1999; Kirton, 1994; Kirton & Pender, 1982; Martinson, 1993) to the successful scientist. However, there is little convincing empirical evidence of these hypothesized relationships, due primarily to the lack, until quite recently, of a valid and reliable criterion measure of creativity (Amabile, 1996; Cooper, 1991; Treffinger, 1993).

Over the years, efforts to develop a valid measure of an individual’s creativity have focused on the evaluation of aspects of creativity as manifested in the products which the individual produces (Besemer & O’Quin, 1986, 1987; Besemer & Treffinger, 1981; MacKinnon, 1978; Parke & Brynes, 1984; Taylor & Sandler, 1972). More recently, the Creative Product Semantic Scale (CPSS) has been shown to be a valid and reliable tool for assessing three salient dimensions of creativity as displayed in products: (a) novelty, (b) resolution, and (c) elaboration and synthesis (Besemer, 1987; Besemer & O’Quin, 1993; O’Quin & Besemer, 1989, 1999). The CPSS appears to be well suited to the evaluation of the creativity displayed in scientists’ products (O’Quin, K. & Besemer, 1999). Currently, Besemer is developing a short form of the CPSS which allows the convenient assessment of these three dimensions of creativity on the basis of judges’ ratings of products on just nine 7-point adjective rating scales (Besemer, personal communication, 2000). Accordingly, this study has been designed to employ the CPSS as a criterion measure of scientific creativity, and to determine the relationships between the aspects of scientists’ creativity measured by the CPSS and the scientists’ scores on measures of tolerance of ambiguity,
intrinsic motivation, and cognitive preferential style.

The rationale which follows will detail the theoretical basis for the relationships hypothesized between the dimensions of creativity measured by the CPSS and the personality constructs of tolerance of ambiguity, intrinsic motivation, and cognitive preferential style.

Theoretical Rationale

Tolerance of Ambiguity

Several theorists have cited tolerance of ambiguity as a personality characteristic crucial to creativity. Dacey (1989) suggested that tolerance of ambiguity is the personal attribute most vital to the creative process. Dacey argued that individuals who cannot tolerate ambiguity tend to cope with ambiguous problem-solving situations by arbitrarily imposing familiar rules or procedures which are comforting, but which restrict the opportunity for novel solutions. In contrast, individuals who can tolerate ambiguity do not foreclose their options by imposing arbitrary structure. Therefore, these individuals keep open the possibility of novel, unexpected, and unconventional solutions. Dacey also noted that tolerance for ambiguity is highly correlated with risk-taking, another characteristic associated with the production of novel approaches to problem-solving situations.

Other theorists have stressed that individuals who are able to tolerate the stress of ambiguity tend to be able to work on problem-solving tasks for long periods of time without either knowing the solution or having any type of closure (Amabile, 1993; Lavey, 1993; Murdock, Isaksen, & Coleman, 1993; Runco, 1993). One would
certainly expect that the ability to continue to confront a difficult problem in a meaningful manner for an extended period of time would be related positively to the ultimate discovery of creative solutions.

Several investigators have developed and/or revised measures of tolerance of ambiguity (Budner, 1962; Kirton, 1981; MacDonald, 1970; Rydell & Rosen, 1966). Kirton (1981) reanalyzed the items contained in earlier scales developed by Budner (1962) and MacDonald (1970) and reported acceptable reliability for a reduced set of 18 items. However, empirical studies of the relationship between tolerance of ambiguity and measures of creativity have yielded only limited support for this relationship (Sternberg & Lubart, 1995).

**Intrinsic Motivation**

Amabile (1987) suggested that:

people are most creative when they are motivated primarily by passionate interest in their own work. This passionate interest is called intrinsic motivation-- the motivation to work on something primarily for its own sake, because it is enjoyable, satisfying, challenging, or otherwise captivating. (p. 224)

One could conceptualize intrinsic motivation as the positive motivating force of the creative individual. Whereas the ability to tolerate ambiguity allows the individual to remain actively involved with a problem-solving situation that may have uncertain resolution; intrinsic motivation provides the force necessary to result in creative production.
Amabile, Hill, Hennessey, and Tighe (1994) developed and validated the Work Preference Inventory (WPI) to measure intrinsic and extrinsic motivational orientations in employees. These investigators also reported significant positive linear correlations in a student sample between the intrinsic motivation scale of the WPI and several measures of creativity, including the Creative Personality Scale (CPS; Gough, 1979), a standardized product rating form, creativity ratings assigned to students by judges, and creativity ratings assigned to students by their instructors. However, when Lubart and Sternberg (1995) studied the relationship between intrinsic motivation and creativity among adult workers, they found a curvilinear relationship, such that the workers who were rated most creative were those near the middle of the distribution of scores on intrinsic motivation. The discrepancy between the findings reported by Amabile and her associates (1994) and those reported by Lubart and Sternberg (1995) may be due to differences in the nature of the samples or to differences in the measures of creativity employed in the two studies.

Cognitive Preferential Style

Kirton (1994) suggested that creativity is related to the individual's cognitive style preferences. Kirton conceptualized cognitive preferential style as a bipolar continuum with “adaptors” at one end of the continuum and “innovators” at the other. Adaptors prefer to problem solve and arrive at decisions on the basis of conventional procedures and group consensus. In contrast, innovators prefer to break away from existing paradigms and adopt new methods or viewpoints. Kirton described the adaptor as “more left-brain dominated” than the innovator, and as inclined to
perceive himself as "intolerant of ambiguity and inflexible" (1994, p. 28).

Kirton (1976, 1977, 1999) developed the Adaption-Innovation Inventory (KAI) to measure cognitive preferential style. Several investigators have reported significant relationships between scores on the KAI and various measures of creativity and related constructs (Clapp & DeCiantis, 1989; Goldsmith, 1984; Masten & Caldwell-Colbert, 1987). However, these studies have been criticized on the ground that the measures of creativity employed were not theoretically distinguishable from the cognitive style dimension measured by the KAI (Fleenor & Taylor, 1994; Stein, 1990).

Statement of the Problem

The inconsistent findings reported to date with respect to the relationships between creativity and the personality characteristics of tolerance of ambiguity, intrinsic motivation, and cognitive preferential style may be attributable in large measure to methodological problems, and particularly to the previous lack of a valid and reliable criterion measure of creativity. The development and validation of the CPSS, and particularly the short form of the CPSS, appears to have ameliorated this measurement obstacle.

Accordingly, this study has been designed to examine the relationships between the personality characteristics of tolerance for ambiguity, intrinsic motivation, and cognitive preferential style and creativity as measured by the CPSS. Due to the particular importance of creativity among scientists, the proposed study will focus on creativity as measured in scientists' products.
Hypotheses

H1: Tolerance of ambiguity, measured by Kirton’s Revised Tolerance of
Ambiguity Instrument, will be positively related to CPSS scores for product (a)
novelty; (b) resolution, and (c) elaboration and synthesis.

H2: Intrinsic motivation, measured by the intrinsic motivation subscale of the
Work Preference Inventory, will be positively related to CPSS scores for product (a)
novelty, (b) resolution, and (c) elaboration and synthesis.

H3: Scientists classified as innovators on the basis of KAI scores will score
significantly higher than scientists classified as adaptors on CPSS subscales
measuring product (a) novelty, (b) resolution, and (c) elaboration and synthesis.

RQ1: Will the following linear combination of predictors, tolerance of
ambiguity, intrinsic motivation, and cognitive preferential style, explain the greatest
proportion of variability in CPSS scores for product novelty than by any one of these
predictors alone?

RQ2: Will the following linear combination of predictors, tolerance of
ambiguity, intrinsic motivation, and cognitive preferential style, explain the greatest
proportion of the variability in CPSS scores for product resolution than by any one of
these predictors alone?

RQ3: Will the following linear combination of predictors, tolerance of
ambiguity, intrinsic motivation, and cognitive preferential style, explain the greatest
proportion of the variability in CPSS scores for product elaboration and synthesis
than by any one of these predictors alone?
Definition of Terms

For the purposes of this study key variables has been both conceptually and operationally defined as follows:

1. **Creativity:** is defined as the ability to respond adaptively to the need for new approaches and new products. Operationally, creativity is defined by scores on the three subscales of the Creative Products Semantic Scale (CPSS; Besemer, 1987; Besemer & O’Quin, 1993; O’Quin & Besemer, 1989, 1999). The CPSS subscales measure the creativity manifested in products produced by individuals along the dimensions of (a) novelty, (b) resolution, and (c) elaboration and synthesis.

   O’Quin and Besemer (1999) defined novelty as referring to “the newness of a product, the extent to which it is original or statistically infrequent” (p. 413). Resolution was defined as the “product’s value or usefulness, or the extent to which it solves a problem” (1999, p. 413). Elaboration and synthesis, also referred to as “style,” refers to the extent to which the product is “well-crafted or elegant” (1999, p. 413).

2. **Tolerance of ambiguity:** is defined as the ability to work on a problem for extended periods of time without knowing the solution to the problem or otherwise achieving closure (Hill & Amabile, 1993; Murdock, Isaksen, & Coleman, 1993; Runco, 1993). Operationally, tolerance of ambiguity is defined by scores on the Revised Tolerance of Ambiguity Instrument (Kirton, 1981).

3. **Intrinsic motivation:** is defined as the desire to work on a task for its own sake, because the work itself is enjoyable, satisfying, and/or challenging.
Operationally, intrinsic motivation is defined by scores on the intrinsic motivation subscale of the Work Preference Inventory (WPI; Amabile, Hill, Hennessey, & Tighe, 1994).

4. **Cognitive preferential style:** is defined as a continuum describing individuals which ranges from adaptors to innovators. Adaptors "conform to established organizational rules and authority" (p. 884) whereas innovators "proliferate ideas and try to implement them despite organizational resistance" (Kirton & Pender, 1982, p. 885). Operationally, cognitive preferential style is defined by scores on the Adaption-Innovation Inventory (KAI; Kirton, 1980, 1994).

Delimitations

The following represents the delimitations of this study:

1. The proposed study is limited to the population of scientists who have been employed for at least two years in a large research and development organization. The findings will not be generalizable to workers in other professions or other organizations, who will have had different professional socialization experiences and/or different organizational cultures.

2. The proposed study is also limited to the particular measure of creativity and the particular predictors of creativity selected. There are alternative approaches to the assessment of creativity, and there are certainly other personality variables and environmental factors which could influence the creative output of scientists. Furthermore, the proposed study will not assess or control for the effects of differences in IQ and training.
3. The proposed study is correlational in nature, since the predictors and
the criterion measures are obtained at a single point in time and are not manipulated
by the investigator. Accordingly, should the hypotheses be confirmed, it will not be
possible for the investigator to draw conclusions with respect to direction of
causality.
CHAPTER II

Review of the Literature

This study examined relationships between creativity among scientists and the personal characteristics of tolerance of ambiguity, intrinsic motivation, and cognitive preferential style. In this chapter, the literature relevant to these relationships was reviewed. The review has been organized under five headings as follows: (a) conceptualizing creativity, (b) measuring creativity, (c) tolerance of ambiguity, (d) intrinsic motivation, and (e) cognitive preferential style.

Conceptualizing Creativity

Until recently, there has been little consensus regarding either the definition or the measurement of creativity (Besemer & O’Quin, 1993; Cooper, 1991; Dreydahl, 1964; Isaksen & Brian-Dorval, 1993; Murdock & Puccio, 1993; Simonton, 1988; Treffinger & Poggio, 1972). Several investigators have even asked whether creativity can be considered a definable construct (Sternberg & Lubart, 1991; Treffinger & Poggio, 1972). According to Sternberg and Lubart (1999), scientific approaches to the definition of creativity may be summarized under four headings: (a) psychometric approaches; (b) cognitive approaches; (c) social-personality approaches; and (d) confluence approaches. In this section of the review, each of these approaches was described and evaluated.
Psychometric Approaches

Current scientific interest in creativity may be traced to Guilford’s (1950) address to the American Psychological Association, in which he lamented the lack of research in this important area. Guilford argued that we generally associate creativity with great artists or eminent scientists, and he suggested that research on creativity had been limited by the fact that such creative individuals are rare and difficult to study in the psychology laboratory. He therefore proposed an alternative paradigm for the study of creativity, one in which individuals from the general population could be studied using paper-and-pencil tests. One such test noted by Guilford was the Unusual Uses Test (Wilson, Guilford, & Christensen, 1953), which requires participants to list as many uses as they can for a common object, such as a paper clip or a brick. The concept of creativity implicit in this test is that of “divergent thinking,” the ability to produce large numbers of unusual ideas in response to a stimulus.

Torrance (1974) carried on this work, developing the Torrance Tests of Creative Thinking. These tests included: (a) the Asking Questions Test, in which respondents view a drawing of a scene and write down all the questions that they can think of pertinent to that scene; (b) the Product Improvement Test, which requires respondents to indicate as many ways as possible to change a toy so that children will have more fun playing with it; (c) the Unusual Uses Test, which ask participants to list interesting and unusual uses for a cardboard box; and (d) the Circles Test, which asks respondents to expand empty circles into different drawings and title these drawings. All the Torrance Tests can be scored for fluency (total number of relevant
responses), flexibility (the number of different categories of relevant responses), originality (the statistical rarity of the responses) and elaboration (the amount of detail provided in the responses).

Amabile (1983) criticized Torrance’s approach to the definition and measurement of creativity as not representing adequately the actual meaning of creativity. It was also argued that one cannot really study creativity in samples drawn from the general population, since the great majority of individuals in these samples would not be considered to be creative (Sternberg & Lubart, 1999).

Cognitive Approaches

Finke, Ward & Smith (1992) presented a cognitive approach to the concept of creativity. They suggested that creative thinking involves a number of cognitive processes, including retrieval, association, synthesis, transformation, analogical transfer, and categorical reduction. Similarly, Wiesberg (1995) suggested that creativity involves the use of ordinary cognitive processes to produce extraordinary products.

While the cognitive approach to the definition of creativity appears to have merit from the point of view of construct validity, there are obvious difficulties associated with the measurement of the internal cognitive processes that are assumed to underlie the creative process. For this reason, Finke (1990) ended up measuring creativity by evaluating the results produced by participants engaging in an experimental creativity exercise. For example, participants might be presented with several different objects, such as a circle, a cube, a parallelogram, and a cylinder. The
participants are asked to imagine combining these objects to produce a practical
object. The objects thus produced are then rated by judges for practicality and
originality. While this approach to the measurement of creativity also appears to have
face validity, it is clear that the rated originality of the products does not establish the
role of the hypothesized underlying cognitive processes in arriving at the creative
products.

