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In Search of the Creative Scientific Personality

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ABSTRACT

IN SEARCH OF THE CREATIVE SCIENTIFIC PERSONALITY

by Maya V. Grosul

This study investigates whether personality is a valid predictor of creativity in science above and beyond demographic characteristics, such as career age, gender, and scientific discipline. Creativity is an act of making something new, original, and useful. Creative achievement in science is the personal ability to generate original, useful, and adaptive scientific theories, research methods, or empirical findings. Personality characteristics can operate as valid predictors of creative achievement in science. This study surveyed 145 scientists throughout the United States. Total creativity index was computed by standardizing and summing the total number of publications, total number of citations, *h*-index, and Soler's creativity index. As expected, openness and neuroticism were significantly positively correlated to creativity in science, while, interestingly, psychoticism was negatively correlated with creativity.

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Creativity is an act of making something new, original, and useful. Many studies of creativity have focused on identifying personality traits related to artistic creativity. But so far, the nature of creativity in science has been inadequately covered in psychology. The emerging discipline of the psychology of science has the deepest commitment to understanding scientific creativity (Simonton, 2004) and the capability to fill the gap in the research by establishing the connection between personality characteristics of scientists and creativity (Feist, 2006).

Because science has been viewed as the process of observation and theory building using logic, empiricism, and analytical thinking, intelligence and academic performance were deemed as powerful predictors of creative performance in science (Higgins, Peterson, Robert, & Lee, 2007). However, some scientists argue that personality characteristics operate as better predictors of creativity in science than intelligence (Feist & Barron, 2003). The primary goal of this study is to evaluate personality characteristics of scientists and examine whether they can predispose people to become creative in science.

Intelligence

A study of intelligence produced about two dozen somewhat different definitions (Neisser et al., 1996). Researchers have not yet come to agree on a clear definition of the essential elements of intelligence. Commonly, intelligence is described as the ability to adapt to the environment, acquire new knowledge, learn from experience, and plan for the future by using information processing, mental speed, memory capacity, and abstract reasoning (Feist & Barron, 2003; Neisser et al., 1996).

Because science includes an intellectual activity, intelligence and science often are viewed as synonymous categories, and scientists are deemed as highly intelligent people. Indeed, scientists as a group do have the relatively high average IQ of about 120 (Simonton, 2004). However, multiple research studies indicated that intelligence serves only as a modest predictor of creativity in science (Barron & Harrington, 1981; Batey & Furnham, 2006; Feist, 1999; Simonton, 2004). For instance, Barron and Harrington (1981) analyzed various studies published on the topic of creativity and intelligence and discovered that correlations between creativity and intelligence range widely from insignificantly negative (r = -.05) to significantly positive (r = +.30). However, creativity in science is more strongly associated with exceptional intelligence than creativity in arts (Simonton, 2004).

Terman's longitudinal study provides the example of the inability of intelligence to predict creativity later in life. About 1,500 highly intelligent children with IQs greater than 140 were selected for a longitudinal study of giftedness started in 1920 by Lewis Terman at Stanford University. The follow-up studies were conducted on average every 10 years. Terman discovered that the "Termites" (Terman's participants) were more likely than their peers to obtain better grades in school, receive higher educational degrees, and acquire well-paying professional careers (Feist, 1999). However, all of them, in spite of the higher than average intelligence, were "relatively uncreative" (Feist, 1999, p. 286). Interestingly, Nobel Prize winners William Shockley and Luiz Alvarez were originally screened for Terman's study but did not meet the IQ cutoff.

In short, intelligence is necessary but not sufficient in explaining creativity in science (Eysenck, 1993; Simonton, 2004). The widely agreed upon "threshold theory" of intelligence serves as the explanation of a wide range of correlations between creativity and intelligence (Batey & Furnham, 2006; Preckel, Holling, & Wiese, 2006; Simonton, 2004; Sternberg & O'Hara, 1999). Intelligence and creativity are related up to a modest IQ score of about 120, but, for IQ score above 120, there is hardly any correlation (Carroll, 1993; Eysenck, 1993; Preckel et al, 2006; Simonton, 2004). Thus, a scientist has to have certain intellectual ability to be able to acquire knowledge necessary for becoming a scientist. However, the degree of intelligence cannot explain creativity in science.

Creativity

Creativity is a topic of a wide scope (Sternberg & Lubart, 1999) and so far it has "resisted clear operationalization and unequivocal definition" (Batey & Furnham, 2006, p. 357). According to most creativity researchers, an idea can be identified as creative when it is both novel and useful. Creative ideas must be unique and original. Repetition of experiments already made by others can only confirm existing theories. Only novel ideas can make a contribution to the advancement of human knowledge. Creative ideas, however, must also be adaptive and useful (Barron & Harrington, 1981; Feist, 2006; Sawyer, 2006; Simonton, 2008; Sternberg & Lubart, 1999). Adaptive ideas introduce practical and valuable solution to a given problems by a certain community (Sawyer, 2006; Simonton, 2008).

Scientific theories cannot exist without person who is responsible for generation of hypotheses and ideas. As a result, creativity can be described as a personal ability to synthesize already available and seemingly unconnected information into something unique and productive (see Figure 1).

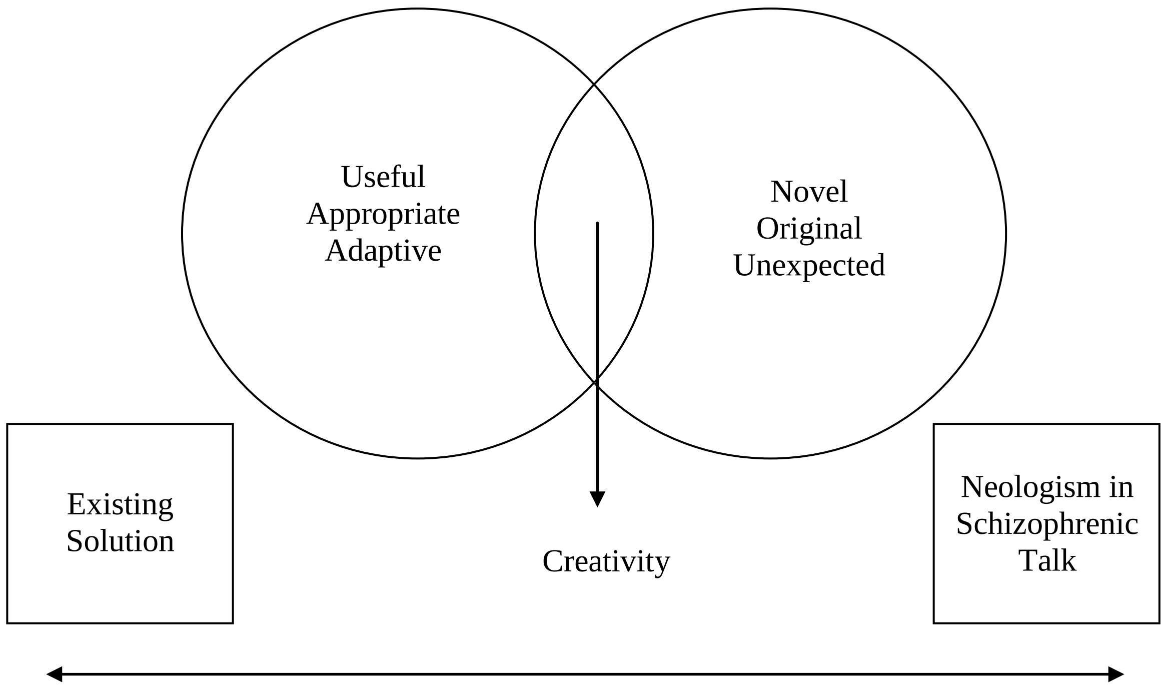

Figure 1. Definition of Creativity

There are four potential ways to study creativity (Simonton, 2008). First, creativity can be studied as a mental process and problem-solving technique. In this case creativity can be measured by divergent thinking tests. Second, creativity can be viewed as a specific personality trait and can be measured with personality inventories. Third, creativity can be defined as a characteristic of a product and can be assessed through the estimation of the value of the product. Lastly, creativity can be described as a function of the environment. Sociologists argue that discoveries and inventions are inevitable products of sociocultural system (Simonton, 2004). Where the effect of available resources (grants, access to laboratory facility with modern equipment, etc.), accessibility to role models and mentors, readiness of the field (collection of phenomena, facts, concepts, variables, constants, techniques, theories, laws, questions, etc), and zeitgeist (conditions and needs of society) are important for fostering of scientific creativity (Batey & Furnham, 2006; Simonton, 2004). For example, a laboratory with access to abundant funding and a variety of technical resources has a greater chance of producing better quality research than a laboratory with insufficient funding and lack of technical support.

