CREATIVITY AND RANDOMNESS

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ABSTRACT

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Major theories of creative cognition are reviewed in the present thesis. These theories are diverse yet seem to converge on similar key processes. One definition of creativity emphasizes going beyond stereotypical responses in the service of truly novel thought patterns. However, the generation of remotely associated elements must be done in a controlled, goal directed manner. To examine stereotypic and novel thought patterns, I used a cognitive measure termed Random Number Generation (RNG). Baseline tendencies reflecting departures from randomness ('trait' tendencies) were assessed, as were tendencies exhibited in a condition in which participants were asked to type number sequences in as random an order as possible ('ability'). Creative originality and creative achievement were found to relate to lower trait randomness on the Repetition of Responses factor of RNG. Creative fluency and creative flexibility, on the other hand, were related to higher ability for randomness according to the Prepotent Associates factor of RNG. Results indicate that the ability to overcome stereotyped sequences is beneficial for generating ideas, but that a certain rhythmicity of responding facilitates creative achievement. Limitations of the study and future directions are discussed.

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Cali Anicha, you have been the light that was always on whenever I needed a friend – I will miss you and Lynn dearly. My Russian Fargo friends – you have become and will remain my family. Lastly, I offer my regards and well-wishes to all of those who supported me in any respect during the completion of the project.

Darya L. Zabelina

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INTRODUCTION

Creativity is a critical and understudied component of effective human functioning. The literature highlights the importance of creativity in play, problem-solving, intelligence, social-emotional functioning, and ultimate career success (Plucker, Beghetto, & Dow, 2004). The basic principle in creativity is the ability to transcend the known, the conventional, by producing something new. That which is long known is entrenched in our long-term representation of experience, guiding our behavior, forming our concepts, directing accumulation of new information, and influencing what we remember and think. The truly creative individuals throughout human history were remarkable in that they created new associations in their minds despite entrenched concepts, and worked through them until the new product emerged (James, 1890).

Theories of Creative Cognition

A number of creative process theories have been proposed throughout the years. These include creativity as: Regression in the service of the ego, associations, defocused attention, lack of fixedness, and flexible control. The following is a brief review of these theories, and a discussion of their relevance to the current study.

Regression in the Service of the Ego

The concept of "regression in the service of the ego" (Kris, 1952) was an early attempt to account for fantasy and artistic creativity. Kris distinguished between primary process thinking, which is analogical and free associative, and secondary process thinking, which is abstract and goal oriented. Kris hypothesized that regression in the service of the ego proceeds in two phases: An *inspirational* and an *elaborational* phase. Creative inspiration involves regression to a primary process state of consciousness. The elaboration stage of the creative process involves a return to a secondary process state. Thus, there is an oscillation from unregulated thinking to regulated thinking. A continual interplay between inspiration (regression) and elaboration (criticism) takes place during the creative process. In Kris' view, if regression predominates, the symbols used in the artwork are egocentric and take on a private meaning. However, if there is too much control, the work of art will appear "cold, mechanical and uninspired" (Kris, 1952, p. 254).

The idea of regression in the service of the ego has been criticized on several grounds (e.g., Arieti, 1976). This is mostly because regressive processes in adults are usually thought to imply pathological mental functioning. Weisman (1971) argues that Kris's use of the term regression when speaking of creativity produces a "terminological disadvantage that detracts from an evaluation of the positive and strong developmental aspects of ego functioning in creative activity" (p. 402). Nass (1984) maintains that the capacity to experience and tolerate early modes of functioning requires a strong ego rather than a regressed one. One could reason, however, that a strong ego is, in fact, one that is partly defined by the flexibility of its various functions (Knafo, 2002). For example, the ego must be able to relax its controls to allow sufficient regression necessary for sleep.

Freud (1953) originally referred to the regressive movement from motor to visual sensations, which takes place in dream life, as a universal phenomenon. Blos (1967) has also called attention to the normative regression in the service of development that takes place universally in adolescence. Geleerd (1964) writes of adaptive regression in adolescence. According to Knafo (2002), it is no coincidence that dreams and adolescence have often been linked to creativity. Both of these phenomena involve normative regressive trends that simultaneously result in expanded creative potential.

In support of Kris' (1952) theory, Martindale (2007) stated that creative inspiration is effortless and tends to occur in states of reverie. In order to increase the probability of having a creative idea, one must regress from conceptual toward primordial cognition. Martindale and colleagues (Martindale, 1999; Martindale & Armstrong, 1974; Martindale & Hines, 1975) reported that highly creative people perform very poorly on biofeedback tasks, unlike less creative people who improve across trials at increasing or decreasing alpha-wave amplitude. This suggests that creative people lack self control in regulating focus of attention, thus providing evidence that primary processes predominate in creative people. Indeed, in one study, conscious cognitive control undermined creative performance: Those participants who were asked to talk through their strategies while performing a creativity task performed worse than those who were allowed to create silently (Schooler, Ohlsson, & Brooks, 1993). Zabelina and Robinson (2010) reported that those people who thought of themselves as little children consequently became more creative. The latter findings suggest that the regressive process of thinking of oneself as a child is important to creativity.

Regression in the service of the ego seems to be especially relevant in the earlier phases of the creative process. The problem space is relatively ill defined and ambiguous in the earlier phases; therefore regressing to the primary processes would enable the individual to explore more concepts in the problem space without having to necessarily concentrate on any one solution. This would potentially increase the likelihood of sampling relevant building blocks for constructing creative solutions. Indeed, Vartanian, Martindale, and Matthews (2009) report that creative people process information faster under conditions of low ambiguity.

It has been argued that the right hemisphere operates in a more free-associative, primary process manner, typically observed in states such as dreaming or reverie (see Grabner, Fink, & Neubauer, 2007). More original ideas have been shown to be accompanied by higher event-related synchronization (as measured by EEG) in the right hemisphere (Grabner et al., 2007). The importance of the right hemisphere in creativity has also been emphasized during divergent thinking (Razoumnikova, 2000), creative story generation (Howard-Jones, Blakemore, Samual, Summers, & Claxton, 2005), and nonverbal creativity, such as imagery and visual art (Bhattacharya & Petsche, 2005). Based on these findings, it would appear that Kris' (1952) regression in the service of the ego theory of creativity has some merit in capturing key processes in creativity.