**Social-Personality Approaches**

Other investigators have focused on personality variables, motivation, and
environmental factors in attempting to understand creativity (Amabile, 1983; Barron,
Some investigators have noted that creative individuals tend to be characterized by
specific personality traits, including self-confidence, the willingness to take risks, and
the ability to tolerate ambiguity (Barron & Harrington, 1981; Hill & Amabile, 1993;
Sternberg & Lubart, 1999). Others have reported that intrinsic motivation is an
essential element of creativity, since it allows the individual to remain on task in
problem-solving situations for long periods of time (Amabile, 1983; Hennessey &
Amabile, 1988). Finally, several investigators have noted that aspects of the social
environment are related to the emergence of creativity (Amabile, 1997, Lubart, 1995

Sternberg and Lubart (1999) have noted that very few studies have considered
both cognitive and social-personality correlates of creativity, asserting that “the
cognitive work on creativity has tended to ignore or downplay the personality and
social system, and the social-personality approaches have tended to have little or nothing to say about the mental representations and processes underlying creativity" (p. 9). However, recent theoretical work on creativity has emphasized that specific conditions must be present in several different domains in order for creativity to emerge (Amabile, 1983; Csikszentmihalyi, 1988, 1996; Sternberg & Lubart, 1991, 1995, 1996). These "confluence" conceptualizations of creativity are considered in the paragraphs that follow.

Confluence Approaches

Amabile (1983, 1996) described creativity as the confluence of domain-relevant knowledge and abilities, creativity-relevant skills, intrinsic motivation, and social environment. Creativity-related skills include a cognitive style that allows one to cope with complexities and break with one's normal mental set during problem-solving, knowledge of techniques and approaches conducive to the generation of novel ideas, such as trying counterintuitive approaches, and a work style characterized by concentrated effort and high energy.

Csikszentmihalyi (1988, 1996) utilized a systems approach to creativity, emphasizing the reciprocal interaction of the individual, the domain, and the field. The domain is a culturally defined symbol system, which preserves and transmits creative products to other individuals and future generations. Examples include the publishing industry in general, the theater industry, the retail art industry, professional associations representing specific academic and professional disciplines, and the scholarly journals associated with such associations. The field consists of the people
who control or influence a domain, including such individuals as editors, critics, gallery owners, the scholars who referee articles submitted to journals, and the policy makers in industry who make decisions regarding which ideas to pursue and put into production. According to Csikszentmihalyi (1996) creative individuals draw upon their knowledge of a particular domain and transform or extend this knowledge through the application of their cognitive skills, personality traits, and motivation.

Another confluence theory of creativity is that presented by Sternberg and Lubart (1991, 1992, 1995, 1996), which they refer to as the “investment” theory of creativity. They suggested that creative individuals are willing and able to “buy low and sell high” in the realm of ideas. Buying low means pursuing and developing ideas and theories that are unknown or out of favor but that have growth potential. Often, when these ideas are presented initially, they encounter considerable resistance in the field. Sternberg and Lubart (1991) argued that creative individuals persist in the face of such resistance and eventually “sell high” (i.e., gain the acceptance of the field for the ideas). Then these creative individuals move on to develop the next new or unpopular idea or theory.

Sternberg and Lubart (1991, 1995) suggested that such creativity results from the confluence of six distinct, but inter-related resources: (a) intellectual abilities, (b) knowledge, (c) styles of thinking, (d) personality, (e) motivation, and (f) the environment. With regard to intellectual abilities, Sternberg (1985) argued that three are particularly important: (a) the synthetic ability to see problems in new ways and to escape the bounds of conventional thinking; (b) the ability to differentiate between ideas that are worth pursuing and those that are not; and (c) the ability to persuade
others that one's ideas are of value.

With respect to the knowledge component of the investment theory of creativity, Frensch and Sternberg (1989) suggested one needs to know something about the current state of a given field in order to move that field forward. On the other hand, extensive knowledge of a particular field can lead to a closed and entrenched perspective, interfering with the individual's ability to move beyond the way in which he or she has viewed problems in the past.

In terms of thinking style, Sternberg (1988) argued that creative individuals tend to manifest a "legislative" cognitive style, which is characterized by a preference for thinking in novel ways of one's own choosing. This preference is distinct from the ability to think creatively described above under the heading of Cognitive Approaches, because it does not focus on the relative efficiency of the individual's various cognitive processes. Rather, emphasizes the individual's thinking style. Clearly, however, an individual may like to think along new lines, but may not come up with very creative ideas. Sternberg also suggested that creative thinkers tend to have the ability to "think globally as well as locally, distinguishing the forest from the trees and thereby recognizing which questions are important and which ones are not" (Sternberg & Lubart, 1999, p. 13).

With regard to the role of personality attributes, the investment model posits that several attributes contribute to creativity. These attributes, summarized by Lubart (1995), include self-efficacy, the willingness to take sensible risks, and the ability to tolerate ambiguity. The concept of buying low and selling high implies the willingness to go against the crowd. One must be willing to defy convention if one
hopes to think and act creatively. One must also be willing and able to convince others of the veracity and value of the ideas or theory being developed.

In terms of motivation, Sternberg and Lubart (1995, 1999) drew upon the work of Amabile when they included intrinsic motivation as a factor that must be present for creativity to emerge. Amabile (1983, 1996) noted that individuals rarely do creative work unless they really love what they are doing and concentrate their attention on the work itself, rather than the potential rewards to be derived from the work.

The final element of the investment theory of creativity is the environment. Creativity is fostered by an environment that supports and rewards creativity. Sternberg and Lubart (1999) pointed out that “One could have all of the internal resources needed in order to think creatively, but without some environmental support (such as a forum for proposing those ideas) the creativity that one has might never be displayed” (p. 13). Environmental support may be present on many levels, including the individual work group, the organization, and society at large.

Lubart and Sternberg (1995) provided some empirical evidence in support of their investment theory of creativity. They obtained peer ratings of the creative performance of 48 adults in each of four creativity domains, including drawing, writing, advertising, and science. They also obtained measures of five of the six resource areas specified in the theory (all except the environment). Lubart and Sternberg found correlations among creative performance ratings across the four creativity domains ranging from .23 to .62, with a median of .36. These low correlations were interpreted as indicating that creativity is relatively domain-specific.
Lubart and Sternberg (1995) regressed creative performance ratings in each creativity domain on the predictors representing the five resource areas. The multiple correlations obtained in these regressions ranged from .61 in the case of drawing to .73 in the case of advertising. All four regressions were significant ($p < .01$ or beyond). In addition, Lubart and Sternberg calculated an overall measure of creative performance and regressed this overall measure on the five predictors. The multiple correlation obtained in this analysis was .83 ($p < .001$). Each of the five resource areas was correlated significantly with the overall creativity measure. These zero-order correlations ranged from .36 ($p < .05$) in the case of the personality resource and measure to .75 ($p < .001$) in the case of the intellectual processes resource measure.

Until recently, a case could be made that there was no consensus regarding how to conceptualize creativity, but it now appears that there is growing acceptance of the confluence approaches. The findings reported by Sternberg and Lubart (1995) clearly support the investment model of creativity, which conceptualizes creativity as the confluence of resources from diverse domains.

Measuring Creativity

Not surprisingly, efforts to measure creativity have paralleled efforts to define the construct. Treffinger and Poggio (1972) noted that the lack of an accepted definition of creativity precluded the development of an instrument of demonstrable validity. They asked, “Does creativity represent a unitary psychological construct, comprised of a specific set of basic aptitudes and traits which are common across a
variety of creative expressions? Or are there 'many creativities,' each comprised of a unique structure of aptitudes and traits?" (p. 254). The evidence of relative domain specificity with respect to creative performances noted above in connection with the investment model of Sternberg and Lubart (1991) would appear to support the latter view. This in turn would suggest the need for many different approaches to the measurement of creativity.

Indeed, the early efforts to assess creativity did involve a variety of different approaches. Hocevar (1981) reviewed the literature on the measurement of creativity, and he concluded that there were ten distinct categories of creativity tests, including: (a) tests of divergent thinking; (b) attitude and interest inventories; (c) personality inventories; (d) biographical inventories; (e) teacher nominations; (f) peer nominations; (g) supervisor ratings; (h) judgments of products; (i) eminence; and (j) self-reports of creative activities and achievements.

Tests of divergent thinking have been discussed in the section on Guilford's (1950) and Torrance's (1974) work on creativity. However, since then a large number of tests of divergent thinking have been developed. Cooper's (1991) critique of these tests included, in addition to the Torrance Tests, the Creativity Assessment Packet (1980), the Structure of Intellect Learning Abilities Test (SOI-LA) (1985), Thinking Creatively with Sounds and Words test (1973), the Thinking Creatively with Action and Movement test (1981), and the Khatena-Torrance Creative Perception Inventory (1976). As previously noted, Amabile (1983) was critical of tests of divergent thinking, because they do not represent adequately the construct of creativity. Cooper (1991) concurred with this view, suggesting that none of these
tests of divergent thinking had clear face validity as a measure of creativity in a broad sense.

Attitude, interest, and personality inventories have sometimes been used in assessing creativity, based on the theory that there are specific attitudes and personality traits that are characteristic of creative individuals. Amabile (1983) reviewed several instruments containing scales that had been linked to creativity, including Gough's California Psychological Inventory (Helson, 1965), Cattell's Sixteen Personality Factor Questionnaire (Cattell & Butcher, 1968), and Gough and Heilbrun's Adjective Check List (Gough, 1979). Amabile (1983) argued that these inventories had not been developed to measure creativity and therefore, that they were all of questionable validity for this purpose.

Biographical inventories and self-reports of creative activities and achievements have been praised on the ground that individuals know more about themselves than others do (Hocevar, 1981). On the other hand, self-report measures are subject to social desirability response set bias, the tendency to depict us in a positive light. Accordingly, Wakefield (1991) suggested the use of self-report measures that describe the characteristics of creativity without directly labeling these characteristics as such. In this way, the tendency to over-report activities considered desirable can be minimized.

With respect to the assessment of creativity among scientists, the use of nominations by teachers, peers, and supervisors has been recommended by Mansfield and Busse (1981). These authors also recommended the use of the Science Citation Index (Mansfield & Busse, 1981) as a measure of creativity, since this index is "one
indicator of the extent to which a scientist's work has influenced other scientists" (1981, p. 15). Hertz (1999) suggested that "another definition of invention comes from the Patent Office, which states that invention is something that is novel and useful: novel, meaning something that someone skilled in the particular field would not know, and useful, meaning that it has some practicality" (p. 95).

However, in assessing scientific creativity, an increasing number of investigators have been focusing on the scientist’s creative products as the criterion (Amabile, 1990; Besemer, 1987; O'Quin & Besemer, 1989; Torrance & Presbury, 1984). The products are rated by experts within the domain. According to Amabile (1990), "A product or response is creative to the extent that appropriate observers independently agree it is creative" (p. 49). Appropriate observers are those familiar with the domain in which the product was created or the response articulated.

Investigators employing consensual assessment approaches to the measurement of creativity in products have reported inter-judge correlations ranging from .56 to .87 (Getzels & Csikszentmihalyi, 1976; Hennessey & Amabile, 1999). Amabile (1996) argued these inter-judge reliabilities demonstrate the construct validity of the criterion of creativity.

Besemer and O'Quin (1993) developed the Creative Product Semantic Scale (CPSS) to allow judges to rate creative products along three dimensions: novelty, product resolution, and elaboration and synthesis. A product is novel when it is germinal and also statistically infrequent. A product has resolution when the product is adequate and useful. A product has elaboration and synthesis when it is organic (e.g., integrative), elegant, complex, understandable, and well-crafted.
Besemer (1987) requested Norwegian high school students \((n = 128)\) to rate each of three creative products (three different designs for chairs) using the CPSS. The CPSS employs nine rating scales to assess the three dimensions of creativity noted above. Novelty is comprised of "original" and "surprising." Resolution is assessed by four scales: "valuable," "logical," "useful," and "understandable." Elaboration and Synthesis is assessed by three scales: "organic," "elegant," and "well-crafted." Factor analysis of the nine rating scales confirmed the three-factor structure and indicated that each scale loaded on the expected dimension. A multivariate analysis of variance comparing the three stimulus chairs on the three dimensions of creativity indicated significant differences in rated creativity in all three areas.

This approach to the measurement of creativity through ratings of creative products represents an elegant approach that provides both valid and reliable assessments. It appears that the CPSS can be used by experts in a given field or by members of the general population (as in the case of the Norwegian high school students). This proposed study will use this approach.

Tolerance of Ambiguity

Tolerance of ambiguity is demonstrated by an individual’s ability to work on a problem for an extended period of time without knowing the solution, without having a prescribed procedure to go through to reach the solution, and without otherwise gaining closure (Budner, 1962; Hill & Amabile, 1993; Lavey, 1993; Murdock, Isaksen, & Coleman, 1993; Runco, 1993).
Two recent discussions of personality factors associated with creativity have placed special emphasis on the importance of tolerance of ambiguity to creativity. Amabile (1983) focuses on the following personality factors as stimulants to the creative act: tolerance of ambiguity, stimulus freedom (i.e., the ability to break away from conventional rules of procedure), functional freedom (demonstrates unusual uses for objects to solve problems), flexibility, risk-taking, preference for disorder, delay of gratification, positive attitude toward hard work, androgyny, and positive feelings about being different. Amabile described tolerance of ambiguity as an essential component of the “creative work style.”

Creative work style as described by Amabile (1990) by the ability to concentrate over long periods of time, the ability to move away from present repeatedly unresolved problems, persistence in the face of difficulty, and high levels of energy. The ability to tolerate ambiguity is critical to concentration over extended periods of time and to persistence in the face of difficulty.

Dacey (1989) listed eight personal qualities of the creative individual: stimulus freedom, tolerance of ambiguity, functional freedom, flexibility, risk-taking, preference for disorder, delay of gratification, and androgyny. Dacey specifically identified tolerance of ambiguity as the personality characteristic most essential to the creative process, whereas the other seven traits are secondary. Several investigators have shown that the willingness to take moderate risks is associated with tolerance of ambiguity (Amabile, 1983; Dacey, 1989; Sternberg & Lubart, 1991, 1992, 1995). Dacey defined an ambiguous situation as one that provides no frame of reference through which to make decisions and take actions. An individual who is able to
tolerate ambiguity will not assume that rules exist when a situation is ambiguous. In contrast, a stimulus-bound individual will tend to apply irrelevant procedures, simply to provide structure.

Efforts to measure tolerance of ambiguity may be traced to Budner (1962) who studied intolerance of ambiguity and other personality factors among medical professionals of various subdisciplines. For the purpose of his study, Budner developed a brief subscale to assess intolerance of ambiguity, as well as subscales to measure dogmatism, inflexibility, conservativeness, extra-punitiveness, and intro-punitiveness. Although Budner found significant differences among physicians within different specialties on the intolerance of ambiguity scale, his measure was criticized by Kirton (1981) as lacking a clear definition of the construct of intolerance of ambiguity and containing an insufficient number of items to provide a reliable tool.