All these approaches are mutually dependent: "Creative products are generated by creative persons using creative processes" (Simonton, 2008, p. 680). The multidimensionality of creativity generates problems for researchers when they try to measure creativity. Some researchers believe that a combination of several techniques will hold the most promise in accessing creativity (Plucker & Renzulli, 1999).

In this study we use creative products to identify creative persons. Therefore, scientific creativity is defined as the personal ability to generate useful and adaptive scientific theories, research methods, or empirical findings. We believe that creativity is a personal quality that predisposes a scientist to produce exceptional and useful outcomes.

Personality

Personality is a “pattern of relatively permanent traits and unique characteristics that give both consistency and individuality to a person’s behavior” (Feist & Feist, 2006, p. 4). Personality influences how people interact with their environment and interpret particular meaning of the situations created by the environment (John, Naumann, & Soto, 2008).

Personality traits exist as a multileveled hierarchical structure, and are relatively stable over the course of life (Barenbaum & Winter, 2008; Costa &, McCrae, 1988; John et al. 2008). Researchers still debate, however, the exact number of the factors that can describe basic tendencies of a person (Costa & McCrae, 1988; Eysenck, 1993; John et al., 2008; Matthews, Deary, & Whiteman, 2003). Some argue for five factors, others for three, and still others for more than five. The current study will concentrate on the two most widely adopted structural models of personality: the Five Factor Model and Eysenck’s Gigantic 3.

Five-Factor Model. The-Five Factor Model is a trait taxonomy widely accepted and used in personality research for prediction of behaviors and important life outcomes (Feist, 1998; John et al., 2008). The Five Factor Model (FFM) of personality is a cluster more specific traits that correlate with each other (McCrae & Costa, 2008). Numerous studies confirm that FFM is robust, replicable, and consistent across languages and cultures measures basic dimensions of personality (Barenbaum & Winter, 2008; John et al., 2008).

The FFM comprises five bipolar factors: openness (imaginative – down-to-earth), conscientiousness (well organized – disorganized), extraversion (outgoing – reserved), agreeableness (trusting – suspicious), and neuroticism (anxious – calm), which are placed on the continuum. All five factors are distributed normally across the population (Feist, 2006).

Eysenck's Gigantic 3. Eysenck proposed a similar model to the Big Five. His was a three-factor structural model of personality that included: neuroticism, extraversion, and psychoticism. Neuroticism and extraversion are essentially the same as the Big-Five. Psychoticism is a bipolar dimension with altruistic, controlled, and socialized on one side of the continuum and aggressive, impulsive and hostile on the other. Eysenck argued that there is a high correlation between psychoticism and creativity (Batey & Furnham; 2006; Eysenck, 1993; Feist, 1998; Rushton, 1990; Sass, 2001).

Eysenck (1993) believed that creative people in general are capable of uniting two or more unrelated entities to generate conceptually new categories (Korba, 1993). Eysenck (1993) defined this ability as the generalization gradient of "overinclusive thinking." People with steep gradients are manipulating a common range of associations. People with flatter gradients have large range of associations and are more likely to produce unique combinations resulting in the generation of creative ideas. Higher scores on psychoticism allow people to be more "overinclusive" in their thinking and operate with a larger sample of ideas, making the formation of novel and unusual combinations more attainable (Eysenck, 1993).

The relationship between psychoticism and creativity has produced mixed results in the research. Some studies find a strong positive correlation between psychoticism and creativity, whereas others do not find any relationship (Batey & Furnham, 2006; Eysenck, 1993; Kline & Cooper, 1986). Batey and Furnham (2006) suggested that such inconsistencies in the empirical findings are partly due to the fact that all three dimensions of personalities proposed by Eysenck contribute to different aspects of creativity.

Creativity and Personality

Some researchers believe that personality characteristics have greater influence on creative achievement than cognitive abilities, such as intelligence (Eysenck, 1993; Feist & Barron, 2003). Terman's study established personality as better predictor of creativity than intelligence (Feist, 1998, 1999, 2006; Feist & Barron, 2003). Barron and Harrington ascertained (1981) that a stable set of personality traits emerges as covariate of creative achievement in various studies.

To attain a better understanding of the relationships between personality and creativity, Feist (1998) conducted a meta-analysis of personality traits associated with scientific and artistic creativity using data from 83 studies. He converted all personality scales to one of the Big Five dimensions and then calculated effect sizes comparing personalities of artists and creative scientists to non-artists and less creative scientists. Feist concluded that creative people in general share a number of personality traits. They are more autonomous, introverted, open to experience, driven, and impulsive (Agronick, 1995; Feist, 1998). However, there are certain domain differences: creative artists tend to be emotionally unstable, sensitive, imaginative, and impulsive, whereas creative scientists are arrogant, self-confident, ambitious, and autonomous (Feist, 1998). In addition, Feist analyzed within group differences and compared a group of highly creative scientists to a group of less creative peers. As a result, more creative scientists scored less on conscientiousness and agreeableness.

Measuring Creativity in Science

Simonton (2004) highlighted the importance of the creative product. He pointed out that process and person simply provide means to the final creation (product). The product, or in our case, concrete contribution to the science, is honored by scientific society above cognitive processes or the personal attributes of a scientist. Therefore, the product is a fundamental criterion that allows us to analyze whether the person is creative or not.

Scientists often communicate their ideas by publishing their work in scientific journals. If other scientists consider their work important, it will be referenced. Citations, therefore, help to establish links between different researchers and their ideas. They carry information about the importance of the work. In other words, they measure the impact of the work on the development of science. However, most publications that have been published in academic journals are never cited (Simonton, 2004). According to Simonton (2004), of 783,339 papers published in 1981, 81% were cited 10 times or less, and 47% were not cited at all.

Therefore, the final product in science can be evaluated through publication and citation analyses, where publication analysis is the measure of productivity of a scientist, and citation analysis is the assessment of the impact that the scientist made to the field (Bouabid & Martin, 2007; Feist, 1997; Garfield & Dorof, 1992). Thus, more creative scientists will have a higher number of publications, and their work also will be highly cited.

Publication count is the oldest and most traditional bibliometric indicator of research output and productivity of individuals, departments, institutions, and nations (Garfield & Dorof, 1992; Glänzel, Debackere, Thijs, & Schubert, 2006, Feist, 1997; Fox, 1983; Soler, 2008). If publications are heavily cited, then the research they describe, has been acknowledged as original and useful (Garfield, 1979b).

If we apply publication and citation analyses to the "new-and-useful" definition of creativity, then, the ability of a scientist to generate new products is evaluated by the total number of publications, and the impact, or functionality of a product, is evaluated by the total number of citations.

Many researchers agree that publication and citation count is, perhaps, the most reliable and robust estimation of creativity in science (Feist, 1994; Garfield & Dorof, 1992; Glanzel, 2006; Simonton, 2004). Interestingly, the distribution of productivity is very similar to the distribution of impact – both are strongly positively skewed (Simonton, 2004). This implies that within any domain of science only small numbers of scientists tend to generate large number of publications, and their publications are cited a lot. Publication and citation data is widely used to estimate relative impact of individuals, journals, departments, institutions, and even nations (Garfield & Dorof, 1992). Garfield and Dorof (1992) also highlighted the possibility of identifying emerging specialties by using careful and balanced interpretation of citation data.