Creativity from a Novel Associations Perspective

According to James (1890), creativity requires "transitions from one idea to another...unheard of combination of elements, the subtlest associations of analogy...where partnerships can be joined or loosened..." and – thus – connectivity. In the *Creative Mind*, Spearman (1931) suggested that a creative idea results from novel combination of two or more ideas that have been isolated from their usual contexts. Mednick (1962) followed up on James' and Spearman's hypotheses, and defined creative thinking as the combination of different associations – the more mutually remote the elements of the new combinations, the more creative the process or solution. According to this theory, a creative idea is simply a combination of remote ideas, with creative people making associations that are more remote than their less creative counterparts (Mednick, 1962; Mednick & Mednick, 1964).

The most widely used means of testing a person's scope of associations was designed by Mednick (1962). The Remote Associates Test (RAT) of creativity presents a subject with 3 words (e.g., "cottage," "Swiss," "mouse"). The person is then required to come up with a fourth word that has a specific kind of associative link that is common to the disparate words ("cheese"). The RAT has been updated by different authors, and is sometimes now called the Compound Remote Associates task (CRA; Bowden & Jung-Beeman, 2003).

Some empirical evidence for the associationistic theory of creativity comes from Mendelsohn and Griswold (1964, 1966), who found that scores on the RAT correlated positively with the use of incidental auditory stimuli in solving anagrams. Mobley, Doares, and Mumford (1992) asked people to combine categories to produce a new category. They found that when more diverse categories were presented, people created new categories that were more creative. In a study conducted by Rychlicka (as cited by Neçka, 1994), people were asked to decide whether two words presented to them were related. Creative people acknowledged the connection between the two words more frequently, particularly in the remote condition, as compared with less creative participants. In a similar study, creative people differed from less creative people in readiness to accept word associations and they were more susceptible to priming (Gruszuka & Neçka, 2002). Vartanian et al. (2009) reported the connection between creativity and the speed of judging relatedness: people with higher creative potential were faster in judging whether two concepts were related or unrelated. Furthermore, there is at least preliminary evidence that individuals can be trained to generate remote associations and that doing so may enhance human creative potential (e.g., Neçka, 1992; Prince, 1978).

There are biological theories that allow us to understand how the brain might facilitate unusual associations. Eysenck (1995) suggested that a lower degree of cortical arousal gives rise to remoter ideational connectivity. Consistent with Eysenck's theory, high levels of arousal lead to EEG desynchronization, which can be viewed in terms of isolated neural activity. Conversely, there is well developed alpha activity, conducive to cognitive integration efforts with relaxed wakefulness (Heilman, Nadeau, & Beversdorf, 2003). Finally, Martindale and Hasenfus (1978) found direct support for the idea that creative individuals had lower levels of resting EEG.

In addition, Heilman, et al. (2003) proposed that the myelination of subcortical connections, which leads to connectivity in the brain, might be important to creativity. Consistent with this view, Diamond, Scheibel, Murphy, and Harvey (1985) performed a histological analysis of Albert Einstein's brain. They found an abnormally high number of glial cells, whose role facilitates myelination.

Creativity as Defocused Attention

Also termed breadth of attention, creativity as defocused attention has arguably been the most prominent theory of creative cognition (Mehrabian, 1995). Individuals with a narrow breadth of attention focus on a relatively small range of stimuli at any one time and tend to filter extraneous or irrelevant stimuli from awareness; such "screeners" are relatively unaffected by their surroundings. In contrast, individuals with a wide breadth of attention focus on a larger range of stimuli at any one time and tend to be more aware of extraneous or irrelevant stimuli; such "nonscreeners" are affected more strongly by their surroundings. Mendelsohn (1976) proposed that a wide spread of attention facilitates creative performance. If people have a broad scope of attention, they have access to more information, which should facilitate combining unique elements into a creative idea.

Creativity as breadth of attention has been described in terms of task complexity. Cognitive research has documented that complex tasks require greater parallel processing (as opposed to serial processing), and thus wider breadth of attention than do simple tasks (e.g., Eysenck, 1993). According to Kasof (1997), creative tasks are inherently high in complexity; therefore, performance on such tasks is facilitated by wide breadth of attention and is hindered by narrow breadth of attention. Indeed, Kasof (1997) found that trait breadth of attention correlated with creative performance (poems rated by judges); creative performance was impaired by exposure to noise; and noise impaired creative performance more in participants whose trait breadth of attention was wide than in those whose trait breadth of attention was narrow. The results of this study support the hypothesis that breadth of attention is positively related to creative performance.

Friedman, Fishbach, Förster, and Werth (2003) tested the hypothesis that a broad or narrow scope of perceptual attention engenders an analogously broad or narrow focus of conceptual attention, which – they hypothesized – would bolster or undermine creative generation. In the first two experiments, participants completed visual tasks that forced them to focus perceptual attention on a comparatively broad or narrow visual area. As predicted, broad (compared to narrow) initial focusing of perceptual attention led to the generation of more original uses for a brick and the generation of more unusual category exemplars. In the third experiment, participants were merely asked to contract their frontalis versus corrugator muscles, producing rudimentary peripheral feedback associated with broad versus narrow perceptual focus. As predicted, frontalis contraction, relative to corrugator contraction, led to the production of more original uses for a pair of scissors. Together, these three experiments provide converging support for the attentional priming hypothesis, suggesting that situationally induced variations in the scope of perceptual attention (and simple cues associated with such variations) may correspondingly expand or constrict the focus of conceptual attention within the semantic network, thereby improving or diminishing creativity.

An argument against the theory of defocused attention in creativity comes from the field-dependent vs. field-independent framework (Martinsen & Kafumann, 1999). The notion of field dependence-independence can be conceptualized as a continuum, with those at the independent end tending to see objects or details as discrete from their backgrounds, and those on the dependent end tending to be affected by the prevailing field or context (Witkin & Goodenough, 1981). Although the findings are somewhat mixed, many researchers have demonstrated a positive relationship between field-independence and creative performance (Cropley, 1997; Martinsen & Kaufmann, 1999; Morris & Berum, 1978). For example, Bahar and Hansell (2000) found an overlap between field independence, high working memory capacity, and a divergent thinking style. Since a field-independent individual can easily break up an organized field and separate relevant material from its context or discern "signal" (what matters) from "noise" (the incidental and peripheral; Johnstone & Al-Naeme, 1991), it would appear that these findings contradict the defocused attention theory of creativity.

Lack of Fixedness

James (1890) suggested that the ability to change strategies was important in creativity. Functional fixedness, a notion introduced by the Gestalt psychologists (Duncker, 1945; Scheerer, 1963; see also Weisberg & Alba, 1981) involves the failure to think of using familiar objects in novel or unfamiliar ways to solve a problem. The classic demonstration of this phenomenon (Maier, 1931) asks participants to bring together the ends of two strings that are hanging too far apart to be reached simultaneously. A pair of scissors is also located in the room. The solution to the problem requires individual to view the scissors in a novel manner as a pendulum weight. Another way of testing functional fixedness is asking participants to generate as many solutions to a particular problem as possible. Each problem is presented with an accompanying example solution, and the score is the number of solutions generated as well as the similarity to the examples provided (Jansson & Smith, 1991).

