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The Effect of Computer-based Biofeedback on Creativity

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Abstract

In recent decades, Psychology has advance empirical studies of creativity, aiming for a better and more concrete understanding of this elusive topic. One branch of these studies investigates creativity's physiological manifestation in an attempt to isolate underlying neurophysiologic mechanisms involved in creative thinking. These studies, through EEG recording of electrical brain activity, indicated that highly creative individuals tend to express a low arousal state as compared to less creative individuals. This experiment investigates the relationship between induced low arousal and creativity. A computer-based biofeedback game is used to induce low arousal. A multivariate analysis of our data revealed no significant change on the Torrance Test of Creativity (TTCT) score as a result of the intervention. There are evident trends, but they fall short of statistical significance. As advocated by previous research, our study also shows that intelligence as measured by the Raven Advanced Progressive Matrices (APM) does not correlate with creativity performances.

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History of the Scientific Study of Creativity

Early Pioneers

Sir Francis Galton conducted the first systematic study on distinguished people and their heritage in 1869. *The Hereditary Genius* would be a landmark into the study of genius and their natural abilities; the idea that genius is born and cannot be taught. In his extensive analysis, he argues for the importance of family lineage and the inheritance of abilities in generating genius. The message seems to be that greatness runs in families: The closer the generational tie, the greater the chance of talent. What Galton didn't account for in his theory of the importance of the family tree was the influence of family and environment on the prominent individuals (Simonton, 1994). Galton did not include himself on the list but he also comes from a well-known family pedigree; he is the half-cousin of Darwin. This work is one of many contributions Galton contributed to psychology. He also invented regression, correlations, eugenics, which gave rise to behavior genetics with his study of twins, and made many other contributions.

Anthropologist Alfred Kroeber had a different perspective on the appearance of genius. His 1944 book, *Configuration of Culture Growth* is another classic work that showed a systemic analysis of these individuals and their contributions. Kroeber tried to disprove Galton by focusing on the culture that which developed these individuals. Whereas Galton titled his chapter by individuals, e.g. "painters", Kroeber titled them by cultural theme, e.g. "painting." In his book, Kroeber set out to show that genius does not appear in the family-tied fashion as Galton indicated, but that the geniuses appear in clusters with other great figures. Culture plays a key role because it requires having the

right person in the right culture to manifest the ability of the individual to greatness. Kroeber says this of culture:

> [E]ver since there has been history and even before it was written, to associate great cultural products and great men…most of the readily accessible data of history are attached to personalities…if the reverse were the case, and history came without names of people, with records only of events and achievements…the culture patterns discussed would [still] reveal themselves, if any thing, more sharply. It is thus clear that while personalities are the medium through which an approach like the present one must largely operate to express itself, they are not of its essence or its goal. (p. 7)

In the span of history, we know there are periods of lavish growth and development and periods of apparent inactivity. It is not surprising that the periods of growth are also periods where we find well-known individuals and their marked contributions. Hence, we need to recognize the essential relationship between the two and not treat them separately from each other. To periods that immediately come to mind are the Age of Enlightenment and the Dark Age. The Dark Age, encompassing roughly 476-1000 AD, was marked by a period of paucity in literature, art, and cultural development. The Enlightenment on the contrary manifested an age of flourishing science, art, culture, and philosophical discourse. Evidently, it appears that creativity does not exist isolated in the individual, but it tends to flourish when cultural circumstances are favorable.

Galton and Kroeber are credited with independent investigative work on the topic of genius, creativity and culture. However, a review of creativity cannot be complete without paying tribute to the past president of the American Psychological Association J.P Guilford. His 1950 presidential address was the stimulant that provoked a systematic inquiry of creativity. In the address, Guilford pointed out the difficult but worthy task of taking on such an elusive research topic. At the time of his speech, Guilford reported:

"[o]f approximately 121,000 titles listed in the past 23 years, only 186 were indexed as definitely bearing on the subject of creativity" (Guilford, 1950, p. 445). This constitutes a mere .0015 percent of all *Psychological Abstracts*. Guilford points out that the neglect of creativity stems from misconception of the correlation between intelligence and creativity, he argues that creative productivity extends well beyond that. It also stems from the lack of practical criterion to establish creative discovery because of its rarity, and a missing effective measurement tool.

To launch into an objective and scientific investigation of creativity we must dispel certain myths. Creativity needs to be dissociated from ideas of magic and divinity; psychologists help to do just that. To take the myth out of a source is to unravel its mystery, as is often the case that the supernatural explanation is one use to cover up a lack of understanding and comprehension of a phenomenon. Creativity is not bestow upon a few, or "the general psychological conviction seems to be that all individuals possess to some degree all abilities" (Guilford, 1950, p. 446). The idea is that creativity exists on a continuum, we all have it, but only a few individuals are recognized as possessing great strokes of creativity. The inevitable question of "why" arises from this insight. An obvious answer is that they appear to be on the higher end of the spectrum. Yet another question, how did they get there? These questions are far from being answered, but 50 and plus years into the field of creativity, some headways are being made which will help us establish better ground for further investigations. The number of *Psychological Abstracts* in creativity has grown to a .01 percent, a vast improvement in the 50 year span (Runco, 2004).