As valuable as citation counts are, they are not without problems. One concern some scholars have about citation analysis is about negative and critical citations that might invalidate citation count as a measure of usefulness (cited from Garfield, 1979a). Garfield (1979a) argued that the goal of citation analysis in not to measure how many times a scientist was right, but to measure individual performance and contribution to the science. Even if author is wrong and being cited because his work is criticized, he still makes certain contribution to the overall practice of science. According to Garfield (1979b), criticism is one of the fundamental functions of scientific communication that helps to advance science.

Other researchers also argue that citation analysis is not as robust as it seems (Garfield, 1979a). For example, self-citations could inflate overall number of citations, misrepresent the importance of individual articles, and make mediocre scientist appear more productive and, therefore, more creative (Aksnes, 2003; Gami, Montori, Wilczynski, Haynes, 2004). New bibliographic metrics, however, such as *h*-index – single number that estimates relative performance of individual scientist - correct for the number of self-citations, making their impact on the overall index very small (Hirsch, 2005).

The h-index. The proposal by Hirsch (2005) to introduce a single digit index to estimate scientific productivity and impact created a remarkable response from the scientific and bibliometric community. The *h*-index is a single-number criterion that was formulated to evaluate the output of a scientist that not only balanced the number of publications and the number of citations per publication but also corrected for self-citations (Bornmann & Daniel, 2005).

The creator of the *h*-index, Hirsch (2005) claimed that *h*-index takes into consideration different elements of citations such as: the total number of papers and citations, the number of citations per paper, the number of significant papers, and the number of citations for each of the most-cited papers. Therefore, the *h*-index is defined as when an author of *N* articles has *h*-number of publications cited at least *h*-number of times and the rest of the articles receive no more than *h* citations (Egghe & Rousseau, 2006). For example, if a scientist has an *h*-index equal to 10, he or she published at least 10 papers that were cited at least 10 times; if he published more, then, the rest of his publications have fewer than 10 citations per paper.

The *h*-index significantly correlates with citation and publication metrics (Glanzel, 2006). Costas and Bordons (2008) compared *h*-index and the numbers of citations and publications of 348 scientists publishing in the various fields of natural science. They found strong positive correlation between the number of citations and *h*-index ($R^2 = .93$) as well as the between the number of publications and *h*-index ($R^2 = .82$). Kulasegarah and Fenton (2010) compared *h*-index and the number of citations and publications using the sample of 182 otolaryngologists from Europe and US. They also found significant correlation between *h*-index and citations ($r = .98$) and between *h*-index and the number of publications ($r = .87$).

There are advantages and disadvantages to the *h*-index. Concerning advantages, the *h*-index takes into account both productivity and impact. The measure is robust and estimates overall performance of a scientist and is not sensitive to one or several extreme values, for example, uncited papers or highly cited papers (Costas & Botdons, 2008). It also corrects for self-citations.

Concerning limitations, the length of the career of a scientist influences *h* number. It also does not take into account the number of the authors and is not sensitive to highly cited papers. Finally, scientists with the same *h*-index can differ on the total numbers of citations or publications.

Creativity index. For similar reasons as the *h*-index, Soler (2007) – statistical physicist from Spain - proposed a different measure of evaluation of productivity and impact and called it *creativity index.* Soler's *creativity index* estimates scientific creativity based on the total number of published papers, total number of citations that the paper receives, total number of references that the paper makes to the previous papers normalized by the total number of authors per paper.

Soler (2007) provided formula for estimation of the *creativity index*:

$C_a = \sum_{i-1}^{N_p} \frac{c(n_i m_i)}{a_i}$; where N_p is equal to the number of published papers, is equal to the number of references for paper "*i*", is equal to the number of citations for paper "*i*", and is the number of authors on paper "*i*". Finally, *c* is the probability that an article with *n* references and *m* citations will have creativity of *c*. While the Soler's *creativity index* can be cumbersome to calculate, a free software program is available for download to facilitate its use (http://www.uam.es/jose.soler/tools.).

According to his definition of creativity, a paper that has lots of references but only a few citations will have a low level of "creativity", while a paper with just a few references and lots of citations, in contrast, will have a very high creativity. The creativity index (C_a) of a particular scientist can then be calculated by summing the total creativity for every paper that author has written, normalized for the number of co-authors in each case.

Soler (2007) pointed out the importance of references in estimation of creativity. He claimed that the creativity index is a measure of added value, rather than the measure of sale, which in his opinion are publication and citation analyses. Soler argued that any creative product consists of two parts: use of previous knowledge and generation of new knowledge. Each reference manifests transmission of the previous knowledge and citations suggest the creation of a new knowledge. Thus, according to Soler (2007), creativity index can filter highly cited articles that consolidate existing information (usefulness) but do not contain much new information (novelty). For instance, publications with fewer citations than references will have small Soler's creativity index value; heavily cited articles with not many references will have the largest creativity index.

In addition, Soler's creativity index takes into account the number of authors per paper (Thompson, Callen, & Nahata, 2009). The issue of multiple authorships and its effect on the estimation of the value of any given paper is very complex and can be described as the Matthew effect: the rich get richer the poor get poorer. VanDalen and Henkens (2001) argued that team of collaborators are potentially more efficient in generating influential product than solitary author. Besides, paper with several authors is more likely to be cited simply because of the greater exposure: each author "brings in" his own network of scientific relations and this paper is available to a wider network of researchers (VanDalen & Henkens, 2001). In reality, it is nearly impossible to quantify the magnitude of the collaboration for each author on paper. Therefore, Soler (2007) simply decided to divide all contribution by total number of author. Neither traditional publication and citation analyses, nor *h*-index take into consideration the number of authors per paper.

Creativity index was developed quite recently. Thompson, et al. (2009) reviewed all new indices in scientific assessment and concluded that so far there is no data validating *creativity index* and comparing it to the existing metrics of scientific output. More studies are needed to validate this measure.

Many researchers suggest that the use of several bibliometric indicators helps to improve objectivity in evaluative process (Bouabid & Martin, 2007; Costas & Bordons, 2007). In the current study we use a combination of standard productivity and impact analyses, *h*-index, and *creativity index.* This will help to minimize of the effect of some of the limitations of these metrics if they are used alone.

Hypotheses

Based on the findings in previous research studies, I predict positive relationships between creativity and the personality traits of openness and neuroticism (Feist, 1998). Creative scientists will score higher on the dimensions of openness and neuroticism. Creativity and agreeableness, on the other hand, will be negatively correlated (Feist, 1993;

Feist & Barron, 2003). Creativity and psychoticism should be positively correlated with highly creative scientists scoring higher on the trait of psychoticism when compared to the less creative peers (Eysenck, 1993).

Methods

Participants

Sample. A priori power analysis conducted with G*Power Version 3.1.0 (Faul, Erdfelder, Lang, & Buchner, 2007) indicated that 53 participants are needed to have 80% power for detecting a medium sized effect (.30) when employing the traditional criterion of statistical significance ($p < .05$). Thus, to conduct hierarchical multiple regression with 9 predictor variables we need at least 53 participants.

Of the 3,183 participants solicited (see sampling procedure section), a total of 318 (10%) responded to the survey, 38 of whom were removed from the sample because they did not complete at least one of the measures, 23 of whom were removed because they did not indicate which field of science they were associated with, and 67 did not provide the code to match personality measures with publication and citation data. Two participants were removed because they did not finish doctorate degree. Lastly, 11 civil engineers, 13 mechanical engineers, and 19 computer scientists were removed from the sample because Web of Science does not provide adequate coverage of publication data for these particular areas (Franceschet, 2009; Tsay, 2009). The remaining 145 participants were between 28 and 81 years of age (M = 50, SD = 12.07), 97 males (66.9%) and 48 females (33.1%). A breakdown of age and gender by the field of science is presented in Table 1.

Table 1

Demographic Characteristics of Age and Gender by the Department.