Empirical evidence suggests that participants who are presented with possible example solutions are more likely to incorporate those solutions in their answers (therefore being less original) than those who are not presented with examples (Jansson & Smith, 1991). In another study, although participants consulted the problem instructions, they tended to follow the examples even when they included inappropriate elements (Chrysikou & Weisberg, 2005). Developmental evidence suggests that older but not younger children are slower to solve a problem by using an artifact for an atypical purpose when the design function is primed immediately prior to the problem presentation than when the design function is not demonstrated (Defeyter & German, 2003; German & Defeyter, 2000).

Lack of fixedness involves shifting back and forth between multiple tasks, operations, or mental sets (Monsell, 1996). Also referred to as "task switching," this ability requires disengagement from an irrelevant task set and the subsequent active engagement of a relevant task set. The findings from creative cognition experiments indicate that negative transfer – when previous examples hinder problem solving – may emerge in a broad range of domains. Some studies in the field of engineering design have suggested that the presentation of examples with a to-be-solved problem may lead to fixation in design problem solving (Jansson & Smith, 1991; Purcell & Gero, 1996; Purcell, Williams, Gero, & Colbron, 1993). There is also evidence that older but not younger children demonstrate functional fixedness (Defeyter & German, 2003; German & Defeyter, 2000), suggesting that acquired knowledge might hinder the ability to generate novel solutions.

Neuropsychological evidence for the functional fixedness phenomenon comes from patients with damage to dorsolateral areas of the frontal lobes. One key symptom of such impairments is perseveration or repeating the same response over and over even when it is clearly no longer appropriate. The symptom is interpreted in terms of difficulty in shifting mental set (Luria, 1966; Stuss & Benson, 1986). Patients with damage to the doroslateral prefrontal cortex are unable to use a comb for purposes other than to comb their hair, or an orange other than to be eaten (Miller & Cohen, 2001). A creative response is by definition "new and appropriate" (Sternberg, 1999), and therefore repeating the same response over and over is necessarily uncreative.

Flexible Control

It has been suggested that both the ability to diffuse attention and generate ideas, and the ability to focus attention and work within certain constraints, may be important for actual creative production (Finke, Ward, & Smith, 1992). Along these lines, Gabora (2002) proposed that a variable focus of attention is the key to the creative process.

Similarly, Martindale (1995, 1999) has argued that as opposed to being in a permanent state of defocused attention, creative people are characterized by a tendency to oscillate back and forth along the primary process-secondary process continuum. Martindale's theory indicates that creative people tend to defocus attention when necessary, as on tasks calling for creative responses. However, they are also capable of focusing their attention on tasks that require focused attention, such as intelligence tests (Martindale & Hines, 1975).

It is possible to illustrate the idea of flexible cognitive control borrowing from Block and Block's (2006) 30-year program of research on ego control and ego resiliency. The ego control construct differentiates individuals on the basis of whether they characteristically express affect and impulse (undercontrol) or characteristically inhibit such tendencies (overcontrol). It is possible that neither end of the continuum would be especially conducive to creativity, but for different reasons. Undercontrolled individuals would be spontaneous, but lack the discipline necessary for sustained creative efforts. On the other hand, overcontrolled individuals would be persistent but lack spontaneity (see Zabelina, Robinson, & Anicha, 2007).

Conversely, ego resiliency is theoretically and empirically distinct from ego control, which involves characteristics exhibited regardless of the situational context (Block & Block, 2006). Rather, resilient individuals are thought to modulate their levels of ego control in a context-specific manner. If the context favors spontaneity (e.g., while on vacation), such individuals are thought to relax ego control. On the other hand, if the context favors a greater degree of vigilance for inappropriate responses (e.g., while on a job interview), such individuals are thought to up-regulate, or in other words recruit, the cognitive control resources of the ego.

Ego resiliency has not typically been assessed in cognitive terms and measures of creative originality and/or creative performance have rarely been administered in this research program (Block & Block, 2006). Nonetheless, Letzring, Block, and Funder (2005) report that ego resilient individuals are viewed by acquaintances and clinicians as playful, imaginative, and possessing a wide range of interests. Such correlates of ego resiliency suggest that higher levels of flexible cognitive control may facilitate higher levels of creative originality and performance.

In support of such ideas, Feist (1999) demonstrated that the problem-solving behavior of eminent scientists was found to alternate between extraordinary levels of focus on specific concepts and playful exploration of ideas. This suggests that successful problem solving may be a function of flexible attention depending on task demands. It has also been suggested that the variable attention involved in creativity is dependent on the stage of the task, with earlier stages benefitting from greater attentional breadth and later stages benefitting from a more focused attention.

In addition, Vartanian, Martindale, and colleagues (Kwiatkowski, Vartanian, & Martindale, 1999; Vartanian, et al., 2009) have demonstrated that if the problem space is relatively ill defined or ambiguous, creative people are more likely to defocus attention. In contrast, when the problem space is relatively well defined and unambiguous, creative people are more likely to focus attention. Similarly, Kwiatkowski et al. (1999) found that creative participants had faster reaction times on an unambiguous Concept Verification Test, but slower reaction times on an ambiguous Stroop color-naming task.

In another investigation, Zabelina and Robinson (in press) linked creativity to flexible cognition, rather than to a steady state characterized by either automatic or controlled processes. They examined this relationship in terms of individual differences in Stroop interference costs (MacLeod, 1991). Individuals with high creative potential and creative achievement did not exhibit higher or lower cognitive control, but were better characterized in terms of their higher levels of flexible cognitive control. On the basis of such results, it appears that creative individuals do in fact modulate the manner in which they recruit and instantiate cognitive control, consistent with recent neurocognitive theories emphasizing the functionality of doing so (e.g., Miller & Cohen, 2001; van Veen & Carter, 2006). In other words, they display higher levels of cognitive control particularly when the context suggests that the recruitment of cognitive control is beneficial.