Kirton (1981) studied the psychometric characteristics of the Intolerance of Ambiguity instrument developed by Budner (1962) and a subsequent measure of intolerance of ambiguity that was developed originally by Rydell and Rosen (1966) and modified later by MacDonald (1970). Kirton administered these two tests to a sample of 562 adults, along with the Rokeach Dogmatism Scale (Rokeach, 1960), the Gough California Psychological Inventory Inflexibility Scale (1956), and the Wilson and Patterson Conservatism Scale (1968). Kirton performed an item analysis on the pooled items from these five inventories.

Based on the item-total correlations obtained in his analysis, Kirton selected a subset of 18 items representing intolerance of ambiguity. Seven of the items were
drawn from the Budner instrument, and 11 were drawn from the measure developed by Rydell and Rosen. Kirton reported an internal consistency reliability coefficient of .65 for the 7-item version of the Budner Instrument, and an internal consistency reliability coefficient of .71 for the 11-item version of the instrument developed by Rydell and Rosen. Kirton did not report an overall reliability coefficient for the total scale.

Thus there is substantial theoretical agreement with respect to the importance of tolerance of ambiguity to creativity. There is also a limited amount of empirical data indicating a relationship between tolerance of ambiguity and measures of creativity or related constructs (Hill & Amabile, 1993; Sternberg & Lubart, 1995).

However, it should be noted that further research must be carried out to demonstrate that this personality trait is essential to creativity among scientists. One certainly would expect this might be the case, since it appears axiomatic that individuals who can tolerate ambiguity was more likely avoid premature closure in problem-solving situations. This in turn would be expected to lead to more creative outcomes.

Intrinsic Motivation

A number of empirical studies have indicated significant relationships between intrinsic motivation and creativity (Amabile, 1990; Amabile & Gryskiewicz, 1987; Garfield, Cohen & Roth, 1969; Helmrich & Spence, 1978; Hyman, 1964; Nicholls, 1972; Poole, Williams, & Lett, 1977; Sternberg & Lubart, 1991). Amabile’s (1983) confluence theory of creativity specified that creativity is the resultant of domain-relevant skills, creativity-relevant skills, intrinsic task motivation,
and a favorable social environment. Amabile (1987) considered intrinsic motivation to be an extremely important predictor, stating that:

the unifying theme in all my research is that people was most creative when they are motivated primarily by a passionate interest in their own work. This passionate interest is called intrinsic motivation—the motivation to work on something primarily for its own sake, because it is enjoyable, satisfying, challenging, or otherwise captivating. (p. 224)

Amabile (1990) expanded upon her perspective on the role of intrinsic motivation in creativity citing Harter’s (1978) theory of “effectance motivation.” According to Harter’s theory, individuals experience a need to be competent, and they experience a great sense of satisfaction when they feel that they are effective. Failure experiences tend to decrease the intrinsic motivation for competence, while success experiences tend to increase this motivation. While intrinsic motivation does not cause one to be creative, intrinsic motivation serves as a necessary stimulator. Also relevant to Amabile’s (1996) intrinsic motivation hypothesis of creativity is her definition of the trait, which encompasses “independence, an absence of conformity in thinking and dependence on social approval” (p. 90).

Amabile, Hill, Hennessey, and Tighe (1994) developed the Work Preference Inventory to assess intrinsic and extrinsic motivation in the work environment. The operational definition of intrinsic motivation in this instrument is motivation based on self-determination (preference for choice and autonomy), competence (mastery orientation and preference for challenge, task involvement), curiosity (preference for the complex), and interest (enjoyment and fun). In contrast, extrinsic motivation is
defined as indicated by concerns with competition, evaluation, recognition, and tangible returns.

Factor analysis of the Work Preference Inventory indicated that intrinsic and extrinsic motivation domains are orthogonal. Thus, there is nothing to preclude an individual who has a high level of intrinsic motivation from being concerned about tangible rewards as well.

Cognitive Preferential Style

Kirton (1994) described cognitive preferential style as a bipolar continuum. At one end of this continuum is the adaptor and at the other end is the innovator. Adaptors tend to solve problems and make decisions using conventional procedures and group consensus. As a result, existing procedures tend to be retained and enhanced. In contrast, innovators tend to break existing paradigms, adopt new viewpoints, and employ new methods. Adaptors are more left-brain dominant. They are inclined to perceive themselves as not creative, although Kirton argued that this perception is not based in fact. Adaptors are more dogmatic than innovators. They are more intolerant of ambiguity, and less flexible. Adaptors are more introverted, humble, conscientious, controlled, subdued, and emotionally tender than innovators. Adaptors also tend to be lower in self-esteem, have a lower capacity for status, and lower self-confidence. They prefer to take fewer risks than innovators.

Kirton (1976, 1980, 1994) developed the Adaption-Innovation Inventory (KAI) to assess cognitive preferential style. This instrument yields interval scale scores having a theoretical range of 32 to 160, with lower scores representing the
innovative end of the continuum. The instrument had also been used to classify respondents as either innovators or adaptors, using a cut-off score of 96 (Fleenor & Taylor, 1994). Kirton (1994) argued that being designated an innovator is not better than being designated an adaptor. On the contrary, Kirton suggested that cognitive preferential style is independent of cognitive capacity, success, cognitive success, and coping behavior. According to Kirton, both adaptors and innovators can exhibit creativity and serve as instruments of change.

However, it should be noted that factor analyses of the KAI indicate a three-factor structure, with dimensions representing originality, efficiency, and conformity (Kirton, 1994; Taylor, 1989). Moreover, Kirton commented that the originality factor contains “items which describe the creative person in much of the literature” (Kirton, 1994, p. 32). Furthermore, Fleenor and Taylor (1994) reported a significant relationship between innovation scores on the KAI and scores on the Creativity Scale of the California Psychological Inventory (CPI-CS) among a large sample of professional managers.

These findings suggest that cognitive preferential style as measured by the KAI may, in fact, be related to creativity. In particular, it would appear that innovators are more likely to demonstrate creativity than adaptors. It is also possible that individuals who score high on the originality factor of the KAI may tend to manifest creativity.
Conclusion

Over the last several decades investigators have made considerable progress in arriving at a consensus regarding the meaning of creativity, embodied in the confluence approaches of Amabile (1983, 1987) and Sternberg and Lubart (1996). Concomitantly, researchers on creativity have made progress in the measurement of creativity, generally choosing to employ ratings of individuals’ creative products (Besemer, 1987; Besemer & O’Quin, 1993; O’Quin & Besemer, 1989, 1999).

In the course of forging a more or less agreed upon conceptual definition of creativity, numerous predictors of creativity have been identified in specific domains. Among those predictors that have been conceptually and empirically related to creativity are tolerance of ambiguity, intrinsic motivation, and cognitive preferential style. The purpose of this study was to expand on the prior research through the study of the relative and interactive effects of these predictors on the creative products of scientists.
CHAPTER III

Methods

This study has been designed to examine the bivariate and multivariate relationships between the creativity of scientists and several personality factors that have been linked to creativity in prior research. The creativity of scientists was defined by Besemer and her associates (Besemer, 1987; Besèmer & O’Quin, 1993; O’Quin & Besemer, 1989, 1999) in terms of the novelty, resolution, and elaboration and synthesis represented in the products of their work. The personality factors investigated are tolerance of ambiguity, intrinsic motivation, and cognitive preferential style. In this chapter, the methods employed in conducting this study are described, including the overall design, the research participants, the procedures to be employed, the instruments used, and the methods of data analysis.

Overall Design

The proposed study was a correlational investigation involving data collected through the use of a survey questionnaire. The study was correlational in nature because all the data was collected at a single point in time, and none of the variables of interest were manipulated by the investigator. The use of a correlational design has the disadvantage that significant relationships identified in the study may not be assumed to imply causality. However, a correlational study using survey techniques
has the advantage of allowing the investigator to obtain substantial amounts of data from relatively large numbers of participants with relative efficiency. Furthermore, a correlational design is appropriate to the study of creativity proposed here, since no prior study has been reported using the specific combination of predictors employed in this study. The discovery of significant relationships in the proposed study may lead to subsequent evaluation of causal hypotheses in longitudinal and/or experimental studies.

Research Participants

Population

The population from which the sample for this study has been drawn was generalized is that of senior research scientists employed in U.S. pharmaceutical and medical device companies. These scientists have either a Master of Science Degree or a Doctoral degree in a scientific field such as Chemistry, Physics or the Life Sciences. Restricting participation to senior scientists is intended to limit variability on extraneous variables such as intelligence, level of education, and productivity. Scientists in these companies are hired on the basis of their academic achievement and their accomplishments within their fields. The title of senior scientist is not simply conferred on the basis of the length of one’s tenure with the company; it is awarded only to those who demonstrate noteworthy scientific accomplishments which advance the company’s position in the marketplace.
Sampling Frame and Judge Selection

The sample was drawn from the senior scientist rosters of several large pharmaceutical and medical device companies in the state of New Jersey. The companies were sampled as needed until the planned minimum sample size was obtained. Judges were solicited from the same companies mentioned above. Three judges were selected based on their field knowledge, accomplishments, and professional status. The judges each held the title of Vice President and headed a research group.

Sampling Strategy

In view of the highly select nature of the population sampled and the need to obtain permission to conduct the study from the companies employing the scientists, a non-random sample of convenience was employed. The investigator endeavored to obtain permission to conduct the study from as many pharmaceutical and medical device companies as necessary to obtain the required minimum sample size. Within each company where permission was obtained, the investigator solicited the participation of every senior scientist having either a Master of Science Degree or a doctoral degree.

Proposed Sample

A minimum sample size of 100 senior scientists was chosen on the basis of consideration of the power of the statistical tests used to evaluate the research hypotheses. A sample of 100 can expect a statistical power of .92 in a test of the
significance of a Pearson correlation between any one of the three dimensions of creativity and any one of the personality variables, assuming a medium effect size (population correlation = .30), and a two-tailed significance test at the .05 level of significance (Cohen, 1988, p. 87).

In addition, a sample size of 100 is adequate for the planned multiple regression analyses carried out to determine the extent to which each of the three dimensions of creativity can be predicted from a combination of the three personality variables and three product terms representing the two-way interactions among these variables. A regression including six predictors satisfies the requirement of a minimum subject-to-predictor ratio of 15 to 1, recommended by Stevens (1996).

Instruments

The survey instrument packet was comprised of four previously developed and validated measures and a background questionnaire developed specifically for the proposed study. The creativity manifested in the scientists' work products was measured by the 9-item Creative Product Semantic Scale (Besemer, 1987; Besemer & O'Quin, 1993; O'Quin & Besemer, 1989). Tolerance of ambiguity was measured by the 18-item Tolerance of Ambiguity Test adapted by Kirton (1981) from two earlier tolerance of ambiguity tests developed by Budner (1962) and MacDonald (1970). Intrinsic motivation was measured by the 30-item Work Preference Inventory (WPI; Amabile, Hill, Hennessey, & Tighe, 1994). Cognitive preferential style was measured by the 32-item Kirton Adaption-Innovation Inventory (KAI; Kirton, 1976, 1999). It is important to note that in order to administer the KAI, the administrator
must be certified. The certification process consists of taking a week long course and passing a test. Each of these measures was selected for use in the proposed study because the measure represents the current state of the art in the assessment of the particular construct. The paragraphs that follow describe each of these measures.

*Creative Product Semantic Scale (CPSS; Besemer, 2001, personal communication)*

The Creative Product Semantic Scale (CPSS) has been developed and modified over time to allow judges to rate the creativity manifested in a given product along the dimensions of novelty, resolution, and elaboration and synthesis (Besemer, 1987; Besemer & O’Quin, 1993; O’Quin & Besemer, 1989). The authors have argued that regardless of the nature of the specific product, these dimensions of creativity are represented and are capable of being evaluated. The CPSS was developed to provide a standardized procedure through which judges could produce valid and reliable assessments of these dimensions (Besemer & O’Quin, 1993). The CPSS has been praised by several investigators in the field of creativity as the most appropriate method for assessing the creativity manifested in a broad range of products (Amabile, 1996; Davis, 1992; Dunbar, 1999; Hennessey, 1994; Plucker & Renzulli, 1999).

The original long form of the CPSS consisted of 43-items that were developed on the basis of the recommendations of experts on creativity in general and creativity within the sciences specifically. Each item is an adjective that represents a characteristic of a creative product, and evaluating judges are asked to indicate on a seven-point Likert-type scale the extent to which the product in question is described by each adjective (1 = Low, 4 = Moderate, 7 = High). Several studies have indicated that inter-judge agreements on the ratings of both scientific and non-scientific
products are high, ranging from .70 and greater (Amabile, 1996; Hennessey & Amabile, 1988).

A factor analytic study of the CPSS based on the ratings assigned to several consumer products by a sample of 128 Norwegian high school students indicated that the items measured the three dimensions of novelty, resolution, and elaboration and synthesis (Besemer, 1987). The novelty dimension loaded on items reflecting the originality or newness of the product. The resolution dimension was subsequently described as representing "how well the product does what it is supposed to do" (Besemer & O’Quin, 1993, p. 355). The elaboration and synthesis dimension, also referred to as "style," loaded on items reflecting the appeal that the product had to the aesthetic sensibilities of the rater. (Besemer, 1987) reported that the internal consistency reliability of the CPSS was good, with alpha coefficients ranging from .77 to .87, depending on the dimension and the specific product being rated.

Creativity in this study was measured by the application of the short form of the Creative Product Semantic Scale (CPSS; Besemer, personal communication, 2000) to sample creative products provided by the participating scientists. The short-form of the CPSS consists of the nine adjectives drawn from the long form of the CPSS that best represent the three dimensions of creativity. The novelty dimension is represented by the adjectives, surprising and original. The resolution dimension is represented by the adjectives, logical, useful, valuable, and understandable. The elaboration and synthesis dimension is represented by the adjectives, organic, elegant, and well-crafted. The empirical derivation of the CPSS short-form items suggests that the subscales of the short form should be valid and reliable, in spite of their
brevity. Work to establish the validity and reliability of the CPSS short form is in progress, and the findings of the proposed study should contribute to this effort.

For this study, this investigator developed a self-report instrument which allows participating scientists to identify a product they had developed, its purpose, and an explanation of how the product functioned (Appendix B). These reports were provided to three judges, each of whom rated the product described using the nine rating scales of the short form of the CPSS. The use of three judges allowed the calculation of inter-judge reliabilities for the study data. The judge's ratings were averaged to obtain a final score for each product on each of the three creativity dimensions.

Tolerance of Ambiguity Test

Kirton's (1981) adapted Tolerance of Ambiguity Test is an 18-item instrument that contains seven items drawn from Budner's (1962) 16-item scale Tolerance of Ambiguity Scale and eleven items drawn from MacDonald's (1970) 20-item Ambiguity Tolerance Test (Appendix C). Kirton readministered these instruments to two samples of adults in southern England (n = 355 and 276, respectively). Kirton performed an item analysis of the original, larger item pools of each of the two earlier tests, and he found that subsets of these seven and eleven items yielded higher internal consistency reliabilities for the respective scales than did the original whole length tests. The internal consistency reliability of the reduced set of Budner items was .65, compared to an internal consistency reliability of .49 for the full-length 16-item Budner test. The internal consistency reliability of the reduced set of
MacDonald items was .71, compared to an internal consistency reliability of .62 for the full-length 20 item-test.