	Age			Gender	
Departments	*n*	*M*	*SD*	*Male*	*Female*
Anthropology	12	53.67	10.12	8	4
Biology	30	50.83	11.06	17	13
Chemistry	19	46.47	14.50	14	5
Geology	10	47.30	10.73	7	4
Physics	23	48.87	11.60	18	5
Psychology	31	49.68	13.92	20	11
Sociology	19	51.37	10.53	13	6
Total	145	49.08	12.05	97	48

Sampling. We used the Carnegie Classification of Institutions of Higher Education developed by the Carnegie Foundation for the Advancement of Teaching (The Carnegie Foundation for the Advancement of Teaching, 2008) as a sampling frame to compile the list of all doctoral/research universities (DRU) including universities with high and very high research activity (RU/VH). Abbreviations in parenthesis are codes used by the Carnegie Classification of Institutions of Higher Education.

Institutions were selected using multi-stage non-probability sampling procedure. The territory of the United States was divided into four clusters using US Census Bureau arrangement: West, Midwest, Northeast, and South (US Census Bureau, 2008). A total of 16-doctorate degree granting institutions, four from each region, were randomly selected from the list by using non-probability proportional sampling procedure.

All participants were distributed evenly throughout the regions. There were 38 participants representing the West, 39 participants from the Midwest, 38 participants from the South, and 30 participants from the Northeast. The breakdown of the participants by the region in the US and gender is presented in Table 2.

Table 2

Demographic Characteristics of Gender by the Region in the US.

Region in the US	Males		Females	
	n	%	*n*	%
West	25	65.8	13	34.2
Midwest	26	66.7	13	33.3
South	27	71.1	11	29.9
Northeast	19	63.3	11	36.7

Lists of all faculty members from all departments of interest (physics, chemistry, computer science, geology and earth science, civil engineering, mechanical engineering, biology, psychology, anthropology, and sociology) were compiled based on the information provided on the departmental web pages. Selection did not guarantee participation.

All faculty members within the selected departments were contacted via e-mail with a letter requesting their assistance in this project (Appendix A) and were given the opportunity to participate in the study. No compensation (financial or otherwise) was given for participation. If interested, participants were guided by the link in the body of the e-mail message to the on-line survey.

Procedure

All participants received an e-mail asking them to participate in the study. If they chose to participate, they followed the link provided in the letter. The link directed them to electronic Web-based survey hosted at SurveyMonkey.com. Participants were given unlimited time to complete the survey but were required to do so in a single session. The only restriction was to complete the survey within one month from receiving the request. After one month the surveys were pulled from SurveyMonkey, and no further data were collected.

The participants were provided with information about the study and were asked to initialize the consent acknowledging that they understand all their rights. After the consent, they proceeded with the study and completed the questionnaires on-line. The entire process took approximately 20-25 minutes. After completing the survey participants were asked to provide initials (codes) for further matching personality data with publication and citation data and to send their current curriculum vitae to the e-mail provided in the invitation letter.

Creativity measures (*h*-indices, publication and citation data) were collected from ISI Web of Knowledge using “Web of Science” (WofS) database. Curriculum Vitas (CV) were used to confirm the accuracy of the search. To initiate the search, last names of each participant with initials was entered into the WofS search engine. The search was limited by the year when PhD was granted.

If the CV was on hand, the results, generated by the WofS, were one by one compared to the CV. The articles listed in the CV were added to the “Marked List”. If articles listed in the CV were missing from the search result, an additional search was conducted by entering either partial initials or the last name of the participant as a search targets. For example, if the initial search for “Grosul M.V.” did not produce desired results, additional search was conducted with either “Grosul M.” or “Grosul” as search target. If the CV was not on hand, each article, produced by the search engine, was reviewed one by one to confirm the author’s institutional affiliation and author’s field of science.

When authorship of all publications was verified, and the total number of publications in “Marked List” of WofS was congruent with participants’ CVs, if available, the “Marked List” was saved. Afterwards, it was converted into readable format using software provided by Soler (2007) (see below for more details). The file generated by the software included the total number of publications, total number of citations, *h*-index, and *creativity index* data.

Materials

Survey Monkey. SurveyMonkey.com was used to compile and deliver electronic survey to all participants. Survey Monkey is an online survey editor that enables subscribers to create their own web-based surveys.

Big Five Personality Inventory (BFI). The five-factor model or Big Five is the most prominent model of personality in psychology (Zhang, 2002). The personality factors were measured using the BFI (John, Donahue, & Kentle, 1991). It is an empirically tested 44-question self-report measure of five dimensions/traits of personality, with responses on a 5-point Likert scale. Sample of the questions include: “I see myself as someone who is talkative” or “Tends to be disorganized” (see Appendix B). The instrument required approximately 10 minutes for completion. We calculated a total score on each personality dimension on a continuum from low to high for each participant. The traits were analyzed in conjunction with each other to calculate a personality profile. Test-retest reliability coefficients ranged from .80 to .90 for BFI administered three months apart as reported by Oliver and Srivastava (1999) and John, Naumann, and Soto (2008). Validity evidence included substantial convergent and divergent relations with other Big Five instruments as well as with peer ratings (Oliver & Srivastava, 1999).

Revised Eysenck Personality Questionnaire - Abbreviated (EPQR-A). A second personality questionnaire was used to assess an additional personality dimension, namely, psychoticism. The EPQR-A is a 24-item inventory consisting of 6 items in each of the four subscales: extraversion, neuroticism, psychoticism, and the lie scale (Francis, Brown, & Philipchalk, 1992). For the current study, however, only the psychoticism scale was used. It is scored on a Yes (1)/No (0) format. Sample questions include: “Is it better to follow society's rules than go your own way?” or “Does your mood often go up and down?” (see Appendix C). The instrument has adequate reliability as reported by

Katz and Leslie (2000) with Cronbach's Alpha equal to .75. Convergent validity of the EPQR-A, which was assessed through the correlation with parent instrument EPQR-S, was .80 (Katz & Francis, 2000).

Creativity assessment. Creativity data (number of publications and citations, *h*-index, and *creativity index*) were collected through the Web of Science (Web of Science, 2009). Web of Science (WofS) is the most comprehensive database to provide citation and publication data from 1975 to present time (Bar-Ilan, 2008). Two databases: Science Citation Index (SCI) and Social Sciences Citation Index (SSCI) – were used to gather citations and publications for this study. However, WofS is limited to searching through the journal publications only, preventing us from including books and book chapters into the count. Besides, WofS does not include some of the peer-reviewed journals. As a result, some of the fields of science were better represented than others in WofS database.

Four independent raters received about two hours of training and underwent two weeks of calibration prior to the actual data collection. Calibration was necessary for raters to understand how to avoid some complications in data search. During calibration all four raters gathered data on the same participants, some with CVs and some without.

The data collection was complicated by the established bibliometric issue know as the "name problem" (Franceschet, 2010). Names of the scientists are usually stored in WofS using their last name and initials (Grosul M. V.), but, sometimes, either partial initials (Grosul M.) or just last name (Grosul) are used. Usage of only partial initials or only last name as targets of search highly increases probability of homonymy conflict of names. In such cases, generated lists were verified and double-checked by all four raters independently. The ratings were compared and discrepancies were discussed and resolved. Pearson's product - moment correlation coefficient of the mean of each possible pair of raters was calculated to assess inter-rater reliability (r = .95).

The total number of publications (P_i) or the number of journal articles produced by scientists across their entire career (Feist, 1997) was used as a predictor of productivity of a scientist. Total P_i did not include books, book chapters, book reviews, comments, abstracts, obituaries, and proceeding papers. The impact of the scientist (C_i) was measured through the calculation of the total number of citations a scientist's work received over his or her entire career (Feist, 1997).