In neurocognitive terms, it is quite apparent that the cognitive capabilities of the human being, relative to other animal species, permit far less reliance on rigid stimulus-response associations and far greater capacities for creative thinking (Fuster, 1995; Miller & Cohen, 2001; Stuss & Knight, 2002). It has been known for a long time that patients with damage to the frontal lobes, including the well-known patient Phineas Gage, demonstrate severe problems in the control and regulation of their behavior, including performing executive tasks associated with creativity. These patients tend to show impairments on tasks such as the Wisconsin Card Sorting Test (WCST) and the Tower of Hanoi (TOH) task (Miyake, Friedman, Emerson, Witzki, & Howerter, 2000). Both of these tasks are sometimes used as measures of creative thinking – WCST, for example, has been suggested by different researchers as a measure of cognitive flexibility (see Miyake, et al., 2000). On the other hand, the TOH is a classic convergent thinking task, measuring the ability to find a solution to a presented problem.

Additionally, Martindale (1999) suggested that creativity is related to variability in level of arousal. In laboratory studies, more creative subjects show more spontaneous galvanic skin response fluctuations (Martindale, 1977), greater heart rate variability (Bowers & Keeling, 1971), and more variability in EEG alpha amplitude (Martindale & Hasenfus, 1978). There is also evidence that creative individuals show the greatest amount of variability in arousal during creative inspiration, as opposed to during baseline conditions (Florek, 1973; Martindale & Hasenfus, 1978). What seems to be true then is that creative people are not more or less aroused all the time. Instead, they switch back and forth from low arousal to high arousal states more easily.

The frontal cortex is a key brain region in creative thinking (Dietrich, 2004; Heilman, et al., 2003). Areas of the frontal cortex underlie cognitive flexibility in divergent thinking (Grabner et al., 2007). The part of the brain that has been linked to successful problem solving and insight is the anterior cingulate cortex (ACC; Kounios et al., 2006). Activity in the ACC is thought to reflect increased readiness to monitor for competing responses, and to apply cognitive control when necessary, shifting to another mode of processing if one proves ineffective (Kounios et al., 2006).

The Present Study

The idea that novel associations are important to creativity seems quite sound. However, novel associations that are farfetched, task irrelevant and just plain bizarre would not qualify as an example of creativity. That is, creative responses or behaviors have to have an element of appropriateness to the task or situational context (Sternberg & Lubart, 1999). Such considerations converge on a cognitive task that has great potential to understanding creative cognition, particularly from an individual differences perspective. Both baseline tendencies toward randomness and the ability to employ control to generate random response sequences were assessed with the Random Number Generation task (RNG; Baddeley, 1986; Mittenecker, 1958). The RNG task seems to require the controlled nonpatterning of thought (Graham & Evans, 1977). It is proposed that this controlled non-patterning of thought is a key element to the creative process.

Research concerning the RNG task began with manipulation studies. Taxing executive attention or working memory significantly impairs RNG performance (e.g., Baddeley, 1966). More recently, studies have linked performance on the RNG task to other individual difference variables in clinical conditions. One study found that individuals high in hypnotic susceptibility could perform better on the RNG task (Graham & Evans, 1977). This result is intriguing, given that there is some relationship between hypnotizability and creativity (Shames & Bowers, 1992). Populations hypothesized to be structurally or functionally deficient in their frontal processing have done poorly on RNG tasks. This includes schizophrenics, and alcoholics (Rosenberg, Weber, Crocq, Duval, & Macher, 1990), as well as Alzheimer's patients (Brugger, Monsch, Salmon, & Butters, 1996). Thus, it may be that participants capable of generating more random sequences may be more creative.

Further, we know something about the brain correlates of good RNG performance. Specifically, inhibition of habitual sequences during RNG is closely related to the processes mediated by the dorsolateral prefrontal cortex (DLPFC; Spatt & Goldneberg, 1993). Studies using transcranial magnetic stimulation (TMS) have shown that deactivating the (left) DLPFC results in impaired abilities to generate random sequences (Jahanshahi et al., 1998; Jahanshahi & Dirnberger, 1999). Similar brain correlates have been identified in ERP studies (e.g., Joppich et al., 2004). Further, there is reason to believe that regions in the right frontal lobe are involved in the suppression of repetitive behavior (Brugger, Monsch, & Johnson, 1996). Because the frontal cortex has also been heavily implicated in creative cognition, a task sensitive to such processes – i.e., the RNG task – may provide significant insights into individual differences in creativity.

Hypotheses

It was hypothesized that creative individuals would perform better in generating random number sequences. Multiple measures of creativity were assessed, including creative potential and evidence of a history of creative achievement. Randomness was assessed with the program of Towse and Neil (1998), and three randomness factors were derived based on prior work of Friedman and Miyake (2004). In a baseline condition, no particular instructions toward randomness were given. At times, performance in this block will henceforth be referred to as 'trait randomness' – i.e., the term used to refer to individual difference tendencies rather than abilities. Following the baseline condition, participants were instructed to be as random in their output as possible. At times, performance in this block will be referred to as 'ability randomness.'

METHOD

Participants and Procedures

Participants were 102 (61 female) student volunteers from North Dakota State University seeking extra credit for their psychology classes. Eighty percent described themselves as While/Caucasian, 7% as Asian or Pacific Islander, 5% as African American, 2% as Hispanic, and the remaining 3% were either Indian, Chinese or White/Asian. Mean age was 19.32 (*SD* = 2.19). Primarily, students were freshmen or sophomores who were enrolled in Introductory Psychology classes. No special recruitment efforts occurred. Rather, students seeking extra credit signed up for any of a number of psychology studies conducted in the department by logging into our SONA participant registration software through the Internet and entering their name within a relevant time-slot. Participants volunteering for the present study did so in relation to a relatively generic title – "Drawing Study". The brief Internet description of the study stated that it would involve a drawing task, a computer task, and some questionnaires.

The laboratory consisted of a large central room for initial instructions and 6 private adjoining rooms for data collection. Thus, assessment sessions always involved fewer than 7 individuals. After reviewing and signing the consent form, participants were delegated to their private cubicle rooms. They first completed a version of the Torrance Test of Creative Thinking (TTCT; Torrance, 1974) and then the Creative Achievement Questionnaire (CAQ; Carson, Peterson, & Higgins, 2005), both further described below. Participants then completed the RNG task and a number of questionnaires administered by a personal computer. The activities were described as independent and the order of measures was held constant in order to facilitate the individual difference comparisons of central interest to the study.

Measures

The Random Number Generation (RNG)

The RNG task was administered on a computer, in a manner generally consistent with the procedures of Friedman and Miyake (2004). Performance was paced with a sound (1 per second), presented via personal headphones. Participants were asked to synchronize their responses with the sound until they produced 100 responses, which completed the relevant block. A distinctive signal was emitted if a participant failed to press a key in the allotted time.

There were two different conditions during the RNG task. The baseline condition was meant to test participants' natural predisposition towards stereotyped or random responses. In this condition, participants were asked to generate numbers by pressing the number keys 1-9 on a keyboard in any way they liked. No specific instructions for randomness were given.