Kirton (1981) found that the correlation between the sum of the seven retained Budner items and the sum of the eleven retained MacDonald items was .56, which he interpreted as indicating that the two revised scales represented related but distinct constructs. Therefore, Kirton continued to employ the two reduced item sets as separate scales. However, Kirton did not present the intercorrelations among the items in the two sets, nor did he conduct an item analysis on the total set of 18 items. In the study proposed here, the intercorrelations among all 18 items was examined, and a factor analysis, a reliability analysis, and an item-analysis was carried out to indicate whether the two sets of items can be used to construct a single scale score representing tolerance of ambiguity, or whether separate scores should continue to be calculated for each of the two reduced item sets. Thus, the study discussed herein will also contribute to our knowledge of the construct of tolerance of ambiguity and to our ability to measure tolerance of ambiguity.

The two sets of items have differing response formats. The Budner items employ a seven-point Likert-type response format (Strongly Agree, Moderately Agree, Slightly Agree, Strongly Disagree, Moderately Disagree, Slightly Disagree), whereas the MacDonald items employ a true/false response format. Therefore, responses to the individual items would be standardized should the item subsets be combined.

Kirton (1981) offered evidence of the validity of each of the two reduced Tolerance of Ambiguity item subsets in the form of significant correlations of
moderate magnitude between each of the Tolerance of Ambiguity measures and Rokeach’s (1960) Dogmatism Scale, Gough’s (1956) Inflexibility subscale from the California Personality Inventory, and Wilson and Patterson’s (1968) Conservatism Scale. Hill and Amabile (1993) demonstrated that the two item subsets were each correlated significantly with judges’ ratings of the creativity displayed in college students’ writing samples.

*Work Preference Inventory (WPI; Amabile, Hill, Hennessey, & Tighe, 1994)*

The WPI (Appendix D) is a 30-item scale that employs a four-point Likert-type response format (*N* = Never or almost never true of you, *S* = Sometimes true of you, *O* = Often true of you, *A* = Always or almost always true of you). The WPI has two primary subscales measuring Intrinsic Work Motivation (15 items) and Extrinsic Work Motivation (15 items). Several items in both the Intrinsic Motivation subscale and the Extrinsic Motivation subscale are reverse coded to minimize response set bias.

The authors described individuals with high intrinsic work motivation as interested in their work, deeply involved in the work, and deriving enjoyment from their work. These individuals are also high on self-determination, competence, and curiosity. They described individuals with high extrinsic work motivation as concerned with competition, evaluation, and recognition. These individuals tend to emphasize remuneration and other tangible incentives associated with their work.

The WPI was normed on an undergraduate sample (*N* = 1308) drawn from two institutions in the northeastern U.S. Factor analysis of the data obtained from this sample confirmed the item composition of the two primary subscales. The internal consistency reliability (alpha) coefficient for the Intrinsic Motivation scale was .79,
and that for the Extrinsic Motivation scale was .78.

With respect to validity, the Amabile and colleagues (1994) reported that within their norm sample, scores on the Intrinsic Motivation subscale were related significantly to several other measures of motivation, including the Need for Cognition Scale and the Realistic and Investigative subscales of the Strong Vocational Interest Inventory. Scores on the Extrinsic Motivation subscale were related significantly to each of the four subscales of the Myers Briggs Type Inventory. In addition, Amabile and her associates (1994) reported that the scores on the Intrinsic Motivation subscale were related significantly to several measures of creativity based on student writing and art samples, as well as to instructors’ ratings of students’ creativity.

The divergent validity of the Intrinsic Motivation and Extrinsic Motivation subscales was indicated by the extremely low correlation between them ($r = .08$). The virtual independence of these scales is noteworthy, since it indicates that an individual who has high intrinsic work motivation is not necessarily low on extrinsic work motivation. Just because one derives satisfaction from the work itself does not imply that the individual is unconcerned with outside recognition or material rewards. A copy of the Work Preference Inventory is presented in Appendix D.

Although the Extrinsic Motivation subscale is mentioned in this section, the reader should note that it is not relevant to the outcome of this study. The hypotheses are only concerned with intrinsic motivation and its correlates.
Kirton Adaptation Innovation Inventory (KAI; Kirton, 1976, 1994, 1999)

The KAI is a 32-item scale that employs a 5-point Likert-type response format (Appendix E). The participant selects a point along a continuum and marks an ‘x’ on a line which ranges from very hard, hard, easy, to very easy. Behind this line, hidden from the participant, is a template which divides the scores into five distinct groupings utilized to score the instrument. The KAI measures cognitive preferential style, conceptualized as a continuum ranging from “adaptation” to “innovation.”

Kirton (1976) described adaptors as preferring to solve problems and make decisions thought the use of conventional procedures and group consensus. They tend to retain and enhance existing procedures. In contrast, innovators tend to break from existing paradigms by using new methods or viewpoints to problem solve.

Kirton (1976) normed the KAI on a sample of 532 adults from Buckinghamshire, Hertfordshire, and London counties. Factor analysis of the instrument based on this sample indicated that the KAI measures three sub-dimensions of cognitive preferential style, namely, originality, efficiency, and rule-conformity. These subdimensions were correlated, with subscale intercorrelations in the norm sample ranging from .36 to .47. The internal consistency reliability coefficients for the three subdimensions in the norm sample were .83 for originality, .76 for efficiency, and .83 for rule-conformity. The internal consistency reliability coefficient for the full-scale KAI in the original norm sample was .88. Kirton (1994) reported internal consistency reliability coefficients for the full-scale KAI obtained in 31 studies carried out with diverse populations by various authors. These coefficients ranged from .79 to .91. The median internal consistency reliability
coefficient in these studies was .87. Thus, it would appear that either the total score for cognitive preferential style or scores for the three subdimensions are sufficiently reliable to be used in research. Kirton (1976) also suggested that individuals with full-scale KAI scores of 95 or less may be classified as adaptors, whereas those with full-scale scores of 96 or more may be classified as innovators.

In the latest manual for the KAI, Kirton (1999) described numerous studies providing evidence of the validity of the test. For example, Goldsmith (1984) reported that full-scale scores on the KAI were correlated significantly with scores on the Originality subscale of the Jackson Personality Inventory ($r = .44, p = .001$). Goldsmith also reported that the KAI was correlated with a self-report measure of risk-taking ($r = .48, p = .001$). In addition, Fleenor and Taylor (1994) reported that in a large sample of managers, full-scale KAI scores were correlated significantly with creativity level scores derived from the California Personality Inventory and the Myers-Briggs Type Indicator. Significant relationships between full-scale KAI scores and various measures of creativity and related constructs have been reported by Masten and Caldwell-Colbert, 1987, Clapp and DeCiantis (1989), and Hill and Amabile (1993).

Evidence of the divergent validity of the KAI was provided by Kirton (1976), who reported that full-scale KAI scores were not correlated significantly with measures of dogmatism (Rokeach, 1960), tolerance of ambiguity (Budner, 1962, MacDonald, 1970), conservatism (Wilson & Patterson, 1968), neuroticism (Eysenck & Eysenck, 1964) or extraversion (Eysenck & Eysenck, 1964).
Background Data Questionnaire

A Background Data Questionnaire was developed for the purpose of describing the sample of scientists who participate in the study (Appendix H). This questionnaire contained demographic questions, information regarding their experience in the field and in their current position.

Procedures

Through telephoning personal contacts, the researcher obtained permission from the companies to introduce her study to their employees with the purpose of soliciting their participation. The participants were solicited at each company by one of two methods. The first consisted of the author convening a general meeting, hosted by the employer, where the author briefly described the study and asked people to volunteer for participation in the study. The second was via e-mail, where again a brief description was provided and individuals were asked to volunteer (Appendix F). The author tallied meeting attendance and number of initial e-mails as well as the number of actual volunteers.

Each volunteer received a packet consisting of a cover letter (Appendix G), consent form (Appendix A), Sample of Scientific Contribution (Appendix B), Tolerance of Ambiguity Test (Appendix C), Work Preference Inventory (WPI, Appendix D), and Kirton Adaption-Innovation Inventory (Appendix E), Demographic Data Inventory (Appendix H) and a self-addressed return envelope. Each of these packets was given an alphanumeric designation so that when the judges later received the Sample of Scientific Contribution, the participants’ names would not appear. The cover letter described the purpose of the study and the requirements of participation. The letter indicated that participation was entirely voluntary and that participants would not be rewarded in any way for their effort, except perhaps with the knowledge
that they had contributed to a research project which may increase our knowledge of
the creative process. The letter also indicated that participation involved completing
a survey and providing an example of one of their creative products, and that the
process was likely to require approximately one-half hour of the participant’s time.
Potential respondents were assured that they were under no obligation to participate,
and that their decision to participate or not participate would have no impact
whatever on any aspect of their employment situation. They were also informed
that if they choose to participate, they were free to discontinue their participation at
any time.

Potential respondents were also assured that the data they provided would be
kept confidential, and that study data would be presented in aggregate form only, so
that no one individual respondent would be linked to any specific response in the
dissertation or subsequent publications. This consideration is important, since some
of the respondents and their creative products may be quite well-known, both within
the scientific community and the general population. Those who agreed to participate
in the study signed informed consent forms (See Appendix A).

Prior to completing the CPSS a one-hour training session was held by Dr.
Besemer with the three judges. Dr. Besemer provided an explanation of each of the
dimensions and sub-dimensions and had the judges rate several samples using the
instrument. The judges were field experts selected specifically because of their
demonstrated acumen in the fields under evaluation. For proprietary reasons, Dr.
Besemer would not allow either her instruments or definitions to be included in this
document.
Demographics

Introductory meetings were held with or e-mails were sent to a total of 175 scientists, of whom 130 volunteered to participate. Of the 130 packets that were distributed to these volunteers, 78% completed surveys (n = 102).

As shown in Table 1 the sample contained 69 males (68.3%) and 32 females (31.7%). One respondent failed to indicate their gender. The majority of respondents described themselves as Caucasians (73.5%), but there were a substantial number of Asians as well (20.6%). Most were married (73.5%). Data for age, years in position and in company were gathered in a grouped fashion (e.g., years with Company may be 0-5, 6-10, etc.) to further protect the identity of the participant. Given that the data were grouped, the results may be described in terms of the most frequently selected category, termed the modal response. Most of the respondents were in the 41 to 50 age group (42.2%). Relatively few respondents (6.9%) were under the age of 30 (See Table 1).

Nearly half of the sample (46.1%) had their doctoral degrees. About one-third (30.3%) reported that they had more than 20 years of experience in the field, and another 24.2% reported that they had between 16 and 20 years of experience. Thus, the respondents were generally quite experienced.

On the other hand, they did not report long tenure with their present company or in their current position. Approximately one third (30.4%) were with their present company 0-5 years. And 68.6% were in their present position for 0-5 years (see Table 1).

Data Analysis

All the data was coded and keyed for analysis using the Statistical Package of the Social Sciences for Windows Version 7.5 (SPSS, 1977). Frequency distributions and
descriptive statistics were obtained on all the background and demographic variables for the purpose of describing the sample. Internal consistency reliability coefficients were obtained for all the scale scores. This is particularly relevant for the adapted
Table 1

*Frequency Distributions of Scientists' Demographic and Background Characteristics*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>Male</td>
<td>69</td>
<td>68.3</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>32</td>
<td>31.7</td>
</tr>
<tr>
<td></td>
<td>No Response</td>
<td>1</td>
<td>--</td>
</tr>
<tr>
<td>Ethnic Background</td>
<td>African American</td>
<td>2</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>Asian</td>
<td>21</td>
<td>20.6</td>
</tr>
<tr>
<td></td>
<td>Caucasian</td>
<td>75</td>
<td>73.5</td>
</tr>
<tr>
<td></td>
<td>Hispanic</td>
<td>1</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>3</td>
<td>2.9</td>
</tr>
<tr>
<td>Birth Order</td>
<td>First, Only</td>
<td>44</td>
<td>43.1</td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>35</td>
<td>34.3</td>
</tr>
<tr>
<td></td>
<td>Last Born</td>
<td>23</td>
<td>22.5</td>
</tr>
<tr>
<td>Marital Status</td>
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<td>20.6</td>
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<tr>
<td></td>
<td>Married</td>
<td>75</td>
<td>73.5</td>
</tr>
<tr>
<td></td>
<td>Divorced</td>
<td>4</td>
<td>3.9</td>
</tr>
<tr>
<td></td>
<td>Remarried</td>
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<td>1.0</td>
</tr>
<tr>
<td></td>
<td>Widowed</td>
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<td>1.0</td>
</tr>
<tr>
<td>Age Group</td>
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<td>6.9</td>
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<td>n</td>
<td>%</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>--------</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>41-50</td>
<td></td>
<td>43</td>
<td>42.2</td>
</tr>
<tr>
<td>over 50</td>
<td></td>
<td>23</td>
<td>22.5</td>
</tr>
<tr>
<td>Highest Degree</td>
<td>Masters</td>
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<td>PhD</td>
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<td>46.1</td>
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<tr>
<td>Postgraduate Years in Field</td>
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<tr>
<td></td>
<td>6-10</td>
<td>21</td>
<td>21.2</td>
</tr>
<tr>
<td></td>
<td>11-15</td>
<td>10</td>
<td>10.1</td>
</tr>
<tr>
<td></td>
<td>16-20</td>
<td>24</td>
<td>24.2</td>
</tr>
<tr>
<td></td>
<td>Over 20</td>
<td>30</td>
<td>30.3</td>
</tr>
<tr>
<td></td>
<td>No Response</td>
<td>3</td>
<td>--</td>
</tr>
<tr>
<td>Years with Present Company</td>
<td>0-5</td>
<td>31</td>
<td>30.4</td>
</tr>
<tr>
<td></td>
<td>6-10</td>
<td>26</td>
<td>25.5</td>
</tr>
<tr>
<td></td>
<td>11-15</td>
<td>18</td>
<td>17.6</td>
</tr>
<tr>
<td></td>
<td>16-20</td>
<td>10</td>
<td>9.8</td>
</tr>
<tr>
<td></td>
<td>Over 20</td>
<td>17</td>
<td>16.7</td>
</tr>
<tr>
<td>Years in Present Position</td>
<td>0-5</td>
<td>70</td>
<td>68.6</td>
</tr>
<tr>
<td></td>
<td>6-10</td>
<td>19</td>
<td>18.6</td>
</tr>
<tr>
<td></td>
<td>11-15</td>
<td>6</td>
<td>5.9</td>
</tr>
<tr>
<td></td>
<td>16-20</td>
<td>3</td>
<td>2.9</td>
</tr>
<tr>
<td></td>
<td>Over 20</td>
<td>4</td>
<td>3.9</td>
</tr>
</tbody>
</table>
tolerance of ambiguity measure, which may be scored as a single scale or two scales, depending on the respective psychometric characteristics of the two configurations. In the paragraphs that follow, the analyses to be carried out to address each hypothesis and research question will be enumerated in turn.