The *h*-index can be defined as the number of papers authored by a scientist with citations each paper receives equal to or greater than *h*. For example, a scientist has an *h*-index of 10 if he published at least 10 papers, each of the papers has at least 10 of citations and the rest of his publications have no more than 10 citations. The software provided by Soler (2007) automatically calculates the *h*-index. The convergent validity of the *h*-index, which was assessed through the correlation with similar metrics of scientific performance, was on average .93 (Costas & Bordons, 2008; Kulasegarah & Fenron, 2010).

The *creativity index* was calculated using data collected from WofS and processed by software provided by Soler (2007). *Creativity index* can be defined as a number that determines scientific creativity. This numbers is calculated by summing total number of published papers, total number of citations that each paper receives, total number of references that the paper cites, and then dividing the result by the total number of authors.

The calculation of the *creativity index* is not simple; however, Soler (2007) provided free software that performs all the calculations based on the information gathered through WofS. *Creativity index* is new and there is not enough research in regards of validity of this metric.

Overall creativity score. To examine the nature of the relationship between creativity variables (P_i, C_i, *h*-index, and *creativity index*), an Exploratory Factor Analysis (EFA) was conducted. Because all our creativity measures were highly correlated among each other, an oblique rotation of the factor loading matrix with Kaiser Normalization was preferred. Oblique rotation relaxes the assumption that all factors must be orthogonal, allowing for correlations between factors. The initial EFA resulted in one extracted factor with eigenvalue over 1.00. The single factor accounted for 90.87% of total variance. This result confirmed our expectation that all creativity measures can be interpreted as one factor and can be combined into a single overall creativity score. We, therefore, standardized all creativity variables (P_i, C_i, *h*-index, and *creativity index*) and transformed them into *z*-scores. Then we summed all the *z*-scores, and acquired standardized values or "overall creativity score." Therefore, an o*verall creativity score* was derived from four measures of scientific research creativity: P_i, C_i, *h*-index, and *creativity index.* The obtained values were standardized and summed to create overall creativity score (Rushton, 1990).

Demographic questionnaire. A demographic questionnaire consisted of 12 demographic questions concerning topics such as gender, race/ethnicity, age, etc. For full list of demographic question see Appendix D. The current study was a part of a larger project; therefore, for this project only some demographic data that is directly related to this study was included in further analysis.

Results

Descriptive Statistics

Geographic region. We conducted omnibus analysis of variance (ANOVA) to verify whether the demographic region (coded west = 1, midwest = 2, south = 3, northeast = 4) had any effect on the responses. All dimensions of personality except Big Five Personality Inventory (BFI) agreeableness, were not differentiated by the geographic region ($p > .05$). Post hoc pairwise comparisons using Tukey HSD test indicated that mean score for agreeableness for Midwest ($M = 3.57$, $SD = .48$, $n = 38$) was significantly different from South ($M = 4.02$, $SD = .71$, $n = 38$) with F (3, 138) = 3.22, $p < .05$, $d = .40$. Interestingly, in our sample people from South tended to be higher on the dimension of agreeableness.

Participants. A series of omnibus ANOVAs were conducted for each personality dimension by departments. Analyses indicated that all participants in all departments were statistically similar on all personality measures ($p > .05$).

Omnibus ANOVA by gender and personality revealed slight difference between men and women (coded male = 1, female = 2). Women scored higher than men on agreeableness, F (1, 140) = 6.06, $p < .05$, $d = .17$, and conscientiousness, F (1, 139) = 4.60, $p < .05$, $d = .17$, but the effect sizes in both cases were small. These results suggested that women tend to be somewhat more conscientious and somewhat more agreeable compared to men across all domains of science.

Omnibus ANOVA for personality measures by CV (coded 1 = CV present; 2 = CV absent) was conducted to verify that there is no difference between participants who submitted full curriculum vitae (CV) and participants who did not submit their CVs. Participants with and without CVs did differ on personality measures ($p > .05$). However, there was a significant difference between departments (coded anthropology =1, biology = 2, chemistry = 3, geology = 4, physics = 5, psychology = 6, sociology = 7) and whether the participant had full or partial CV, F (6, 138) = 2.28, $p < .05$, $d = .65$. Post hoc pairwise comparisons using Tukey HSD test indicated that sociologists had the highest return rate (90%) and biologist had the lowest CV return rate (42.1%). But, even with the large effect size, considering that overall there was no difference between scientists with or without CV the latter results would not have any influence on our main hypothesis testing.

Creativity measures. Publications, citations, *h*-indices, and creativity indices are always positively skewed in the population (Feist, 1997). In order to meet the assumption of normality all creativity measures (number of publications (P_i), number of citations (C_i), *h*-index, and Soler's creativity index) were transformed using logarithmic transformation procedure before being standardized and summed to create overall creativity score. Descriptive statistics for all creativity measures before logarithmic transformations are presented in Table 3.

Table 3

Descriptive Statistics of Creativity Measures before Logarithmic Transformation.

Creativity	n	Min	Max	*M*	*SD*	Skewness	Kurtosis
Publications (P_i)	145	1	500	37.26	60.83	4.65	27.54
Citations (C_i)	145	0	15582	1080.99	2029.48	4.28	23.00
The *h*-Index	145	0	58	12.48	10.84	1.57	3.19
Creativity Index	145	0	1580.66	129.56	244.62	3.49	14.01

After logarithmic transformation all creativity measures were normally distributed and not skewed or peaked. Results after transformation are presented in Table 4.

Table 4

Descriptive Statistics of Creativity Measures after Logarithmic Transformation.

Creativity	n	Min.	Max	*M*	*SD*	Skewness	Kurtosis
Publications (P_i)	145	.69	6.22	3.01	1.10	.13	.05
Citations (C_i)	145	.01	9.65	5.65	2.02	-.80	.20
The *h*-Index	145	.01	4.08	2.27	.88	-.42	-.34
Creativity Index	145	.01	7.37	3.50	1.83	-.08	-.92

Personality items. We calculated descriptive statistics for all personality items. The scores on all personality variables, except openness, were normally distributed, not skewed, and not peaked. Scores on openness were slightly negatively skewed (skewness = -.82) and slightly peaked (kurtosis = 1.09).

Correlations. Pearson product-moment correlation coefficients were computed between all variables: age, gender, career age, full or partial CVs, extraversion, agreeableness, conscientiousness, neuroticism, openness, psychoticism, publications (P_i), citations (C_i), *h*-index, *creativity index*, and overall creativity score. All creativity variables (P_i, C_i, *h*-index, and *creativity index*) were significantly positively correlated with career age. The average correlation coefficient between age and all creativity variables was $r = .50$, $p < .01$, indicating, not surprisingly, that when people develop their academic career they tend to publish more papers, and their papers tend to accumulate more citations.

All Pearson product-moment correlations between all variables are provided in Table 5. Gender was significantly positively correlated with agreeableness and conscientiousness, indicating that overall women tend to have higher score than men on the scale of openness and conscientiousness. Extraversion was significantly positively correlated to conscientiousness, openness, and Eysenck's psychoticism scale. Agreeableness was positively correlated to conscientiousness. Finally, openness was positively correlated to Eysenck's psychoticism scale.

All creativity measures (the overall creativity score, C_i, *h*-index, and *creativity index*), except P_i were significantly positively correlated to openness with average correlation index of $r = .22$, $p < .05$, indicating that people who score higher on openness tend to have more citations, higher *h*-index, and higher *creativity index* (see Table 5). Interestingly, the correlation between P_i and openness was not significant ($r = .19$, p > .05), indicating that openness does not have direct influence on productivity of a scientist and mostly affects only impact of a scientist to the field.

Psychoticism and the *h*-index were significantly negatively correlated to P_i. The correlation for P_i and psychoticism was r = -.20, p < .05 and for psychoticism and *h*-index r = -.19, p < .05. This result suggests that more productive scientists and scientists with higher *h*-index tend to have lower score on psychoticism.

All creativity variables (P_i, C_i, *h*-index, and *creativity index*) were significantly positively correlated among each other with average correlation of r =.95, p <.01. Pearson product-moment correlations between all variables are provided in Table 5.