Specific instructions for randomness were then presented. This constituted an experimental condition and was meant to assess participants' ability to generate random sequences. In this condition, participants were asked to use numbers 1-9 using an analogy of picking a number out of a hat, typing it, putting it back into the hat, picking a second number, and so forth, and then picking another number. It was noted that a random sequence would not exclude repetitions or adjacent number values.

Abbreviated Torrance Test for Adults (ATTA)

A shortened form of the Torrance Test of Creative Thinking (TTCT: Torrance, 1974), termed the Abbreviated Torrance Test for Adults (ATTA: Goff & Torrance, 2002), was used. The TTCT has excellent psychometric properties based on 25 years of development and evaluation (Kim, 2008; Millar, 2002). The TTCT also has the largest set of scoring norms available to the creativity literature (Davis, 1997). The predictive validity of the TTCT has been established across a broad age range, including within longitudinal criterion validity studies (Davis, 1997).

The ATTA consists of three activities, one involving verbal responses and two involving figural responses (e.g., using incomplete figures to make pictures). Goff and Torrance (2002) provide evidence for the reliability and validity of ATTA scores. Responses are scored for fluency (i.e., a count of the number of pertinent responses), flexibility (i.e., the ability to process information or objects in different ways, given the same stimulus), and originality (i.e., the number of responses that are unique and original), with summary scores summed across the three activities (Goff & Torrance, 2002). Flexibility and originality were scored according to the ATTA scoring manual. In scoring flexibility, 1 point was given for each number of different ways the triangles in Activity 3 were used. For example, the same design features given to multiple triangles would indicate a lack of creative flexibility. In scoring originality, a common response from the manual was given a score of 0 and other responses that were appropriate were given a score of 1.

<u>The Creative Achievement Questionnaire (CAQ)</u>

Capacity for creative potential and its manifestation in creative performance can often be independent (Ivcevic, 2009). Thus, it was deemed important to assess individual differences in creative behavior as well in terms of the CAQ (Carson et al., 2005). Individuals were asked to characterize their prior creative achievements in 10 artistic domains (architectural design, creative writing, culinary arts, dance, humor, inventions, music, scientific inquiry, theater and film, & visual arts). For each domain, participants could indicate that they had made 0 achievements ("I have no training or recognized talent in this area"), had some training (e.g., scored as 1: "I have taken lessons in this area"), with 6 other ascending levels of creative performance (e.g., scored as 7: "My choreography has been recognized by a national publication"). To score creative achievement in a general manner, scores were averaged across the 10 different domains involved. Carson et al. report extensive evidence for the reliability and validity of such Total Creative Achievement scores.

Randomness Quantification

The RG Calc program (Towse & Neil, 1998) produces 19 randomization indices. Friedman and Miyake (2004) performed a factor-analysis of these 19 indices and found that 14 of them loaded fairly highly onto 3 higher-order factors. These factors are: Prepotent Associates, which reflects the tendency to produce stereotyped sequences; Inequality of Responses, which is the tendency to use responses unequally often; and Repetition of Responses, or the tendency to repeat responses at equal intervals. I also factor-analyzed our own data and found a very similar factor structure. It was deemed best to use the factor loadings of Friedman and Miyake (2004), however, to insure comparable factors across past, present, and future studies. Most of the analyses below use such factor scores, which have intuitive meaning and allow for the reduction of Type I error.

The following are the indices that load onto each of the three factors: Prepotent Associates: TPI (turning point index), A (total adjacency), Runs, RNG (Evan's number generation score), & RNG2 (analysis of interleaved diagrams); Inequality of Responses: RNG2, R (redundancy), Coupon, & Mean RG (mean repetition cap); and Repetition of Responses: Phi4, Phi3, Phi2, Phi5, Phi6, Phi6. In all cases, indices are listed in terms of the highest to lowest loading, respectively. In order to calculate scores for each factor, individual indices were z-scored and averaged with indices reverse-scored if necessary. Analyses of the scores revealed that all of six (block x factor) distributions were positively skewed. To correct for positive skew, 2.5 *SD* outliers were replaced with such outlier cut-off values. In addition, analyses were based on log-transformed scores.

RESULTS

RNG Descriptive Results

Correlations among the three RNG factors are reported in Table 1. As the table demonstrates, in the baseline condition there were significant positive correlations between Prepotent Associates and Inequality of Responses, $r = .31, p < .01$, and between Inequality of Responses and Repetition of Responses, $r = .36, p < .01$. However, there was no correlation between Prepotent Associates and Repetition of Responses, $r = -.11, p > .05$. In the experimental condition, however, only the relationship between Prepotent Associates and Inequality of Responses was significant, $r = .49, p < .01$, the other two $|rs| < .18$.

Friedman and Miyake (2004) suggested that RNG performance reflects three non-overlapping processes and indeed they found very low correlations among the three factors in their study. Present results suggest possible qualifications to the independence idea, at least with respect to the relationship between abilities to overcome prepotent associates and to use all numbers equally often. Friedman and Miyake only included what would be considered this study's experimental condition. Therefore, it is interesting to observe that correlations among the factors are at least slightly different at baseline, potentially foreshadowing divergent correlational patterns to be reported later.

Finally, factor scores were significantly correlated across blocks, indicating some relationship between trait and ability aspects of randomization performance. In my opinion, these correlations pose some potential problems for conceptualizing randomization performance, even in an experimental block, as ability-pure. That is, there also appear to be trait stylistic factors that contribute to these purported ability measures.

Table 1. Correlations among RNG Factors

	BInequality of Responses	BRepetition of Responses	EPrepotent Associates	EInequality of Responses	ERepetition of Responses
BPrepotent Associates	.31**	-.11	.37**	.16	-.03
BInequality of Responses	---	.36**	.34**	.53**	.17
BRepetition of Responses		---	.10	.48**	.27**
EPrepotent Associates			---	.49**	-.08
EInequality of Responses				---	.17

B = Baseline Condition
E = Experimental Condition
**$p < .01$

For purposes of factor scoring, indices were z-scored separately by block. Because of this, it would not be meaningful to compare mean factor scores across blocks. Instead, to compare randomization performance across blocks, it is necessary to conduct analyses at the index level. Means for each index – by condition – are presented in Table 2. In addition, 14 repeated measures ANOVAs were performed. As can be seen from the table, participants were more random in the experimental conditions on 8 out of 14 indices, compared to the baseline condition. Specifically, participants generated more random sequences in the experimental condition on indices that go into the factor Prepotent Associates and on most indices that go into the factor Repetition of Responses. Only one of the four indices composing the Inequality of Responses factor was significantly different by condition.