The first hypothesis states that tolerance of ambiguity, as measured by Kirton’s Revised Tolerance of Ambiguity Instrument, would be related positively to CPSS scores for product (a) novelty, (b) resolution, and (c) elaboration and synthesis. This hypothesis concerns the bivariate relationships between tolerance of ambiguity and the three CPSS creativity dimensions. This hypothesis concerns interval scale measures only and was be tested by calculating Pearson correlations among the variables of interest. These correlations were evaluated in two-tailed tests at the .05 level of significance.

The second research hypothesis states that intrinsic motivation, measured by the Intrinsic Motivation subscale of the Work Preference Inventory, would be related positively to CPSS scores for product (a) novelty, (b) resolution, and (c) resolution and synthesis. This hypothesis concerns the bivariate relationships between intrinsic motivation and the three CPSS creativity dimensions. This hypothesis, like Hypothesis One, concerns interval scale measures only. The hypothesis was tested in the same manner as Hypothesis One (i.e., by calculating Pearson correlations among the variables of interest). These correlations were evaluated in two-tailed tests at the .05 level of significance.

The third hypothesis specifies that the two groups (adaptors vs. innovators) will differ significantly on each of the three CPSS product subscales. Accordingly, a
statistical procedure must be employed which provides a separate test for each 
subscale. A one-way Multivariate Analysis of Variance (MANOVA) was used to 
obtain an overall test of significance of the difference between the two groups across 
the three variables; follow-up univariate tests were employed to provide the specific 
significance test for each of the three subscales (Tabachnick & Fidell, 1989).

Hypotheses 4 through 6 were addressed by three multiple regression analyses, 
one predicting each of the three creativity dimension scores.

Hypothesis 4 explored whether significantly greater variability in the Product 
Novelty dimension of the CPSS was explained by the combination of tolerance of 
ambiguity, intrinsic motivation, and adaptation/innovation than by any one of the 
predictors. This hypothesis was tested by a direct-entry multiple regression analysis 
in which Product Novelty was predicted from six predictors. These predictors were 
the scores for tolerance of ambiguity (assuming a single score is used for this 
domain), intrinsic motivation, the undichotomized full-scale KAI score, and three 
product terms representing the three two-way interactions among these predictors. In 
each of the three analyses, an F-test for the significance of the overall regression was 
calculated, as were t-tests for the significance of the unique contribution of each of 
the six predictors.

Hypothesis 5 explored whether significantly greater variability in the Product 
Resolution dimension of the CPSS was explained by the combination of tolerance of 
ambiguity, intrinsic motivation, and adaptation/innovation than by any one of the 
predictors. This hypothesis was tested by a direct-entry multiple regression analysis 
in which Product Novelty will be predicted from six predictors. These predictors are
the scores for tolerance of ambiguity (assuming a single score is used for this
domain), intrinsic motivation, the undichotomized full-scale KAI score, and three
product terms representing the three two-way interactions among these predictors. In
each of the three analyses, an F-test for the significance of the overall regression was
calculated, as were t-tests for the significance of the unique contribution of each of
the six predictors.

Hypothesis 6 explored whether significantly greater variability in the Product
Elaboration and Synthesis dimension of the CPSS was explained by the combination
of tolerance of ambiguity, intrinsic motivation, and adaptation/innovation than by any
one of the predictors. This hypothesis was tested by a direct-entry multiple regression
analysis in which Product Elaboration and Synthesis was predicted from six
predictors. These are the scores for tolerance of ambiguity (assuming a single score
is used for this domain), intrinsic motivation, the undichotomized full-scale KAI
score, and three product terms representing the three two-way interactions among
these predictors. In each of the three analyses, an F-test for the significance of the
overall regression was calculated, as were t-tests for the significance of the unique
contribution of each of the six predictors.
CHAPTER IV

Results

In this chapter, the results of the study are presented. It opens with the descriptive statistics for the personality measures and the measure of creativity employed in the study. A one-sample t-test routine was used to compare the mean of the research sample to the mean given for the norm group on each measure. These statistics are followed by a review of the reliabilities obtained for each of the measures and a factor analysis conducted in order to determine the viability of using the Tolerance of Ambiguity test employed by this study. The latter part of the chapter presents the results of statistical analyses carried out to test the research hypotheses, which concern the relationships between measures of the creativity embodied in the scientists’ products and the personality measures. SPSS for Windows Version 7.5 (1997) was used for these procedures.

Preliminary Results

Descriptives

To examine the Work Preference Inventory in terms of how the study participants fared in contrast to the norm group, the final scores on the Work Preference Inventory were computed as the average of the scores on the items comprising the Intrinsic Motivation Scale (15 items) and the Extrinsic Motivation Scale (15 items). Since responses to each item are made on four point Likert-type
scale having response options ranging from one to four, the theoretical range of scale scores is also from one to four. In the present sample, scores on Extrinsic Motivation ranged from 1.33 to 4.00, with a mean of 2.35 (SD = 0.48) (see Table 2). Amabile, Hill, Hennessey and Tighe (1994) reported a mean of 2.42 for Extrinsic Motivation for the 1,027 individuals in their norm sample. Scores on Intrinsic Motivation ranged from 2.29 to 3.66, with a mean of 3.01 (SD = 0.32). Amabile and her colleagues reported a mean of 3.16 for Intrinsic Motivation for the norm sample (see Table 2).

Kirton (1976) suggested that individuals with total KAI scores of 95 or less should be classified as innovators, and those with KAI scores of 96 or more should be classified as adaptors. Using this cut-off score, 55 of the scientists in the present study (65.5%) were classified as innovators, and 29 (34.5%) were classified as adaptors. The remainder of the sample was assigned missing values on the KAI, due to missing responses to one or more of the items.

These findings suggest that the scientists in this study were about as innovative as one might have expected, although it must be noted that Kirton specifically suggested that one should not place greater value on innovation than on adaptation.

Comparison of scores on the KAI subscales between the study and the norm sample reveals some significant results. The study sample mean (45.25) on the subscale Sufficiency of Originality was somewhat higher than the norm (40.78) reported by Kirton (1999). The study sample mean on the subscale Efficiency was 16.92, while the norm group mean was 18.82. On Rule Conformity the study sample mean was 29.26 and the norm sample mean was 35.39 (see Table 3).

Since the 18-item Tolerance of Ambiguity measure did not have a single score definition by which to compare the study participant scores against the norm group, the study scores were calculated by summing the items for each of the two item
Table 2

*Ranges, Means, Standard Deviations, and Alpha Size for Predictor Variables*

<table>
<thead>
<tr>
<th>Variable Scale/Subscale</th>
<th>n</th>
<th>Range</th>
<th>M</th>
<th>SD</th>
<th>Alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tolerance of Ambiguity:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18-item analysis</td>
<td>97</td>
<td>18-57</td>
<td>40.52</td>
<td>6.53</td>
<td>0.69</td>
</tr>
<tr>
<td>11-item analysis</td>
<td>97</td>
<td>11-22</td>
<td>17.08</td>
<td>2.35</td>
<td>0.62</td>
</tr>
<tr>
<td>7-item analysis</td>
<td>101</td>
<td>7-35</td>
<td>23.39</td>
<td>5.27</td>
<td>0.53</td>
</tr>
<tr>
<td><strong>Work Preference Inventory:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intrinsic Motivation</td>
<td>100</td>
<td>2.27-3.67</td>
<td>3.01</td>
<td>0.32</td>
<td>0.69</td>
</tr>
<tr>
<td>Extrinsic Motivation</td>
<td>93</td>
<td>1.33-4.00</td>
<td>2.35</td>
<td>0.48</td>
<td>0.63</td>
</tr>
<tr>
<td><strong>Kirton Adaption-Innovation Inventory:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Originality</td>
<td>97</td>
<td>29-65</td>
<td>45.25</td>
<td>7.96</td>
<td>0.84</td>
</tr>
<tr>
<td>Efficiency</td>
<td>93</td>
<td>8-35</td>
<td>16.92</td>
<td>5.94</td>
<td>0.86</td>
</tr>
<tr>
<td>Rule Conformity</td>
<td>94</td>
<td>13-50</td>
<td>29.26</td>
<td>8.17</td>
<td>0.82</td>
</tr>
</tbody>
</table>

subsets. These raw score totals can be compared to the norms provided for the two item sets by Kirton (1981).
When scores were computed by summing, the mean for the seven-item scale with the six-point Likert-type format was 23.29 ($SD = 5.27$). This compares to a mean of 26.62 ($SD = 7.89$) reported by Kirton (1981) for his norm sample, drawn

Table 3

*T-Test Results for Study Sample in Comparison to Norm Sample*

<table>
<thead>
<tr>
<th>Measure</th>
<th>Study Sample</th>
<th>Norm Sample</th>
<th>$t$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$M$</td>
<td>$SD$</td>
<td>$M$</td>
</tr>
<tr>
<td>Tolerance of Ambiguity:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11-item analysis</td>
<td>5.92</td>
<td>2.33</td>
<td>5.49</td>
</tr>
<tr>
<td>7-item analysis</td>
<td>23.39</td>
<td>5.27</td>
<td>26.62</td>
</tr>
<tr>
<td>Work Preference Inventory:</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Intrinsic Motivation</td>
<td>3.01</td>
<td>.32</td>
<td>3.16</td>
</tr>
<tr>
<td>Extrinsic Motivation</td>
<td>2.35</td>
<td>.48</td>
<td>2.42</td>
</tr>
<tr>
<td>Kirton Adaption-Innovation Inventory:</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Originality</td>
<td>45.25</td>
<td>7.96</td>
<td>40.78</td>
</tr>
<tr>
<td>Efficiency</td>
<td>16.92</td>
<td>5.94</td>
<td>18.82</td>
</tr>
<tr>
<td>Rule Conformity</td>
<td>29.26</td>
<td>8.17</td>
<td>35.39</td>
</tr>
</tbody>
</table>

*Note. *$p < .05$, **$p < .01$, ***$p < .001$*
from the general population in southern England. The mean for the eleven-item scale with the true false (0,1) format was 5.92 (SD = 2.33). This compares with a mean of 5.49 (SD = 2.53) reported by Kirton for his sample. Thus the scientists in the present sample scored slightly lower than Kirton’s sample on the seven-item scale, but slightly higher on the eleven-item scale (see Table 3).

Descriptive statistics are shown in Table 4 for each judge’s product ratings on each of the three CPSS subscales. Ratings on the CPSS items are made on 7-point Likert-type scales with response options ranging from one to seven, and subscale scores are computed as the average of the ratings of the items comprising each subscale. Therefore, the theoretical range of ratings on each subscale is from one (least creative) to seven (most creative); a rating of 4.0 would correspond to the midpoint of the rating scale.

The data in Table 4 indicates that all three judges assigned average ratings below 4.0 on novelty, suggesting that, in general, they did not consider the products submitted to be particularly novel (surprising or original). In contrast, all three judges had mean ratings above 4.0 on resolution, suggesting that they did tend to give the products rather high marks on logic, utility, value, and understandability. Mean ratings on elaboration or style varied from 3.53 in the case of judge 2 to 4.71 in the case of judge 3. Two of the judges assigned ratings with a mean above 4.0 on this dimension, while the third judge had a mean rating below 4.0. Thus the products of the participating scientists were rated more toward the middle of the scale on elaboration.

**T-Tests**

The SPSS one-sample t-test routine was used to compare the mean of the research sample to the mean given for the norm group on each measure (SPSS, 1997;
See Table 3). Since each sample mean was compared to a different scalar quantity obtained from the appropriate norms tables, one-sample t-tests had to be used for these comparisons. This information is interesting because it gives the reader some insight into how the research sample may differ from the norm group (Witte, 1989).

On the WPI, the sample mean for Extrinsic Motivation of the scientists in this study did not differ significantly from the mean of the norm sample \[ t(93) = 1.49, p = .141 \] (see Table 3). However, the mean for Intrinsic Motivation of the scientist sample was significantly lower than the mean of the norm sample \[ t(100) = 4.64, p < .001 \] (see Table 3). Thus, the scientists in this study were comparable to the WPI norm group on extrinsic motivation, but surprisingly somewhat lower than the norm group on intrinsic motivation.

The t-test for the KAI reveals that all three study samples were significantly different. However, it should be noted that the study sample differences are not greater than one standard deviation apart from that of the norm sample and thus should be considered only slightly different from the norm (see Table 3).

Differences were between the sample population and the norm sample on the Tolerance of Ambiguity scale were statistically significant \[ t(100) = 6.34, p < .001 \]; and \[ t(96) = -2.13, p < .05 \], respectively (see Table 3). However, the magnitudes of these differences were relatively small. Thus, it does not appear that the scientists in the present study were very much more or less tolerant of ambiguity than were the members of the general population who participated in Kirton’s (1981) study.
Table 4

*Descriptive Statistics by Judge for Product Ratings on Three CPSS Subscales*

<table>
<thead>
<tr>
<th>Judge</th>
<th>Subscale</th>
<th>$n$</th>
<th>Minimum</th>
<th>Maximum</th>
<th>$M$</th>
<th>$SD$</th>
<th>Alpha</th>
</tr>
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<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>novelty</td>
<td>98</td>
<td>1.00</td>
<td>6.50</td>
<td>3.53</td>
<td>1.68</td>
<td>.82</td>
</tr>
<tr>
<td></td>
<td>resolution</td>
<td>95</td>
<td>1.75</td>
<td>6.50</td>
<td>5.19</td>
<td>1.09</td>
<td>.79</td>
</tr>
<tr>
<td></td>
<td>elaboration</td>
<td>94</td>
<td>1.00</td>
<td>6.33</td>
<td>4.43</td>
<td>1.41</td>
<td>.90</td>
</tr>
<tr>
<td>Judge 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>novelty</td>
<td>94</td>
<td>1.00</td>
<td>6.50</td>
<td>2.88</td>
<td>1.68</td>
<td>.89</td>
</tr>
<tr>
<td></td>
<td>resolution</td>
<td>94</td>
<td>1.00</td>
<td>7.00</td>
<td>4.95</td>
<td>1.18</td>
<td>.87</td>
</tr>
<tr>
<td></td>
<td>elaboration</td>
<td>94</td>
<td>1.00</td>
<td>6.33</td>
<td>3.53</td>
<td>1.53</td>
<td>.90</td>
</tr>
<tr>
<td>Judge 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>novelty</td>
<td>86</td>
<td>1.00</td>
<td>7.00</td>
<td>3.72</td>
<td>1.59</td>
<td>.86</td>
</tr>
<tr>
<td></td>
<td>resolution</td>
<td>86</td>
<td>2.75</td>
<td>7.00</td>
<td>5.17</td>
<td>0.88</td>
<td>.45</td>
</tr>
<tr>
<td></td>
<td>elaboration</td>
<td>86</td>
<td>1.00</td>
<td>6.67</td>
<td>4.71</td>
<td>1.12</td>
<td>.71</td>
</tr>
</tbody>
</table>
Reliabilities

The Statistical Package for the Social Sciences (SPSS, 1997) reliability subroutine was used to obtain internal consistency reliability coefficients (coefficient alpha) for each measure (see Table 2). The coefficients were examined to determine if participant responses were sufficiently consistent (Borg & Gall, 1989). The Cronbach alpha technique was used to determine internal consistency of the adapted Tolerance of Ambiguity measure (Cronbach, 1970). It was important to use this technique because the scoring of the 18-item measure required different weights be assigned to the original two tests (Borg & Gall, 1989). Internal consistency reliabilities were obtained for the 18-item scale and for the seven- and eleven-item subsets. These reliabilities were alpha = .69 for 18-item scale, compared to .53 for the seven-item scale, and .62 for the eleven-item scale. Thus, it made more sense to employ a single measure of tolerance of ambiguity based on all 18 items (see Table 2).