Table 5

Correlation Matrix for All Variables

	1	2	3	4	5	6	7	8
1. Career Age		-.11	-.13	.01	-.03	-.07	.07	-.08
2. Gender			.05	.07	.14	.21*	.18*	.12
3. Region in the US				.07	.14	.06	-.05	-.04
4. Partial or Full CV					.01	-.06	-.05	.16
5. Extraversion						.07	.26**	-.12
6. Agreeableness							.27**	-.29**
7. Conscientiousness								-.25**
8. Neuroticism		.12	-.04	.16	-.12	-.29**	-.25**	
9. Openness	.09	.01	.01	.01	.36**	.06	.15	.02
10. Psychoticism	-.15	-.12	-.01	.05	.18*	-.06	-.05	.06

Table 5 (continued)

11. Publications P_i	.52**	-.12	.01	-.01	-.02	-.05	-.03	.11
12. Citations C_i,	.49**	-.11	.05	.01	.03	-.06	-.02	.14
13. The *h*-Index	.54**	-.14	.02	.01	-.01	-.09	-.4	.10
14. Creativity Index	.58**	-.14	.01	.08	.05	-.08	-,02	.09
15. Overall creat. score	.56**	-.13	.02	.03	.01	-.06	-.03	.11

Table 5 (continued)

	9	10	11	12	13	14	15
1. Career Age	.09	-.15	.52**	.49**	.54**	.58**	.56**
2. Gender	.01	-.01	-.12	-.12	-.11	-.14	-.13
3. Region in the US	.01	-.01	.01	.05	.02	.01	.02
4. Partial or Full CV	.01	-.19*	-.01	.01	.01	.08	.03
5. Extraversion	.36**	-.20	.03	-.01	.05	-.14	.01
6. Agreeableness	.06	-.02	-.05	-.06	-.09	-.08	-.08
7. Conscientiousness	.15	-.05	-.03	-.02	-.04	-.02	-.03
8. Neuroticism		.06	.11	.14	.10	-.02	-.03
9. Openness		.22*	.16	.21*	.21*	.22*	.21*
10. Psychoticism			-.20*	-.13	-.19*	-.12	-17

Table 5 (continued)

11. Publications P_i				.89**	.93**	.76**	.94**
12. Citations C_i,					.96**	.87**	.97**

Table 5 (continued)

13. The *h*-Index	.87**	.99**
14. Creativity Index		.92**
15. Overall creat. score		

n = 125
*Correlation is significant at the .05 level (2-tailed).
** Correlation is significant at the .01 level (2-tailed).

Multiple Regression

To test our main hypotheses, we conducted a hierarchical multiple regression analysis with 5 personality variables as predictors: openness, extraversion, conscientiousness, neuroticism, and psychoticism. Three other demographic variables were held constant (covariates) by being placed first in the equation: career age, gender (coded males = 1, females = 2), department (coded anthropology =1, biology = 2, chemistry = 3, geology = 4, physics = 5, psychology = 6, and sociology = 7). Overall creativity score was entered as the criterion variable. The purpose of the analysis was to examine whether the six personality factors can predict creativity in science above and beyond the demographic characteristics. Analysis was performed using SPSS version 16 software for PC and consisted of the two steps. Demographic variables (career age, gender, and department) were entered first, then, personality variables (extraversion, openness, agreeableness, conscientiousness, neuroticism, and psychoticism) were entered. Table 6 displays correlations between Overall creativity score and all predictor variables, R^2, change in R^2 (ΔR^2) and standardized regression coefficients (β).

Table 6

Correlations between Overall Creativity Score and Predictor Variables, R^2, and change in R^2 (ΔR^2), standardized Regression Coefficients (β), and Squared Semipartial Correlations.

Variables	Zero order *r*	β	R^2	ΔR^2	sr^2
Step 1: Demographics			.33**		
Career Age	.56**	.55**			.293
Gender	-.13	-.07			.003
Department	-.12	-.09			.008
Step 2: Personality Variables			.41**	.08*	
Extraversion	.01	.04			.001
Agreeableness	-.08	.03			.001
Conscientiousness	-.03	-.07			.004
Neuroticism	.11	.18*			.026
Openness	.21*	.19*			.029
Psychoticism	-.17*	-.16*			.023

n = 125
*Correlation is significant at the .05 level (2-tailed).
** Correlation is significant at the .01 level (2-tailed).

Step 1: Demographics. To control for possible effect of the demographic variables - career age, gender, and department - were entered in the first step. In the first step demographic variables accounted for 33% of total variance in overall creativity score and made a significant contribution to the regression model (R^2 = .33, F (3, 122) = 19.60,

$p < .001$). When estimation was adjusted for the population, which gives us some idea how well this model can generalize to our population, demographic variables accounted for 31% of the variance ($R^2_{adj} = .31$). Of the three predictors entered in the first step only career age produced significant contribution and added significant weight to the model ($\beta = .56$, $t = 7.29$, $p < .001$). Carrier age was positively related to the overall creativity score, indicating that when people progress in their career they tend to have higher creativity score. Career age accounted uniquely for 29% of the variance ($sr^2 = .54$). Interestingly, gender was not correlated with overall creativity, suggesting that men and women are equally creative in their scientific productivity.

Step 2: Personality variables. Personality variables - extraversion, openness, agreeableness, conscientiousness, neuroticism, and psychoticism - were entered in the second step. Overall, the model was found to be significant, $R^2 = .41$, $F(9, 116) = 8.88$, $p < .001$, over and above demographic variables. The two steps accounted for 41% of variance in overall creativity score with the adjustment for the population $R^2_{adj} = .36$. As a set, personality variables accounted for additional 8% of the variance explained in creativity over and above the demographic variables ($\Delta R^2 = .08$, $F(6, 116) = 2.70$, $p < .05$). However, only psychoticism ($\beta = -.16$, $t = -2.13$, $p <.05$, $sr^2 = -.023$), neuroticism ($\beta = .18$, $t = 2.26$, $p <.05$, $sr^2 = .026$), and openness ($\beta = .19$, $t = 2.39$, $p <.05$, $\mathrm{sr}^2 = .029$) explained unique variance in total creativity. That is, when all the shared variance with other predictors is removed, these personality variables still explain variance in total creativity.

Thus, based on the main analysis we can state that higher scores on openness and neuroticism can predict creativity in science. Interestingly, psychoticism was negatively related to creativity. Therefore, lower scores on psychoticism are related to creativity in science.

Discussion

In the present study we examined the possibility that personality variables can serve as predictors of creativity in science above and beyond demographic variables, such as career age, gender, and department. We predicted positive relationships between overall creativity and the personality traits of conscientiousness, openness, neuroticism, and psychoticism above and beyond demographic variables (Feist, 1998). Our predictions were partially confirmed. We found significant positive relationships between openness, neuroticism, and creativity in science. These results are in line with the previous research (Feist, 1998) and provide additional support for the positive relationship between personality traits of openness and neuroticism and creative achievement in science. What is the most impressive about these findings is the fact that even once age, which is highly correlated with career creativity, is held constant, personality variables still explain variance in creativity.

Personality and Creativity

Openness. Openness can be explained as need for variety, change, and novelty (McCrae & Costa, 2008). We found positive relationship between openness and creativity in science. Openness was also moderated group differences between high creative scientists and low creative scientists. High creative scientists scored significantly higher than low creative scientists on openness. Based on our results, scientists, who have wide imagination, who are curious, and open to new experiences, tend to be more creative than their conventional and down-to-earth colleagues. Scientists, who do not value novelty and do not have motivation to seek novel experiences, typically, do not appreciate creative behavior (Feist, 1998).

Interestingly, openness was significantly positively correlated to almost all our creativity measures (overall creativity score, number of citations, *h*-index, *creativity index*), except publications. Thus, higher scores on openness have greater effect on the impact of a scientist than his productivity.

Neuroticism. Neuroticism can be described as a tendency to experience dysphoric affect, especially, sadness, hopelessness, and guilt (McCrae & Costa, 2008). Higher levels of anxiety, vulnerability, and emotional sensitivity usually covary with higher levels of creativity (Feist, 1998). We found a positive relationship between neuroticism and creativity in science. As a result, emotionally reactive and sensitive scientists are more likely to be creative in science.