The most important result to emerge from Table 2 is that people were able to randomize their performance to a greater extent when given instructions to do so. This speaks to the validity of the task and, to some extent, the different nature of the response patterns produced in the two blocks. Interestingly, the factor with the greatest trait-like aspect (cross-block correlation) was associated with indices that varied relatively minimally from baseline to the experimental condition. At the very least, it appears that scores of this factor may reflect more trait than ability.

Gender differences in random number generation were also examined. There were no gender differences in the baseline condition, all *p*s $> .05$. However in the experimental condition, when instructions for randomness were present, males were more random than females on the Prepotent Associates and Inequality of Responses factors, $r = .26, p < .05$, and $r = .28, p < .01$, but not on Repetition of Responses, $r = .03, p > .05$. These results indicate that males might be on average better than females at imagining and manipulating number sequences, and may reflect the nature of the symbols, as men often score higher on tasks involving numeric processing (Allen, 1974; Contreras, Rubio, Peña, Colom, & Santacreu, 2007). It would be interesting to change the nature of the symbols such that participants had to type in letters rather than numbers at random. In such a case, women might exhibit higher abilities, as women often score higher on tasks involving verbal stimuli (Kimura & Clarke, 2002).

Table 2. Mean Differences between Baseline and Experimental Conditions

	Baseline *M*	Experimental *M*	*F*
Prepotent Associates			
TPI	72.91	80.76	7.91**
A	35.64	27.49	20.09**
Runs	2.07	1.21	25.38**
RNG	.42	.39	3.08†
RNG2	.40	-1.17	4.48*
Inequality of Responses			
RNG2	.40	-1.17	4.48*
R	4.17	4.70	.66
Coupon	17.49	16.54	.68
Mean RG	9.17	9.07	.88
Repetition of Responses			
Phi4	-2.61	-3.02	3.47†
Phi3	-.83	-2.48	18.16**
Phi2	-.70	-1.17	1.00
Phi5	-2.09	-2.58	5.17*
Phi6	-2.18	-2.44	1.89
Phi7	-1.96	-1.86	.33

Note. TPI (Turning Point Index) = the number of responses that, as numerical values, mark a change between ascending and descending sequences. A (Adjacency) = percentage of adjacent numbers given. Runs = variability in the phase length. RNG = distribution of response pairs. RNG2 = pairing of every alternate response. R = redundancy. Coupon = mean number of responses produced before all the response alternatives are given. Mean RG = mean repetition gap. Phi4-Phi7 = repetition tendency over different lengths for binary sequences.

† <.10, *p < .05, **p < .01

Creativity Descriptive Results

Means and standard deviations for ATTA fluency ($M = 10.64$, $SD = 3.79$), flexibility ($M = 3.08$, $SD = 1.73$), and originality ($M = 5.60$, $SD = 3.54$) were similar to those of the test developers (Goff & Torrance, 2002). The same was true ($M = 11.00$, $SD = 8.18$) for scores from the CAQ measure of creative performance (Carson et al., 2005). The correlation between ATTA fluency and CAQ scores was significant, $r = .33$, $p < .01$. This relationship is not surprising, given the fact that both measures assess the quantity of output at some level. On the other hand, correlations between CAQ scores and ATTA originality, $r = .15$, $p > .05$, and ATTA flexibility, $r = .17$, $p > .05$, were not significant. The non-significance of these relationships is consistent with Runco's (2004) suggestion that creative potential (primarily in terms of originality) and creative behavior are dissociable. A history of creative behaviors, for example, would likely be influenced to a greater extent by developmental exposure to the arts and a history of formal training, irrespective of the originality of a person's thinking.

ATTA fluency and flexibility were significantly correlated, $r = .67$, $p < .01$. This finding is consistent with previous research (Goff &Torrance, 2002). Further, it stands to reason that the more responses a person produces, the larger the chance that a greater variety of solutions to the same problem or activity will be found. On the other hand, there was no relationship between ATTA originality and ATTA fluency, $r = .09$, $p > .05$, nor between ATTA originality and ATTA flexibility, $r = -.13$, $p > .05$. Creative originality is very different from fluency and flexibility (Runco, 2004). For example, greater effort should manifest itself in terms of greater fluency, but there may be inherent limitations on a person's creative originality nonetheless. Originality, then, has been conceptualized in terms of creative potential regardless of the number of ideas generated (Goff &Torrance, 2002). As will be found below, different RNG factors in fact predicted originality vs. fluency.

Creativity and Random Number Generation

I sought to predict the creativity measures on the basis of RNG performance. Recall that one novel feature of the investigation was the inclusion of a baseline RNG block that was thought to assess a person's sequential habits of mind independently of ability-related considerations. Correlations between baseline RNG factors and the creativity measures are reported in the first three columns of Table 3. To interpret the correlations, it is important to keep in mind that higher RNG scores indicate greater departures from random sequencing. Of interest, I was able to predict *both* a person's originality and history of creative behavior on the basis of the Repetition of Responses RNG factor. The sign indicates that higher levels of repetition, rather than lower, were associated with higher levels of creativity. This is a fascinating result that will be discussed more fully later. The other two baseline RNG factors – Prepotent Associates and Inequality of Responses – were non-predictive of any of the creativity scores.

Table 3. Correlations among Creativity Measures and RNG Factors

	BPrepot. Assoc.	BInequal. of Resp.	BRepet. of Resp.	EPrepot. Assoc.	EInequal. of Resp.	ERepet. of Resp.
Fluency	-.07	-.14	.13	-.33**	-.09	-.03
Flexibility	-.13	-.16	.07	-.21*	-.10	-.02
Originality	.01	.13	.23*	.13	.19	.08
CAQ	-.07	.17	.32**	-.16	.12	.13

B = Baseline Condition
E = Experimental Condition
$^*p < .05$, $^{**}p < .01$

I now turn to the experimental condition, in which explicit instructions to be as random as possible were presented. These correlations are reported in the final three columns of Table 3. As shown there, the pattern of correlations was quite different. First, the Repetition of Responses factor no longer predicted ATTA originality or CAQ scores. Thus, the correlations earlier reported reflect habits of mind rather than abilities. Second, I was now able to predict fluency and flexibility, which had not been the case in the baseline condition. Specifically, greater abilities to overcome Prepotent Associates predicted higher levels of fluency and flexibility. This makes sense, as Prepotent Associates might trap the mind into perseverative solutions to the same task, a point further discussed below.