Reliability coefficients were also computed in this study for the Extrinsic and Intrinsic Motivation Scales based on the responses of the participating scientists. The values of coefficient alpha obtained were .63 for the Extrinsic Motivation Scale and .69 for the Intrinsic Motivation Scale.

Internal consistency coefficients were obtained for each of the three KAI subscales for the scientists in the present sample. These coefficients were .84 for originality, .86 for efficiency, and .82 for rule conformity. These compare to reliabilities reported above by Kirton’s norm sample (.83 for originality, .76 for efficiency, and .83 for rule conformity). In the present sample the internal consistency reliability coefficient for the total KAI was .91 and clearly in line with Kirton’s (1994) reported internal consistency reliabilities for the total KAI.

The creativity manifested in the scientists’ products was measured using the Creative Product Semantic Scale-Short Form (CPSS), a nine-item rating scale
designed to allow a judge to rate the creative dimensions of: (a) novelty (two items); (b) resolution (four items); and (c) elaboration and synthesis (three items). In order to determine both the internal consistency and the inter-judge reliability of the CPSS, three trained judges independently rated each of the products submitted for evaluation by the participating scientists.

Table 4 shows the reliability coefficients obtained on the three CPSS subscales. As indicated earlier the level of reliability coefficient gives us an understanding of whether the rater’s scoring is reasonably consistent.

Table 5 presents the inter-judge correlations between the ratings of the three pairs of judges on each of the three subscales. The inter-judge rating demonstrates whether there is agreement between the raters’ on the item being evaluated. The data

<table>
<thead>
<tr>
<th>CPSS Subscale</th>
<th>Judge 1 with Judge 2</th>
<th>Judge 1 with Judge 3</th>
<th>Judge 2 with Judge 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Novelty</td>
<td>.63</td>
<td>.43</td>
<td>.56</td>
</tr>
<tr>
<td>Resolution</td>
<td>.46</td>
<td>.25</td>
<td>.40</td>
</tr>
<tr>
<td>Elaboration &amp; Synthesis</td>
<td>.55</td>
<td>.66</td>
<td>.59</td>
</tr>
</tbody>
</table>

in Table 4 suggests that the internal consistency of the three scales for any one judge is quite good. The only exception is the alpha coefficient of .45 for the third judge on
the resolution subscale. The other eight alpha coefficients ranged from .71 to .90, with a median of .87. The median is reported to provide the reader with an indication of the typical reliability coefficient in this set. These reliabilities are comparable to those reported by Besemer (1987) who indicate that the internal consistencies for the three scales ranges from .77 to .87, depending on the dimension and the specific product being rated.

The inter-judge reliabilities presented in Table 5 ranged from .25 to .66, depending on the dimension being rated and the pair of judges whose ratings were being correlated. These data suggest that any one judge is reasonably consistent in his evaluation of the several aspects of creativity displayed in scientists’ work products, but that various judges differ substantially in these assessments. In short, it appears as the old adage states that creativity is in the eye of the beholder. Besemer (1987) did not report inter-judge reliabilities for the CPSS.

In view of the lack of inter-judge reliability obtained for the CPSS subscales, the research hypotheses, discussed later in this chapter, were tested for each judge separately, using each judge’s ratings on the three CPSS subscales as measures of creativity.

Factor Analysis

In this study in order to determine the advisability of combining the two item sets to form a single scale for the Tolerance of Ambiguity Measure, the responses of the participating scientists to these 18-items were factor analyzed, using a principal components solution. Principal components analysis is used when an investigator is trying to determine whether there is a relationship between variables
<table>
<thead>
<tr>
<th>Factor</th>
<th>Eigenvalue</th>
<th>Factor 1/Item</th>
<th>Communality</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.06</td>
<td>1</td>
<td>0.27</td>
</tr>
<tr>
<td>2</td>
<td>1.76</td>
<td>2</td>
<td>0.14</td>
</tr>
<tr>
<td>3</td>
<td>1.48</td>
<td>3</td>
<td>0.28</td>
</tr>
<tr>
<td>4</td>
<td>1.36</td>
<td>4</td>
<td>0.03</td>
</tr>
<tr>
<td>5</td>
<td>1.24</td>
<td>5</td>
<td>0.23</td>
</tr>
<tr>
<td>6</td>
<td>1.17</td>
<td>6</td>
<td>0.06</td>
</tr>
<tr>
<td>7</td>
<td>1.10</td>
<td>7</td>
<td>0.07</td>
</tr>
<tr>
<td>8</td>
<td>1.07</td>
<td>8</td>
<td>0.30</td>
</tr>
<tr>
<td>9</td>
<td>0.88</td>
<td>9</td>
<td>0.04</td>
</tr>
<tr>
<td>10</td>
<td>0.71</td>
<td>10</td>
<td>0.22</td>
</tr>
<tr>
<td>11</td>
<td>0.67</td>
<td>11</td>
<td>0.27</td>
</tr>
<tr>
<td>12</td>
<td>0.66</td>
<td>12</td>
<td>0.09</td>
</tr>
<tr>
<td>13</td>
<td>0.62</td>
<td>13</td>
<td>0.13</td>
</tr>
<tr>
<td>14</td>
<td>0.56</td>
<td>14</td>
<td>0.19</td>
</tr>
<tr>
<td>15</td>
<td>0.53</td>
<td>15</td>
<td>0.10</td>
</tr>
<tr>
<td>16</td>
<td>0.44</td>
<td>16</td>
<td>0.13</td>
</tr>
<tr>
<td>17</td>
<td>0.38</td>
<td>17</td>
<td>0.06</td>
</tr>
<tr>
<td>18</td>
<td>0.34</td>
<td>18</td>
<td>0.44</td>
</tr>
</tbody>
</table>
which might be indicative of an underlying structure and the investigator has no hypotheses as to what that latent structure might be (Tabatchnick & Fidell, 1989). The principal components analysis yielded a first factor having an eigenvalue of 3.06 that explained 17% of the variance in the items. The eigenvalues and communalities for the solution are presented in Table 6. The data in Table 6 indicate that the eigenvalue of the next strongest factor was 1.76, followed by eigenvalues of 1.48 for factor three, and 1.36 for factor 4. Thus the scree test clearly suggested a one-factor solution.

Hypothesis 1

It was hypothesized that tolerance of ambiguity, measured by Kirton’s Revised Tolerance of Ambiguity Instrument, would be related positively to CPSS scores for product (a) novelty; (b) resolution, and (c) elaboration and synthesis. This hypothesis suggests that tolerance of ambiguity would be related positively to the creativity displayed in the scientists’ products. Since this hypothesis concerned the relationships between pairs of interval scale variables, Pearson Product-Moment Correlations were used to test the hypothesis (Witte, 1989). These correlations are presented in Table 7. The data in Table 7 indicate that the correlations between scores on the Kirton Tolerance of Ambiguity Test and ratings on each of the three dimensions of creativity assessed by the CPSS for each of the three judges were not significant. There is only one significant correlation, that between tolerance of ambiguity and novelty as rated by judge 3 ($r = .22, p = .049$). The magnitude of the correlation is weak, and the relationship pertains for only one judge of the three. Therefore, hypothesis one was not supported.
Table 7

Correlations between Tolerance of Ambiguity and Rating on the Three CPSS Subscales for Each of Three Judges

<table>
<thead>
<tr>
<th>CPSS Subscale</th>
<th>Judge 1</th>
<th>Judge 2</th>
<th>Judge 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Novelty</td>
<td>-.03</td>
<td>.17</td>
<td>.22*</td>
</tr>
<tr>
<td></td>
<td>(93)</td>
<td>(89)</td>
<td>(82)</td>
</tr>
<tr>
<td>Resolution</td>
<td>.02</td>
<td>-.13</td>
<td>-.18</td>
</tr>
<tr>
<td></td>
<td>(91)</td>
<td>(89)</td>
<td>(82)</td>
</tr>
<tr>
<td>Elaboration &amp;</td>
<td>.08</td>
<td>-.03</td>
<td>.12</td>
</tr>
<tr>
<td>Synthesis</td>
<td>(89)</td>
<td>(89)</td>
<td>(82)</td>
</tr>
</tbody>
</table>

*Note. * p < .05; number of cases in parentheses

Hypothesis 2

Intrinsic motivation, measured by the intrinsic motivation subscale of the Work Preference Inventory, would be related positively to CPSS scores for product (a) novelty, (b) resolution, and (c) resolution and synthesis. The second hypothesis suggests that scientists’ intrinsic work motivation was related positively to the degree of creativity displayed in their products. Again, the Pearson Product Correlation was used as the relationships being investigated are between pairs of interval variables.

Table 8 shows the correlations between scientists’ scores on intrinsic work motivation
and the ratings of creativity assigned by the three judges on the three CPSS subscales. None of these nine correlations was significant. Thus, the data do not support Hypothesis Two.

Hypothesis 3

Scientists classified as innovators on the basis of KAI scores would score significantly higher than scientists classified as adaptors on CPSS subscales measuring product (a) novelty, (b) resolution, and (c) resolution and synthesis. The third research hypothesis stated that scientists classified as innovators on the basis of their KAI scores would display significantly greater creativity in their products than scientists classified as adaptors. To test this hypothesis, a Multivariate Analysis of Variance (MANOVA) was run. A MANOVA was calculated as two groups of participants were being compared on several interval scale variables and its’ use protects against an inflated Type I error (Tabachnick & Fidell, 1989). Those scientists classified as innovators were compared to those classified as adaptors on each of the three CPSS creativity subscales as derived from each of the three judges.
predictors, would explain the greatest proportion of variability in CPSS scores for product novelty.

The fourth hypothesis asks whether a significantly greater proportion of the variability in judges' ratings of product novelty could be explained by a linear combination of scientists' scores on tolerance of ambiguity, intrinsic work motivation, and cognitive preferential style than by any one of these predictors alone. To address this hypothesis, three direct entry multiple regression analyses were run. Multiple regression was selected as the hypothesis is attempting to discover significant variability in each of the dependent variables using a combination of predictors. In these analyses, the dependent variables were the scores assigned by the three judges on the novelty subscale of the CPSS. In each analysis, there were six predictors: (a) tolerance of ambiguity; (b) intrinsic work motivation; (c) cognitive preferential style; (d) a product term representing the interaction of ambiguity and intrinsic work motivation; (e) a product term representing the interaction of tolerance of ambiguity and cognitive preferential style; and (f) a product term representing the interaction of intrinsic work motivation and cognitive preferential style.
Table 9

*CPSS Creativity Ratings for Three Judges by Innovator vs. Adaptor Classification*

<table>
<thead>
<tr>
<th>Judge</th>
<th>Scientist Group</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Adaptors</td>
<td>Innovators</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>( n = 41 )</td>
<td>( n = 22 )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Univariate Subscale</td>
<td>( M )</td>
<td>( SD )</td>
<td>( M )</td>
<td>( SD )</td>
<td>F-Test</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Judge 1</td>
<td>Novelty</td>
<td>3.42</td>
<td>1.72</td>
<td>3.73</td>
<td>1.51</td>
<td>0.45</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Resolution</td>
<td>5.13</td>
<td>1.16</td>
<td>5.23</td>
<td>1.05</td>
<td>0.09</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Elaboration</td>
<td>4.42</td>
<td>1.51</td>
<td>4.65</td>
<td>1.38</td>
<td>0.35</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Judge 2</td>
<td>Novelty</td>
<td>2.72</td>
<td>1.61</td>
<td>3.30</td>
<td>1.69</td>
<td>1.56</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Resolution</td>
<td>4.95</td>
<td>1.24</td>
<td>5.19</td>
<td>1.12</td>
<td>0.64</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Elaboration</td>
<td>3.46</td>
<td>1.50</td>
<td>3.71</td>
<td>1.62</td>
<td>0.36</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Judge 3</td>
<td>Novelty</td>
<td>3.72</td>
<td>1.60</td>
<td>3.98</td>
<td>1.57</td>
<td>0.36</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Resolution</td>
<td>5.22</td>
<td>0.78</td>
<td>5.00</td>
<td>1.10</td>
<td>0.94</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Elaboration</td>
<td>4.72</td>
<td>1.22</td>
<td>4.68</td>
<td>1.14</td>
<td>0.01</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note.* *\( ^*p < .01, **p < .05*
In none of these three analyses was the test for the significance of the regression significant. The F-statistics for the regressions were as follows: where the dependent variable was the CPSS product novelty rating of judge 1, \( F(6, 68) = 0.302, p = .934 \); where the dependent variable was the product novelty rating of judge 2, \( F(6, 65) = 1.12, p = .358 \); and where the dependent variable was the product novelty rating of judge 3, \( F(6, 61) = 0.81, p = .560 \).

Therefore, hypothesis 4 was not confirmed. The combination of the three predictors and their two-way interactions did not explain significant variability in the product novelty ratings of any of the three judges.

*Research Question 2*

Which of the following predictors, tolerance of ambiguity, intrinsic motivation, or cognitive preferential style or a linear combination of all three predictors, would explain the greatest proportion of the variability in CPSS scores for product resolution. The fifth hypothesis suggested that a significantly greater proportion of the variability in judges' ratings of product resolution could be explained by a linear combination of scientists' scores on tolerance of ambiguity, intrinsic work motivation, and cognitive preferential style than by any one of these predictors alone. This hypothesis was tested by means of three multiple regression analyses analogous to those used in connection with hypothesis four. The dependent variables in the three new analyses were the scores assigned by the three judges' for product resolution; the predictors were identical to those tested in hypothesis four.

None of these three regressions were significant. The F-statistics for the regressions were as follows: where the dependent variable was the CPSS product resolution rating of judge 1, \( F(6, 67) = 0.235, p = .964 \); where the dependent variable was the product resolution rating of judge 2, \( F(6, 65) = 2.12, p = .094 \); and
where the dependent variable was the product resolution rating of judge 3, \( F(6, 61) = 0.73, p = .626 \).