Agreeableness. Agreeableness is the willingness to be cooperative and compassionate during interpersonal conflicts (McCrae & Costa, 2008). Based on the previous research we predicted a negative relationship between creativity and agreeableness (Feist & Barron, 2003). This prediction was not confirmed. We did not find a significant relationship between creativity and agreeableness.

According to Simonton (1988) there are two ways to make contributions to science. First, there are scientists who work to advance "normal science". They work within existing paradigms and develop preciseness and accuracy of predictions within existing theory. Simonton calls them "advancers". Others are revolutionary scientists. They can be described as "daring iconoclasts" who ignore traditional boundaries.

Simonton (2004) points out that scientific creativity requires an optimal tradeoff between iconoclasm and traditionalism. Thus, there is a possibility that scientists-iconoclasts will score much lower on agreeableness than advancers.

Psychoticism. According to Ludwig (1995), highly creative individuals often show symptoms of psychopathology (cited from Simonton, 2004). Based on this inference, we predicted positive relationships between psychoticism and creativity. According to Feist (1998), scientists should score a half standard deviation higher than non-scientists on psychoticism. Surprisingly, in our study psychoticism was negatively related to creativity. In our sample creative scientists were opposite of hostile, impulsive, and manipulative.

Eysenck (1993) introduced psychoticism as one of the major factors of personality and proposed a positive relationship between psychoticism and creativity. He argued that creative people tend to be overinclusive in their thinking. Overinclusiveness is based on the lack of ability to use selective attention and properly filter unnecessary information. Overinclusiveness has the benefit of creating wide attentional focus by lowering cortical arousal (Eysenck, 1993). The level of arousal determines the size of neural networks involved in the process of problem solving (Heilman, 2005). A high level of arousal and focused attention suppresses the ability to use remote cortical sites. Low level of cortical arousal gives access to greater amount of associative areas, while higher level of cortical arousal makes behavior more stereotypical (Martindale, 1999). Having the ability to use a wide array of associative areas promotes unusual and creative thinking.

The relationship between psychoticism and creativity has produced mixed results in the literature (Batey & Furnham, 2006). There is a possibility that higher score on psychoticism is domain specific and depends on the field of science. As a consequence, scientists in certain areas of science will score higher on psychoticism than scientists in other areas of science. Ludwig (1998) suggested that scores on psychoticism depend on the amount of emotional involvement of the scientific discipline. According to his theory, psychologists, for example, would be more susceptible to mental illnesses and score higher on psychoticism than less personal and less emotional pathologists. Thus, additional studies are needed to understand the relationship between psychoticism and the domains of science.

In addition, there might be a difference in psychoticism between the advancers and revolutionary scientists. The latter, according to Simonton (2004), might exhibit higher rates of psychopathology. This conclusion is based on the study of Ludwig (1998) who discovered similar pattern among artists. Artists who create in more formal and more traditional styles have lower scores on psychoticism compared to the artists who use surrealistic and modernistic styles. Therefore, there is a possibility that revolutionary scientists have higher predisposition to psychotic reaction than their more conventional peers.

Also, one of the biggest problems in survey research is also nonresponse issue. Nonresponders could be different from responders on psychoticism. There is a possibility that highly creative revolutionary scientists were too busy with their work and did not consider our survey important.

Interestingly, in our study more publications were correlated to the lower score on psychoticism. This indicates that productivity depends on a low score on psychoticism. It is possible that more conventional and less impulsive people are able to publish more.

Based on the results of our study, other creativity measures (number of citations, *h*-index, *creativity index*) were not related to psychoticism. Thus, the higher score on psychoticism was not related to the impact, measured with citations.

Effect of personality on creativity. According to McCrae and Costa (2008) one of the assumptions of Big Five factor theory is proactivity. It refers to the locus of causation of human actions within the person. "Personality is actively - and interactively - involved in shaping people's lives." (McCrae & Costa, 2008, p. 162).

The main function of personality traits is to lower thresholds for the trait congruent behavior (Feist, 1998). Feist (1998) argued that some patterns of personality traits that consist of biological predispositions (genes, brain structure) and psychological tendencies make creative behavior more likely to occur. Biological predispositions set foundations for the personality. For example, polymorphism of human dopamine D4 receptor gene is associated with openness (Munafo et al., 2008). Mice with D4 receptor knockout exhibited reduced behavioral response to novelty compared to normal mice (Dulawa et al., 1999).

Psychological tendencies shape the form of the expression of biological predispositions based on the reaction threshold. For example, higher scores on neuroticism lower the threshold for dysphoric affect and hopelessness. Therefore, openness to experience and predisposition to sadness may lower the threshold for finding solution that is novel and original (Feist, 1998).

Implications

Creativity is very important for the society in general and for individuals in particular (Batey & Furnham, 2006). Explaining scientific creativity can help educators to identify and foster unique and creative scientific talents early in life (Sawyer, 2006). One of the theoretical goals of this study is to explore the nature of scientific creativity and to identify the distinguishing traits that can describe creative personality in science. Previous research has suggested the relationship between personality traits and creativity in science (Feist, 1998). Many previous studies, however, were either limited to assessing personality traits of scientists without assessing the degree of their creativity (Gouch, Bradley, & McDonald, 1991; Wilson & Jackson, 1993) or limited to a particular discipline (Wispe, 1963) or a particular generation (Garwood, 1964). This study extends the previous literature and theoretical understanding of creativity by evaluating not only scientists from different generations, but also from different disciplines.

Furthermore, most previous research used only the total number of publications and the total number of citations to evaluate creative input of scientists (Busse & Mansfield, 1984). Since then new measurements of productivity and impact of scientists have been developed. For example, *h*-index has been widely used by bibliometrics and scientometrics for evaluation of individual impact of scientists and collective impact of departments or journals but has seldom been used in the psychology of science to evaluate creative input of scientists.

Creativity is a complex matter. Future research should continue to develop the idea that measuring only the number of citations and publications cannot assess creativity in science.

Previous studies used subjective measures to operationalize creativity. Some researchers used self-reports and peer-ratings to evaluate creativity (McDonald, 1991). Others assessed creativity by using score on divergent thinking tests (Garwood, 1964) or personality inventories (Ham & Shaughnessy, 1991). Our study operationalized creativity through rational and objective measures of productivity (publications) and impact (citations).

Limitations and Future Directions

There are at least several limitations to this study. Using Web of Science (WofS) as a main source for all publication and citation information not only limited us to the evaluation of journal publications, that are represented in the WofS, but also prevented us from evaluating computer science and engineering areas due to their poor coverage in WofS database.

In addition, we would also argue that the WofS does not adequately cover social science. According to Meho and Yang (2007) WofS search is limited to the journals listed with Thomson Reuters (former Institute of Scientific Knowledge). However, only a number of journals in social science are listed with Thomson Reuters. For example, Meho and Yang (2007) indicated that chemistry, biology, physics, and medical science represent 69.3% and 84.6% of all journals listed with Thomson Reuters, and only between 4.4% to 18.7% of journals represent management, history, and education.

Publication and citation culture differs across disciplines: while some disciplines (physics, chemistry) tend to publish more journal articles, others (psychology, anthology) publish books and book chapters. The same problem can emerge even if we try to compare the number of publications and citations within discipline. For example, one area of biology may produce more publications and citations than another area of biology. Consequently, the more published area will be better represented in the WofS. Future study could use other bibliographic sources which will allow inclusion of books and book chapters to the overall publications and citations count.

Another limitation is related to the choice of personality measure. Although the Big Five Inventory (BFI) is valid and reliable measure of creativity, it is relatively short and lacks of the depth of personality evaluation of NEO PI-R. The latter consists of 240 items and offers the possibility to evaluate trait specific variance inside of the major five personality dimensions. Thus, if this study was to be replicated, NEO PI-R is would be preferable for better understanding of the nature of scientific personality.