Two multiple regressions were performed to further understand the findings. In the first regression, baseline Repetition of Responses factor scores were entered as a DV and ATTA fluency, flexibility, originality, and CAQ scores were entered as predictors. ATTA originality and CAQ remained significant predictors of baseline Repetition of Responses, $t = 2.10$, $p < .05$, $\beta = .21$, and $t = 3.04$, $p < .01$, $\beta = .31$, respectively (see Table 4). Thus, tendencies to repeat responses at various lags independently predicted creative potential and creative behavior.

A second multiple regression was performed on data from the experimental condition. In this case, the Prepotent Associates factor was entered as a DV and all four creativity scores were entered as predictors. With the overlapping variance of fluency and flexibility controlled, the former variable was a significant predictor while the latter variable was not (see Table 5). This result, too, makes sense on the basis of wider theories of fluency, as further discussed below. Originality was now a positive predictor of prepotent associations. However, given that there was no zero-order correlation of this type, I am reluctant to discuss this finding further.

Table 4. Baseline Condition Repetition of Responses as a Function of Fluency, Flexibility, Originality, and CAQ

Variable	B	SEB	β	*t*
Fluency	-.01	.02	-.09	-.62
Flexibility	.02	.05	.05	.34
Originality	.04	.02	.21	2.10*
CAQ	.02	.01	.31	3.04**

*$p < .05$
**$p < .01$

Table 5. Experimental Condition Prepotent Associates as a Function of Fluency, Flexibility, Originality, and CAQ

Variable	B	SEB	β	*t*
Fluency	-.07	.03	-.37	-2.70**
Flexibility	.03	.05	.09	.64
Originality	.04	.02	.21	2.08*
CAQ	-.01	.01	-.06	-.55

*$p < .05$
**$p < .01$

A final set of correlations was performed. In this case, experimental RNG factor scores were subtracted from corresponding baseline RNG factor scores. Such difference scores capture the extent to which the person could randomize their response output relative to their own baseline tendencies. These correlations are reported in Table 6. As shown there, the Prepotent Associates difference score positively predicted output fluency in the creativity task. This correlation reinforces an ability-related contribution to fluency.

Table 6. Correlations among Creativity Measures and the Influence of Instructions on RNG Factors

	Prepot. Assoc. Difference	Inequal. of Resp. Difference	Repet. of Resp. Difference
Fluency	.24*	-.06	.13
Flexibility	.08	-.06	.08
Originality	-.12	-.06	.13
CAQ	.08	.06	.17

*$p < .05$

DISCUSSION

In the present study, the relationship between creativity and randomness was examined. Previously, random number generation has been examined from the ability perspective only, where instructions for randomness were explicit (e.g., Friedman & Miyake, 2004). In the present study, however, I assessed it from a trait perspective as well, where no instructions for randomness were given. This condition was thought to assess trait or habitual patterns of thinking quite independently of any ability related context. In this respect, this study's methods and findings were entirely novel.

Past research indicates that it is practically impossible to generate truly random sequences (Rabinowitz, 1970; Wagenaar, 1972). Our results do not dispute such a claim. However, they do suggest that there are meaningful individual differences in the extent to which people conform to mathematical randomness, both as a trait and ability. In addition, I was able to support the idea that individuals can increase their levels of random output with instructions to do so (see Table 2), demonstrating that it is in fact possible to willfully become more random in generating number sequences.

The main purpose of the study, however, was to assess whether creative individuals differ in their trait randomness and/or ability to produce random sequences. Initially there were no differentiated hypotheses concerning which RNG factors would predict which aspects of creativity, instead predicting only that creative people would exhibit higher trait and ability randomness. The findings were quite interesting in that they differentiated between cognitive processes involved in creative fluency and flexibility vs. creative originality and creative achievement. Specifically, it was found that people with high scores on ATTA originality and CAQ were less random than their low scoring counterparts on the Repetition of Responses factor of the RNG, particularly so in the baseline condition, providing evidence for trait randomness. People scoring high on ATTA fluency and flexibility, however, did not differ from their low scoring counterparts in the baseline condition, but were more random on the Prepotent Associates factor in the experimental condition. These findings are interpreted below.

Fluency, Flexibility, and Randomness

Creative fluency is the ability to produce a number of responses to a given stimulus. Doing so should be facilitated by avoiding repeating retrieval strategies, which would tend to produce similar responses over and over again. In the case of the ATTA, an example question is "Just suppose you could walk on air or fly without being in an airplane or a similar vehicle. What problems might this create? List as many as you can." One could well imagine that prepotent associations would lead individuals to imagine very common responses, such as hitting objects or falling down, without being able to move on to less prepotent answers to the question. It is for such reasons that highly prepotent individuals likely exhibited lower levels of creative fluency as well.

Flexibility can be thought of as the anti-thesis to functional fixedness (e.g., Duncker, 1945), as it involves the use of a familiar object in novel or unfamiliar ways. Although flexibility has some different attributes than fluency, similar tendencies toward Prepotent Associates would also seem to be problematic. In this case, a mind characterized by Prepotent Associates would similarly perseverate on common or obvious solutions to creativity problems, undermining flexibility levels as a result. It is likely because both the ATTA task and the experimental block of the RNG task encouraged participants to try hard that prepotent associations from the experimental block were more predictive.

An additional perspective on the present findings comes from neuropsychological investigations. Such investigations have shown that the frontal lobes are key mediators of creative fluency and flexibility (Miller & Cohen, 2001; Spatt & Golenberg, 1993). Additionally, functional fixedeness (lack of flexibility) is especially evident in patients with damage to the dorsolateral prefrontal cortex (Miller & Cohen, 2001). Turning to the brain areas supporting effective randomization performance, similar brain areas have been implicated (Jahanshahi et al., 1998; Jahanshahi & Dirnberger, 1999). Thus, it is possible to understand the present findings in terms of their reliance on similar functional processes of a prefrontal type.

Originality, Creative Achievement, and Randomness

Creativity requires novel, unique associations. However, associations that are novel but inappropriate cannot be considered creative (Runco, 2004). Children, for example, or patients with psychopathology, often produce unique, but entirely inappropriate responses. Poincare (1913, as cited in Martindale, 2009) proposed that the creation of a creative idea is akin to numerous atoms set in motion and moving around in space where they are enclosed. When atoms collide, they produce new combinations. This process happens subconsciously, the role of which is to set the atoms in motion. Poincare points out that "our will did not choose them at random, it pursued a perfectly determined aim (p. 115)" – i.e., we subconsciously *choose* which of the atoms to set in motion on the bases of a potential combination that will lead to a desired solution.