Therefore, hypothesis 5 was not confirmed. The combination of the three predictors and their two-way interactions did not explain significant variability in the product resolution ratings of any of the three judges.

**Research Question 3**

Which of the following predictors, tolerance of ambiguity, intrinsic motivation, or cognitive preferential style or a linear combination of all three predictors, would explain the greatest proportion of the variability in CPSS scores for product elaboration and synthesis. The sixth research hypothesis asks whether a significantly greater proportion of the variability in judges’ ratings of product elaboration/synthesis can be explained by a linear combination of scientists’ scores on tolerance of ambiguity, intrinsic work motivation, and cognitive preferential style than by any one of these predictors alone. This hypothesis was similarly tested by means of three multiple regression analyses analogous to those used in connection with hypothesis four. The dependent variables in these three analyses were the scores assigned by the three judges’ for product elaboration/synthesis; the predictors were identical to those tested in hypothesis four.

None of these three regressions were significant. The F-statistics for the regressions were as follows: where the dependent variable was the CPSS product elaboration/synthesis rating of judge 1, \( F(6, 64) = 0.94, p = .472 \); where the dependent variable was the product elaboration/synthesis rating of judge 2, \( F(6, 65) = 3.60, p = .125 \); and where the dependent variable was the product elaboration/synthesis rating of judge 3, \( F(6, 61) = 0.95, p = .443 \).
Therefore, hypothesis 6 was not confirmed. The combination of the three predictors and their two-way interactions did not explain significant variability in the product elaboration/synthesis ratings of any of the three judges.
CHAPTER V

Conclusions and Discussion

The objective of the study was to discover relationships between the personality characteristics of the scientists that were measured and the creativity displayed in the products which the scientists submitted. Each scientist provided a written example of their product. Some of these examples included either the formula or the molecular description of their discovery, while others provided copies of their patent submissions. Products rated included: (a) the methodology responsible for indicating the physical stability of an emulsion, (b) the method of manufacture of Galanthamine in high yield purity substantially free of epigalanthamine, (c) the process for yielding a pure single enantiomer of Ritalin for the treatment of Attention Deficit Hyperactivity Disorder, and (d) an automated, dual column, sample extraction and chromatographic system which resulted in simplifying the analytical testing of plasma samples. With the exception of a weak correlation between tolerance of ambiguity and the novelty ratings assigned to the scientists’ products by one of the three judges, the study did not find significant relationships between the personality characteristics and the products. In addition, there were no correlations between the Tolerance of Ambiguity Scale and the three judges’ ratings of product novelty, resolution, and style, and there were no correlations between Intrinsic Motivation and the judges’ ratings of the products on the three dimensions of creativity. Furthermore, scientists
classified as adaptors did not differ significantly from those classified as innovators on the ratings of product novelty, resolution, and style assigned by any of the three judges. These results differed from the previous studies reported in Chapter II, in that prior studies did show correlations between the personality indices of tolerance of ambiguity, intrinsic motivation, and cognitive preferential style. However, it should also be pointed out that prior studies employed paper and pencil tests of creativity rather than product ratings.

There may be two different explanations for why the major hypotheses of this study were not confirmed. One explanation focuses on possible methodological problems which may have prevented the hypothesized relationships from emerging, in spite of the fact that the relationships might actually exist. The second explanation involves rethinking the theoretical basis for the stated hypotheses, on the assumption that the hypothesized relationships do not exist.

Methodological Issues

With regard to methodological problems which may have prevented actual relationships between scientists’ personalities and the creativity of their work from manifesting themselves in this particular study, the sample, and issues surrounding the measurement of the variables of interest, was considered.

Variables Measured and Operationalization of these Variables

The second area that might explain the lack of statistical significance of the results of this study to explain significant and meaningful findings in scientists’
creativity has to do with the specific variables that were investigated and the operationalization of these variables in the study. This pertains to creativity and to the predictors of creativity.

**Creativity**

The scientists’ creativity was assessed, in this study, by means of a rating scale that allowed judges to determine the level of creativity displayed in products that had been produced and were subsequently selected by the scientists as representative of their creative work. Although it is most certainly true that the Creative Product Semantic Scale (CPSS) represents the current state of the art in the field of creativity research, there are aspects of this measure that are potentially problematic.

First, the creativity of the scientist and the creativity of his or her work do not appear to be the same thing. There were many factors that may have influenced the degree of creativity manifested in the scientists’ products, including the nature of their task assignments and their work environment. It is possible that a procedure which controls for such external factors, by restricting the environment in which the product is developed, would more accurately result in a product indicative of the creativity of the scientists. For example, Finke (1995) used an experimental creativity exercise to measure creativity. In this procedure, participants were presented with a standard set of objects, and they are asked to imagine how they might combine these objects to produce something practical. The objects they produced were then rated by judges for creativity. This procedure, with a standardized set of stimulus objects,
standard time limits, and standard work conditions, eliminated many of the potential sources of extraneous variability that might affect the work product. It is possible that the use of such a standardized procedure could have eliminated the variability that obfuscated the results in this study, herein described, and thus may have resulted in demonstrating the correlation between the creative product and the creative scientist.

Second, and in addition to the issue of extraneous sources of variability, there is the question of whether or not the judges rating the products share the same underlying concept of creativity. The presence of the three distinct domains of creativity which are measured by the CPSS (novelty, resolution, and elaboration/synthesis) suggests that there are multiple meanings of creativity. It is, therefore, likely that different judges might judge differently. One judge might feel that the originality of a product was the most important criterion of creativity. Whereas another judge might place greater emphasis on the aesthetics of the product. A third might think that the manner in which a product meets a need is the most significant aspect. The question then becomes whether or not any two judges even share the same definition of novelty, the same definition of resolution, and the same definition of elaboration/synthesis.

With respect to these considerations, it must be pointed out that the three judges each displayed respectable internal consistency in their individual ratings of the products across the several CPSS items, but when you compare their scores on each of the three domains there were very low inter-judge reliabilities. Stated simply, and in spite of having been provided with a definition for each of the domains, any
one judge seemed to have a good idea of what he meant by novelty or resolution, or style, but the judges as a group did not agree with each other. As suggested above, these findings may be interpreted as indicating that creativity is in the eye of the “judge”.

Amabile (1990) alluded to this problem when she stated that a product or response is creative to the extent that appropriate observers independently agree that it is creative. In this study, the independent judges did not agree as to the relative degree of creativity displayed in the product samples. Inter-rater reliability coefficients observed in this study ranged from .25 to .66, depending on the CPSS dimension and the particular pair of judges whose ratings were being correlated. The median inter-rater reliability coefficient in this study was .55, which is poor. In contrast Hennessey & Amabile (1988) have reported comparable inter-rater reliabilities ranging from .56 to .87.

The inter-rater reliabilities reported by Hennessey and Amabile (1999) suggest that it is at least possible for judges to achieve moderate agreement on the creativity manifested in products. Perhaps the judges employed by Hennessey and Amabile were very familiar with the research on creativity, such that they may have developed a shared set of ideas regarding the nature of the several creativity dimensions assessed by the CPSS. The judges, in the present study, apparently, did not agree nearly as well on the nature of creativity as expressed in these products. These findings indicate the importance of using “appropriate” observers, that is observers should be experts in the field from which the products they are rating come.
Furthermore, Sternberg and Lubart (1991) suggested that the meaning of creativity may be highly domain specific. That is, what one may consider creative for a scientist working in a pharmaceutical company may have nothing to do with the creativity displayed in a work of art or a piece of creative writing. This latter observation leads one to speculate that entirely separate definitions may need to be used in the assessment of “creativity” in different areas of endeavor. Certainly, the relative importance of the CPSS domains of novelty, resolution, and style would be expected to differ dramatically from field to field. For example, style would appear to be very important to artists, whereas resolution might be the most crucial domain of creativity for an engineer or inventor. It is possible that separate measures of creativity must be developed for each field or discipline. It is even possible that domains other than novelty, resolution, and style are required from one industry to another. This observation is later explored in this chapter in the discussion of the semantic differential technique (Osgood, Suci, & Tannenbaum, 1957).

The Sample

A crucial question is whether the participating scientists were really creative individuals. As noted in the literature review, Guilford (1950) argued in his well-known address to the American Psychological Association, that we generally associate the term “creativity” with great artists or eminent scientists. He suggested that research on creativity had necessarily been limited by the fact that such individuals are very rare and even more difficult to study in the psychology laboratory. Almost all participants in the present study were scientists working for
major pharmaceutical companies. All the participants had either masters' degrees or
doctoral degrees in a scientific discipline, and the majority had the word "scientist" in
their job title.

However, a scientist might not necessarily be a creative individual who
produces products that reflect this creativity. And, scientists who work for
pharmaceutical companies might not necessarily be creative individuals. For
example, the mean novelty ratings assigned to the products the scientists submitted
for evaluation ranged from 2.88 to 3.72 by the three judges who employed a 7-point
likert-type response scale to rate the products. On these scales, a rating of 1 would
indicate that the judge did not find the product to be novel at all, and a rating of 7
would indicate that the judge found the product to be extremely novel. Thus the
mean novelty ratings of all three judges fell below the midpoint on the rating scale,
indicating that the judges did not find the products submitted to be particularly novel.

Interestingly, the judges mean ratings, with respect to the resolution of the
products and the elaboration and synthesis of the products, were somewhat higher.
But the novelty and originality of the product would logically appear to be more
representative of the creativity of its author than either the resolution of the product
(i.e., how well the product does what it is supposed to do) or the elaboration and
synthesis of the product (i.e., the extent to which the product appeals to the aesthetic
sensibilities of the rater). Thus, the products that were submitted tended to impress
the judges more because of what they did and how they looked, as opposed to how
creative they were.
It also appeared that the participating scientists admitted that they had no creative product to submit to the study. Several of the participants stated directly that they had not produced anything very creative, and, that the nature of their work was not very creative. These respondents indicated that they were generally assigned to projects which were fairly specific and circumscribed in nature, where there was relatively little room for bold or innovative thinking.

In addition, several of the respondents indicated that much of their work took place in groups. It is possible that working in groups might be somewhat limiting with respect to the production of extremely novel or original ideas. Individuals might be apprehensive about sharing really novel ideas, in the event that they may be viewed as eccentric or out of touch with reality. Several investigators have noted that aspects of one’s social environment are related to the emergence of creativity (Amabile, 1996; Lubart, 1999; Simonton, 1991, 1997). Sternberg and Lubart (1991) note that environmental context can either promote or diminish creativity by either, for example, nourishing the process with stimuli, materials and reinforcement or actively suppressing new ideas, withholding resources and evaluating the potentially creative idea negatively. The authors speak of how in one environment a work project may be actively encouraged and perceived in a positive manner, while in another the same product may be perceived as bizarre. It is possible that the task structure and the work environment of scientists working in drug companies is not conducive to the development of truly creative products.

A related factor has to do with the motivations of the scientists who work for major pharmaceutical companies. Amabile (1997) has suggested that an individual
can only be creative if he or she truly loves his or her work. That is, the motivation to
do the work must be primary if not completely intrinsic. However, this motivational
picture conjures up images of independent scientists toiling diligently in their own
laboratories, working on projects of their own choice that they consider to be
particularly challenging, working until dawn each day for little or no compensation,
and placing family and friends on the back burner of life. These images do not fit the
scientists who participated in the present study. These men and women work for
large companies, where they earn very good salaries, enjoy good benefits and have
considerable job security. In short, these men and women do not conform to the
stereotypical image of the exhausted scientist whose scientific creativity is clearly the
driving force in their lives.

Another relevant characteristic of this sample is their extensive level of
experience. The modal response category on the survey item asking for “years in the
field post-graduation” was “over 20 years”. Frensch and Sternberg (1989) noted that
it is necessary to have extensive knowledge of a field before one can contribute to the
field. But, they also suggested that extensive knowledge of a field can also lead to a
closed or entrenched perspective which may interfere with the individual’s ability to
move beyond, the way in which he or she has conceptualized problems in the past.
One might also speculate that individuals with such extensive experience may simply
be experiencing burnout or looking forward to retirement.

Still, another aspect of the sample that may have influenced the results, is that
the level of care taken by the participating scientists when they actually completed the
survey and when they selected and described their representative creative products.
On the one hand, the scientists were volunteers. When this investigator explained the nature of the study and solicited the participation of the scientists, it was specifically stated to all potential respondents that they were under no obligation to participate in the study, and that their participation, or lack thereof, would in no way affect their employment. This would tend to suggest that the participants had some level of intrinsic interest in the study and some motivation to complete the research instruments carefully and thoughtfully.

However, there might have been a certain amount of social desirability pressure influencing the scientists' decisions regarding participation. Because this investigator was known by a few key participants at each of the sites visited, it is possible that people felt obligated to participate. During the process of reviewing the returned survey instrument (requesting a description of the participant's product), this investigator noted several cases in which items were omitted. So while participants may have felt pressure toward social desirability, these survey omissions may suggest a relatively low level of motivation on the part of some respondents. A low level of motivation and resulting carelessness could have introduced a component of response variability; and any factor leading to increased error variance would have diminished the statistical power of the test and in doing so makes it harder to confirm the hypotheses.

*Predictors of Creativity*

In this study, it was attempted to predict creativity from three personality variables: (a) tolerance of ambiguity, (b) intrinsic work motivation, and (c) the
cognitive styles of adaptation/innovation. The literature provided ample justification for hypothesizing that these variables are related to creativity. But, it must be pointed out that personality factors represent only one aspect of creativity. The confluence theory of creativity, which now appears to be widely accepted within the field of creativity research, posits that creativity is, in reality, the confluence of many factors, including, knowledge and ability relevant to the specific field of endeavor, creativity-relevant skills, personality variables, and the social environment (Amabile, 1983, 1996). Sternberg and Lubart (1999) mentioned six distinct domains that contribute to creativity: intellectual ability, cognitive style, knowledge, personality, motivation, and environment. This study explored only half of these variables.

Variability due to intellectual ability, knowledge, and environment was not assessed. In the event of complex interactions among predictors from the several different confluence domains, the failure to include intelligence, knowledge, and environmental factors might limit the amount of variability explained by tolerance of ambiguity, intrinsic work motivation and adaptation/innovation. Future research should include more predictors drawn from the various confluence domains.