Further research can evaluate the difference in personalities between domains of science. For example, there is a possibility that psychoticism is dependent on the field of science, where social science would score higher on psychoticism and physical science would score lover on psychoticism.

The current study furthered our understanding of personality and creativity in science. Openness to experience appears to be the strongest association with scientific creativity. Therefore, future research could focus on whether openness to experience is more of a cause of or an effect on creativity in science.

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Appendix A

Letter to Participants

Dear Faculty Member,

My name is Gregory Feist, Associate Professor of Psychology at San Jose State University. I am also founding president of the **International Society for the Psychology of Science and Technology** and founding Editor-in-Chief of its new peer-reviewed *Journal of Psychology of Science & Technology* (see http://www.psychologyofscience.org for more details).

In collaboration with Drs. Mark Batey (England) and Neelam Kumar (India) we are investigating the psychological influences that shape career choices for scientists and engineers. More specifically we are asking "*Why do particular people maintain their interest and motivation for science and engineering from adolescence to adulthood?*" Science and technology are increasingly vital to social and economic progress and yet recent studies show a declining interest in the current generation in becoming a scientist, mathematician, or engineer. But we need to uncover the reasons for the successes—those who have developed and maintained their interest from adolescence on through adulthood.

We need your help, however. If you participate, you will respond to an online survey that contains a set of questionnaires and a brief demographic survey. The entire time involved is **only 15-20 min**. The questionnaires are self-administered on the World Wide Web using the SurveyMonkey survey tool. Participation in the study is voluntary and rest assured that it has full approval from the Institutional Review Board at San Jose State University (protocol #S0804110). Of course, we will gladly provide you with summary results upon request.

If you agree to participate, please **go to one of the following link**:
http://www.surveymk.com/s.aspx?sm=JkimF1I51UdF8GRXOBypPg_3d_3d
If you are willing to participate and devote 15-20 minutes of your time to helping us understand how psychological influences affect people's decisions to go into and stay in science, we would be most grateful. If you participate please try to complete the survey **within 7 days** of receiving this e-mail. *If you need a little more time, please take it.*

Thank you for your cooperation and time!! This kind of research can only be carried out with your help. If you have any questions, contact me at psychofscience@gmail.com or greg.feist@sjsu.edu.

Sincerely,
Gregory J. Feist, PhD
Associate Professor of Psychology
President, International Society for the Psychology of Science & Technology
Editor-in-Chief, *Journal of Psychology of Science & Technology*

Appendix B

Big Five Personality Inventory

Big Five Personality Inventory
Please indicate the extent to which you agree or disagree with each of the statements below using the following scale:

Agree Strongly	Agree a little	Neither agree nor disagree	Disagree a little	Disagree strongly

I see myself as someone who…
1. Is talkative.
2. Tends to find fault with others.
3. Does a thorough job.
4. Is depressed, blue.
5. Is original, comes up with new ideas.
6. Is reserved.
7. Is helpful and unselfish with others.
8. Can be somewhat careless.
9. Is relaxed, handles stress well.
10. Is curious about many different things.
11. Is full of energy.
12. Starts quarrels with others.
13. Is a reliable worker.
14. Can be tense.
15. Is ingenious, a deep thinker.
16. Generates a lot of enthusiasm.
17. Has a forgiving nature.
18. Tends to be disorganized.
19. Worries a lot.
20. Has an active imagination.
21. Tends to be quiet.
22. Is generally trusting.
23. Tends to be lazy.
24. Is emotionally stable, not easily upset.
25. Is inventive.
26. Has an assertive personality.
27. Can be cold and aloof.
28. Perseveres until the task is finished.
29. Can be moody.
30. Values artistic, aesthetic experiences.
31. Is sometimes shy, inhibited.
32. Is considerate and kind to almost everyone.
33. Does things efficiently.
34. Remains calm in tense situations.
35. Prefers work that is routine.
36. Is outgoing, sociable.
37. Is sometimes rude to others.
38. Makes plans and follows through with them.
39. Gets nervous easily.
40. Likes to reflect, play with ideas.
41. Has few artistic interests.
42. Likes to cooperate with others.
43. Is easily distracted.
44. Is sophisticated in art, music, or literature.

Appendix C

Revised Eysenck Personality Questionnaire - Abbreviated (EPQR-A)

Revised Eysenck Personality Questionnaire - Abbreviated (EPQR-A)

Please answer “yes” or “no” to the following questions:

1. Does your mood often go up and down?
2. Are you a talkative person?
3. Would being in debt worry you?
4. Are you rather lively?
5. Were you ever greedy by helping yourself to more than your share of anything?
6. Would you take drugs which may have strange or dangerous effects?
7. Have you ever blamed someone for doing something you knew was really your fault?
8. Do you prefer to go your own way rather than act by the rules?
9. Do you often feel ‘fed-up’?
10. Have you ever taken anything (even a pin or button) that belonged to someone else?
11. Would you call yourself a nervous person?
12. Do you think marriage is old-fashioned and should be done away with?
13. Can you easily get some life into a rather dull party?
14. Are you a worrier?
15. Do you tend to keep in the background on social occasions?
16. Does it worry you if you know there are mistakes in your work?
17. Have you ever cheated at a game?
18. Do you suffer from ‘nerves’?
19. Have you ever taken advantage of someone?
20. Are you mostly quiet when you are with other people?
21. Do you often feel lonely?
22. Is it better to follow society’s rules than go your own way?
23. Do other people think of you as being very lively?
24. Do you always practice what you preach?

Appendix D

Demographic Survey

Demographic Survey

As a part of our study we would like you to answer the following questions. Your responses will be kept confidential and only persons directly involved in this study will have access to your responses.

1. What is your gender?
2. What is your race/ethnicity?
3. What is your age?
4. What is your birth-order (e.g., first, second, etc.)?
5. What is the number of generations your father's family has resided in the United States?
6. What is the number of generations your mother's family has resided in the United States?
7. What is the highest level of education that you have completed?
8. What department/area of science to you associate with (e.g., biological, computer and informational, engineering, geosciences, mathematical and physical, or social, behavioral, and economic sciences)?
9. What is the highest degree awarded at your university?
10. What is your primary occupation?
11. What is your job title?
12. Please select the region where you reside within the United States:

Appendix E

Signed Approval Form

San José State
UNIVERSITY

Office of the Provost
Associated Vice President
Graduate Studies & Research

One Washington Square
San Jose, CA 95192-0025
Voice: 408-924-2427
Fax: 408-924-2612
E-mail: gradstudies@sjsu.edu
http://www.sjsu.edu

To: Dr. Gregory Feist
Department of Psychology
San Jose State University
One Washington Square
San Jose, CA 95192-0120

Chad Kempel

From: Pamela Stacks, Ph.D.
Associate Vice President
Graduate Studies and Research

Date: October 27, 2008

The Human Subjects-Institutional Review Board has registered your study entitled:

"Profile of Scientists"

This registration, which provides exempt status under Exemption Category 2, of SJSU Policy S08-7, is contingent upon the subjects included in your research project being appropriately protected from risk. This includes the protection of the anonymity of the subjects' identity when they participate in your research project, and with regard to all data that may be collected from the subjects. The approval includes continued monitoring of your research by the Board to assure that the subjects are being adequately and properly protected from such risks. If at any time a subject becomes injured or complains of injury, you must notify Dr. Pamela Stacks, Ph.D. immediately. Injury includes but is not limited to bodily harm, psychological trauma, and release of potentially damaging personal information. This approval for the human subject's portion of your project is in effect for one year, and data collection beyond October 27, 2009 requires an extension request.

Please also be advised that all subjects need to be fully informed and aware that their participation in your research project is voluntary, and that he or she may withdraw from the project at any time. Further, a subject's participation, refusal to participate, or withdrawal will not affect any services that the subject is receiving or will receive at the institution in which the research is being conducted.

If you have any questions, please contact me at (408) 924-2480.

Protocol # S0804110