In this light, while randomness can be functional in producing a large number of responses (fluency) that differ from each other (flexibility), creative originality, and especially creative achievement, would require choosing a particular response and focusing on it, while abandoning all other responses. In fact, the capacity to ignore irrelevant stimuli is an important aspect of the creative process (Gabora, 2002). Simonton (1999), using a Darwinian framework to explain artistic and scientific creativity, noted that "the creative genius has a facility for generating variations (new combinations of ideas) and retaining those that are most 'fit' or useful.

To the onlooker, this would look like lack of randomness, for a person is dedicating all of his/her attentional resources to one particular object/response. That is what was found in the present study. Participants scoring higher on creative originality and creative achievements showed lower randomness on the Repetition of Responses factor of RNG.

Conclusions

The results of the present study indicate that both random and non-random processes are important to creativity. Hence, our findings provide partial support for the flexible cognitive control theory of creative cognition (Martindale, 1995, 1999; Zabelina & Robinson, in press). Flexible cognitive control theory posits that creative people are characterized by a tendency to oscillate back and forth along the primary process-secondary process continuum (Martindale, 1995, 1999). It seems appropriate then that the ability for randomness, such as random associations, would be associated with creative fluency and creative flexibility. This could be especially so in the initial stages of the creative process, while one is coming up with various solutions to a particular problem.

Focusing on a potential successful answer to a problem and elaborating on it further, i.e., becoming less random, is associated with creative originality and creative achievement. Recall that Feist (1999) demonstrated that the problem-solving behavior of eminent scientists alternated between extraordinary levels of focus on specific concepts and playful exploration of ideas. Focusing on a particular solution might be beneficial in the later stages of the creative process, when one already has a pool of possible solutions to choose from.

The present study, although providing an initial examination of an important issue, is certainly not without limitations. The Random Number Generation task allowed us to assess random behavior in a controlled setting. It would potentially be important to examine these processes outside of the laboratory. That is, more research is needed to assess the generalizability of our findings to actual behavior. In addition, further research could help to determine the roles that the various randomness factors play at different stages of creative behavior.

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APPENDIX A: CREATIVE ACHIEVEMENT QUESTIONNAIRE (CAQ)

Directions: Place a check mark beside sentences that apply to you. Next to sentences with an asterisk (*), write the number of times this sentence applies to you.

A. Visual Arts (painting, sculpture)

__ 0. I have no training or recognized talent in this area. (Skip to Music).

__1. I have taken lessons in this area.

__2. People have commented on my talent in this area.

__3. I have won a prize or prizes at a juried art show.

__4. I have had a showing of my work in a gallery.

__5. I have sold a piece of my work.

__6. My work has been critiqued in local publications.

*__7. My work has been critiqued in national publications.

B. Music

__0. I have no training or recognized talent in this area (Skip to Dance).

__1. I play one or more musical instruments proficiently.

__2. I have played with a recognized orchestra or band.

__3. I have composed an original piece of music.

__4. My musical talent has been critiqued in a local publication.

__5. My composition has been recorded.

__6. Recordings of my composition have been sold publicly.

*__7. My compositions have been critiqued in a national publication.

C. Dance

__0. I have no training or recognized talent in this area (Skip to Architecture)

__1. I have danced with a recognized dance company.

__2. I have choreographed an original dance number.

__3. My choreography has been performed publicly.

__4. My dance abilities have been critiqued in a local publication.

__5. I have choreographed dance professionally.

__6. My choreography has been recognized by a local publication.

*__7. My choreography has been recognized by a national publication.

D. Architectural Design

__0. I do not have training or recognized talent in this area (Skip to Writing).

__1. I have designed an original structure.

__2. A structure designed by me has been constructed.

__3. I have sold an original architectural design.

__4. A structure that I have designed and sold has been built professionally.

__5. My architectural design has won an award or awards.

__ 6. My architectural design has been recognized in a local publication.

*__7. My architectural design has been recognized in a national publication.

E. Creative Writing

__0. I do not have training or recognized talent in this area (Skip to Humor).

__1. I have written an original short work (poem or short story).

__2. My work has won an award or prize.

__3. I have written an original long work (epic, novel, or play).

__4. I have sold my work to a publisher.

__5. My work has been printed and sold publicly.

__6. My work has been reviewed in local publications.

*__7. My work has been reviewed in national publications.

F. Humor

__0. I do not have recognized talent in this area (Skip to Inventions).

__1. People have often commented on my original sense of humor.

__2. I have created jokes that are now regularly repeated by others.

__3. I have written jokes for other people.

__ 4. I have written a joke or cartoon that has been published.

__5. I have worked as a professional comedian.

__6. I have worked as a professional comedy writer.

__7. My humor has been recognized in a national publication.

G. Inventions

__0. I do not have recognized talent in this area

__1. I regularly find novel uses for household objects.

__2. I have sketched out an invention and worked on its design flaws.

__3. I have created original software for a computer.

__4. I have built a prototype of one of my designed inventions.

__5. I have sold one of my inventions to people I know.

*__6. I have received a patent for one of my inventions.

*__7. I have sold one of my inventions to a manufacturing firm.

H. Scientific Discovery

__0. I do not have training or recognized ability in this field (Skip to Theater)

__1. I often think about ways that scientific problems could be solved.

__2. I have won a prize at a science fair or other local competition.

__3. I have received a scholarship based on my work in science or medicine.

__4. I have been author or coauthor of a study published in a scientific journal.

*__5. I have won a national prize in the field of science or medicine.

*__6. I have received a grant to pursue my work in science or medicine.

__7. My work has been cited by other scientists in national publications.

I. Theater and Film

__0. I do not have training or recognized ability in this field.

__1. I have performed in theater or film.

__2. My acting abilities have been recognized in a local publication.

__3. I have directed or produced a theater or film production.

__4. I have won an award or prize for acting in theater or film.

__5. I have been paid to act in theater or film.

__6. I have been paid to direct a theater or film production.

*__7. My theatrical work has been recognized in a national publication.

J. Culinary Arts

__0. I do not have training or experience in this field.

__1. I often experiment with recipes.

__2. My recipes have been published in a local cookbook.

__3. My recipes have been used in restaurants or other public venues.

__4. I have been asked to prepare food for celebrities or dignitaries.

__5. My recipes have won a prize or award.

__6. I have received a degree in culinary arts.

*__7. My recipes have been published nationally.

Scoring of the Creative Achievement Questionnaire

1. Each check-marked item receives the number of points represented by the question number adjacent to the checkmark.

2. If an item is marked by an asterisk, multiply the number of times the item has been achieved by the number of the question to determine points for that item.

3. Sum the total number of points within each domain to determine the domain score.

4. Sum all ten domain scores to determine the total CAQ score.