Theoretical Considerations

The other possibility that must be considered when a study does not yield the anticipated results is that, regardless of any second thoughts or misgivings one may have regarding the methods employed, the hypothesized relationships may simply not exist. However, in the case of the present study, the literature provides empirical evidence suggesting that relationships do exist between creativity and the personality

The failure of the present study to demonstrate similar relationships among the population of scientists employed by pharmaceutical companies, therefore, underscores the complexity of the issues of the definition and operationalization of creativity. These relationships are further obscured by the crucial role played by the specific characteristics of the field of endeavor being considered and the work environment in which creativity is either displayed or not displayed. However, it seems reasonable to conclude, that creativity, like truth and beauty, means very different things to different people, both with a single professional group and especially across professions. It is quite possible that creativity, as defined by Amabile and measured by the CPSS, is a concept of marginal relevance to scientists working for pharmaceutical companies. The temptation is to retreat to the level of an exploratory study of these scientists which would not begin with the question, “How do you define and measure creativity within the population of scientists working in pharmaceutical companies?” but rather with the question, “What are the dimensions one might use to differentiate among scientists working in pharmaceutical companies?” This question would turn our focus toward what type of scientist would develop a successful product, as opposed to the creative product (as was explored in this study).
The focus on scientists’ creation of a successful product would allow individuals working in the field to identify the descriptors that should be used to evaluate their peers. The semantic differential technique (Osgood, Suci, & Tannenbaum, 1957) would appear to be a useful approach to employ in this type of investigation, since it is an unobtrusive technique that would require responding scientists to rate a concept such as a “scientist working for a pharmaceutical company” on a wide range of apparently unrelated paired opposite adjectives that tend to have no clear socially desirable pole. These ratings are, then, subjected to factor analysis to identify the underlying dimensions that respondents are using to evaluate the stimulus object. Such a study might reveal that, for scientist working in a drug company, analytical precision is a more salient factor than creativity in determining how favorably we evaluate the individual in comparison to his or her peers.

This suggestion represents a departure from the trend of current research on creativity. More than just a departure, an exploratory study employing a technique such as the semantic differential to define the dimensions relevant to evaluating an individual in a particular field, for this study represents a retreat to a more formative stage inquiry. Implicit in this suggestion is the notion that the course of research to date may have “gotten off course”. Also, implicit in this suggestion is the belief that changing the methodological paradigm employed to evaluate individuals working in fields where products can be creative can likely yield a new direction in the study of creativity.
Additional Implications for Future Research

In spite of the lack of results found in this study, and as noted in the literature there is a strong need to uncover the dimensions of creativity (Basadur, 1993, Rickards, 1999). Creativity is necessary to the adaptive changes that evolution requires and in our current environment of "rapidly accelerating changes in technology and environment, organizations that survived due to high efficiency, now recognize a need for a balance of adaptability and efficiency" (Basadur, 1993, p. 283). Given the outcome of this study and some of the above stated observations, it is also recommended that future studies of creativity capture the environmental factors created by group characteristics, when seeking for correlates of creative product outcome, using the semantic differential technique.

Practical Significance for Organizational Development Practitioners and Counseling Psychologists

The original premise for this study, as indicated in Chapter One, was that an essential element to the furthering of our nation’s prosperity is the augmentation of the scientific and engineering talent pools. Understanding the precursors to the scientists’ creative endeavors would allow psychologists and other interested parties to give better direction to such individuals on how to hone their talents. Research endeavors aimed at furthering such lofty goals should be of interest to both the organizational development practitioner and the counseling psychologist. The organizational development practitioner is generally employed by a Company to assist in employee development with the aim of improving output. In the example studied by this research, the output could be
a creative discovery resulting in a blockbuster drug. The counseling psychologist is interested in assisting their client in the realization and optimization of their abilities. Having an output which is desired, such as a creative product, certainly would reinforce and reward such endeavors.
References


Appendix A

Consent Form
Consent to Serve as a Participant in Research

I, ____________________________

(NAME)

of ____________________________

(ADDRESS)

give my consent to participate in the research project entitled ‘Indices of Scientific Creativity’, conducted by Helene Katz under the sponsorship of M. O’Hare, Ph.D., and the Psychology Department at Seton Hall University. I am aware that these data was kept confidential and that the principal investigator will follow the American Psychological Association ethical standards, including those for research with human subjects.

I understand that the only requirement of the study was to provide a sample of work that I have developed in the course of either my work or education and to fill out four questionnaires in one session, which will take approximately thirty minutes. I also understand that results of this research was coded in such a manner that my identity will not be attached physically to the data I contribute. In addition, I realize the purpose of this project is to examine the performance of groups of individuals, not to evaluate the performance of a particular individual.

This research project is expected to provide further information on creativity among scientists in the workplace, identify elements of an individual’s approach to work that may foster creativity, generalize these finding to discuss how workplace conditions can be developed in support of the scientist’s creative efforts. The results of this research
may be published or otherwise reported to scientific bodies, but the individual participants will not be identified in any such publication or report.

This project has been reviewed and approved by the Seton Hall University Institutional Review Board for Human Subjects Research. The IRB believes that the research procedures adequately safeguard the subject’s privacy, welfare, civil liberties, and rights. The Chairperson of the IRB may be reached through the Office of Grants and Research Services. The telephone number of the Office is (973) 275-2974. The telephone number of the Doctoral Candidate & Principal Investigator (Helene Katz) is (973) 744-0574.

I have read the material above, and any questions I asked have been answered to my satisfaction. I agree to participate in this activity, realizing that I may withdraw without prejudice at any time.

________________________________________    __________
Signature of Participant                      Date

________________________________________    __________
Signature of Doctoral Candidate Principal Investigator    Date

Name of Research Project: *Indices of Scientific Creativity*

Participation Requested: Complete and return the enclosed: Personal Preference Profile, KAI Inventory, Tolerance of Ambiguity Inventory and Demographic Data Inventory, Sample of Scientific Contribution, and this Consent Form for Research Participants.
Appendix B

Sample of Scientific Contribution
Sample of Scientific Contribution

This study is of a correlational nature and we will therefore be matching at a later date your Personal Preference Profile, the KAI Inventory, and Demographic Data Inventory with the sample scientific contribution that you supply to this study. It is important for this study that the sample that you provide is exemplary of your workstyle. It is not necessary for the sample to be of particular noteworthiness or economic value. However it is important that enough information be given so that the viewer has a full understanding of the sample's function, purpose and design.

If the sample is a 3-dimensional object please provide a photograph of it. If it is 2-dimensional, such as a formula, please provide the formula. If it is a process, please provide a brief statement describing the process.

Please understand that we are seeking a brief but complete statement of your work, not to extend beyond the 2 attached pages.

i. Attach photo or visual representation here. Please also provide a written description of the sample:
ii. Please provide statement of the Work Sample’s purpose:
iii. Describe the problem that was solved by the example you provided:

iv. Please provide statement of how the work sample functions:
v. Is this example unique in some way? Please explain.
Appendix C

Tolerance of Ambiguity Scale
PLEASE NOTE:

Copyrighted materials in this document have not been filmed at the request of the author.

They are available for consultation, however, in the author's university library.

These consist of pages:

Appendix C, pages 120-121 (Tolerance of Ambiguity Scale)

Appendix E, pages 125-126 (KAI-I)
Appendix D

Work Preference Inventory
Work Preference Inventory

Working Adult Version

Teresa M. Amabile, Ph.D.

Please rate each item in terms of how true it is of you. Please circle one and only one letter for each question according to the following scale:

N = Never or almost never true of you
S = Sometimes true of you
O = Often true of you
A = Always or almost always true of you

N S O A 1. I am not that concerned about what other people think of my work.
N S O A 2. I prefer having someone set clear goals for me in my work.
N S O A 3. The more difficult the problem, the more I enjoy trying to solve it.
N S O A 4. I am keenly aware of the income goals I have for myself.
N S O A 5. I want my work to provide me with opportunities for increasing my knowledge and skills.
N S O A 6. To me, success means doing better than other people.
N S O A 7. I prefer to figure things out for myself.
N S O A 8. No matter what the outcome of a project, I am satisfied if I feel I gained a new experience.
10. I am keenly aware of the promotion goals I have for myself.
11. Curiosity is the driving force behind much of what I do.
12. I'm less concerned with what work I do than what I get for it.
13. I enjoy tackling problems that are completely new to me.
14. I prefer work I know I can do well over work that stretches my abilities.
15. I'm concerned about how other people are going to react to my ideas.
16. I seldom think about salary and promotions.
17. I'm more comfortable when I can set my own goals.
18. I believe that there is no point in doing a good job if nobody else knows about it.
19. I am strongly motivated by the money I can earn.
20. It is important for me to be able to do what I most enjoy.
21. I prefer working on projects with clearly specified procedures.
22. As long as I can do what I enjoy, I'm not that concerned about exactly what I'm paid.
23. I enjoy doing work that is so absorbing that I forget about everything else.
24. I am strongly motivated by the recognition I can earn from other people.
25. I have to feel that I'm earning something for what I do.
26. I enjoy trying to solve complex problems.
NSOA 27. It is important for me to have an outlet for self-expression.
NSOA 28. I want to find out how good I really can be at my work.
NSOA 29. I want other people to find out how good I really can be at my work.
NSOA 30. What matters most to me is enjoying what I do.
Appendix E

The Kirton Adaption-Innovation Inventory
PLEASE NOTE:

Copyrighted materials in this document have not been filmed at the request of the author.

They are available for consultation, however, in the author’s university library.

These consist of pages:

Appendix C, pages 120-121 (Tolerance of Ambiguity Scale)

Appendix E, pages 125-126 (KAI-I)
Appendix F

Study Description
I am a student at Seton Hall University and am seeking scientists to participate in my dissertation study. As you have demonstrated an interest in advancing the field of creativity I thought that you might be willing to volunteer. The posting describing the study is just below. After you read the posting and should you be interested in participating please respond to my e-mail address (above) and advise me of the best way to get my materials to you.

Thanking you in advance, Helene Katz

Posting for Experienced Scientist:

Wanted: Doctoral student seeks scientists, with either a minimum of 5 years of experience as a scientist or a Ph.D. (in any of the sciences), to participate in a dissertation study.

Your task: to complete both a paper-pencil survey and a consent form as well as provide demographic data (e.g., age, gender). You will also be asked to provide a sample of your own work. There is no restriction on the type of sample that you select other than it be of your own doing. It is anticipated that these tasks will take 30 minutes of your time.

Purpose of study:

The investigation is attempting to:

- To enhance knowledge regarding creativity among scientists in the workplace.
- Identify elements of an individual's approach to work that may
foster creativity.

- Generalize these finding to discuss how workplace conditions can
  be developed in support of the scientist's creative efforts.

Please note your identity was held in confidence throughout and upon conclusion of the
study. The dissertation to be written will not identify you or the corporation. A copy of
the results of this study was made available to all participants upon request.

Thanks again, Helene
Appendix G

Cover Letter
Cover Letter to Research Participants

As part of a small sample of scientists you are being asked to participate in a scientific investigation that was the subject of a doctoral dissertation being conducted at Seton Hall University, South Orange, NJ. The investigation is attempting to:

1. Add to the currently limited knowledge about creativity among scientists.
2. Identify characteristics that foster creativity.
3. Generalize these findings to discuss how the corporate environment and trends may impact on creativity.

As a research participant, you are being requested to spend 30-45 minutes of your time providing demographic data and information on a scientific contribution of your own selection, and completing several measures including: the Work Preference Inventory, The Tolerance of Ambiguity Scale and the Kirton Adaption-Innovation Inventory. All information that is received from you was kept strictly confidential. Results of this research was coded in such a manner that your identity will not be attached physically to the data you contribute. The key listing your identity and subject code number was kept separate from the data in a locked file accessible only to the project director. This key listing subjects’ identities was physically destroyed at the conclusion of the project in approximately one year. You may discontinue your participation at any time you wish. The dissertation to be written will not identify you or the company that you work for. A copy of the dissertation was made available to all participants upon request.

Because I am surveying a small sample of scientists, your response is important. The identification number printed on the attachments was used only so I may follow-
up on returns. If you are willing and able to participate in this study, please complete and return the enclosed consent form.

Thanking you in advance for your participation,

Helene Katz

Doctoral Candidate and Principal Investigator

Note: Please return all attachments, sealed in the enclosed envelop, ASAP, and no later than November 3rd, to: Helene Katz, 65 Union Street, #32, Montclair, NJ 07042. Should you elect not to participate please return the enclosed forms to the same address. Thank you.
Appendix H

Demographic Data Inventory
Demographic Data Inventory

1. Gender: Male: _______ Female: _______

2. Ethnic Group: (Check only one).
   Black: _______ Caucasian: _______ Hispanic: _______
   Asian-American or Pacific Islander: _______
   American Indian or Alaskan Native: _______
   Other: Please Specify: __________________________

3. Marital Status: (Check only one).
   Single: _______ Married: _______ Separated: _______
   Divorced: _______ Remarried: _______ Widowed: _______

4. Age: (Check only one).

5. Number of years in field post-graduate:
   0-5 Years: _______ 5-10 Years: _______ 10-15 Years: _______
   15-20 Years: _______ Over 20 Years: _______

6. Years with present company:
   0-5 Years: _______ 5-10 Years: _______ 10-15 Years: _______
   15-20 Years: _______ Over 20 Years: _______

7. Title of current position: __________________________

8. Highest degree conferred (e.g., Master’s in Science; Ph.D.): _______

9. Years in current position:
   0-5 Years: _______ 5-10 Years: _______ 10-15 Years: _______
   15-20 Years: _______ Over 20 Years: _______

11. Number of Papers delivered (other than Patent Application): ________

12. Number of Publications delivered: ________

13. Number of Presentations delivered: ________

14. Please list hobbies or interests: (Please check off all those which pertain)
   Drawing: ________ Painting: ________ Sculpting: ________
   Collecting art: ________ Collecting records or music: ________
   Composing music: ________ Playing an instrument (Specify): ________
   Crafts (Woodwork, metal work, etc.) Specify: ________
   Writing (poetry, stories, etc.) Specify: ________
   Electronics: ________ Other (Specify): _________________________

15. What physical or athletic avocations do you engage in: (Please check off all which apply):
   Running/Jogging: ________ Walking: ________ Sailing: ________
   Gardening: ________ Skiing: ________ Swimming: ________
   Bike riding: ________ Football, etc (Specify): _________________________
   Tennis: ________ Other (Specify): _________________________

16. When have you had your best ideas, illuminations, and insights?
   (Please check off all which apply):
   While directly addressing a problem at work: ________
   On vacation: ________ Dreaming: ________
   While working on something else: ________
   As you fall asleep: ________ While relaxing: ________
While exercising: _______  Upon waking: _______

In the bath/shower: _______  Other (Please specify): _______

17. Is your scientific problem solving accompanied by any of the following (Please check off all which apply):

Visual images: _______  Musical themes: _______
Kinesthetic feelings: _______  Emotional feelings: _______
Other (specify): _______

18. Would you describe your typical scientific contribution as: (Select one only)

Outside of the current structure or thinking: _______
Building on existing ideas: _______

19. Please provide your birth order (e.g., first born, 2nd born): _______

20. How many older/younger brother(s) did you have (e.g., 2 older, 1 younger):

______ older brother(s)  _______ younger brother(s)

21. How many older/younger sister(s) did you have (e.g., 2 older, 1 younger):

______ older sister(s)  _______ younger sister(s)