Can Creativity be Measured?

Creativity is traditionally associated with divergent thinking. Creativity researchers adopted the divergent thinking (DT) test from Alfred Binet's open-ended, multiple-solution measures, e.g. ink blots, sentence invention. The development and use of divergent tests continued steadily up to the 1950s, where Guilford's landmark speech took place. Guilford himself had been investigating measures of studying creativity, including a list of abilities which he believed to measure creativity. These factorials included sensitivity to problem, fluency, generation of novel ideas, flexibility, synthesizing and analyzing ability, and so forth. Guilford's attempt at a systematic measurement of creativity influenced later models of divergent thinking test. Divergent tests have demonstrated validity and reliability in measuring what we might identify with creativity, originality or imagination. Harrington and Barron's meta-analysis of over 70 studies showed a statistically significant positive correlation between various divergent tests scores and their achievement. However, DT tests are not perfect and they often do fail to show significant relationships. One of the confounding factors is that DT tests don't account for the different abilities underlying creative behavior across fields (Barron & Harrington, 1981).

To begin systematic research into creativity, a standard measurement needs to be established to a certain extent. Of these, the most well known is E. Paul Torrance's Torrance Test of Creative Thinking (TTCT). Torrance's creativity test is drawn from characteristics of creativity as hypothesized by Guilford. Torrance is most noted as being the "Father of Creativity," his extensive research resulted in a battery of standardized tests that allowed for a quantification of creative abilities. Since its inception in 1974, the

TTCT has become internationally known; it has been translated into 32 languages, and used in over 2,000 research studies (Neumeister & Cramond, 2004). There are figural and verbal versions of the TTCT and each comes in two forms, A and B. Examples of TTCT questions include figural completion given an abstract stimulus; imagining probable effects as a result of a novel situation; listing uncommon use of common objects, e.g. tin can, and so forth. The criteria Torrance used to assess creativity include, but are not limited to, fluency, originality, flexibility, elaboration and resistance to closure. The measure of fluency in creative tests is based on the correlation between quantity and quality. If one has a large pool of ideas, it is more likely the case that few of the many will be good ones. On the other hand, if there are only a small number of choices to pick from, the probability of a creative idea decreases. The other factors are used to distinguish the quality of response, whether it is truly creative or simply nonsensical.

Torrance himself conducted tests of validity on his creativity test. One of his studies concerned a group of high school students initially assessed in 1959, most of whom were followed up 7 years later and then again in another 12 years. The latter study showed high correlations between the test and the actual student performance. Even 22 years later, similar correlations were found. Torrance concluded his study (1988) with the following two remarks:

1) Young people identified as creative on the basis of creativity tests during the high schools years tend to become productive, creative adults.

2) At least 12 years after high school graduation appears to be a more advantageous time than seven years as the time for a follow up of creative adults. (as cited in Eysenck, 1995, p. 95)

From a more objective standard, Kim (2006) conducted a review on the reliability and validity of TTCT-figural. She concluded that for the purpose of the test, it displayed adequate reliability and validity. However, this excludes the 1998 revision of the TTCT-Figural. Kim (2006) has also brought up confounding factors such as culture, language, race, gender and demographic difference that was absent in the early 20th century. It is possible that the general increase observed in IQ scores over time might also occur with the TTCT. No single test can measure all aspects of any one thing, and the same is said of the TTCT. A general guideline for creativity studies is that a minimum of two different creative measurements should be used.

Furthermore, A. J. Cropley (1972) conducted a five-year longitudinal study of the creativity tests' validity. In 1965, grade 7 students (n=320) from a Midwestern junior high school were accessed with a battery of creativity tests and an intelligence test. Five years later, 111 of those students were tracked down in high school and were again reassessed. Their creativity rating was based on their nonacademic involvement and achievement in art, drama, literature and music. For example, a score of 0 indicated no involvement; whereas a 6 might have meant that the student had a composition performed at the professional level setting. A correlation of .52 was found for male and .51 for female. This is a fairly strong correlation and provides evidence that creativity scores can detect creative potential in the long run.

As E.L Thorndike noted, "everything that exist exists in some quantity and can therefore be measured" (as cited in Eysenck, 1995, p. 83). Although we can argue that creativity is elusive, hard to define and difficult to measure, there are evidences that it can be quantifiable within certain range of reliability and validity. But be caution that

creativity does not exist as one entity; it is a combination of various factors. If we accept that the variables we are measuring are different aspects of creativity, then we can say that we are measuring creativity. Arguably, no single measurement of creativity can create a complete picture, but by using a combination of them, we can obtain satisfactory results.

A Definition of Creativity

Now we come to a definition of creativity. Creativity is often defined by the resulting products or ideas created by the creative person. This definition is far from satisfactory as it sounds more like a tautology than an actual definition. What is the creative product and who is the creative person? Earlier investigation of creativity centered on the study of the creative individuals and their personalities. According to Barron and Harrington (1981), the creative person has a "fairly stable set of core characteristics" (p. 453); these include high valuation of esthetic qualities in experience, broad interest, intuition, high energy and so forth. Terman and Oden's (1959) study showed that personality impacts individual achievement when IQ is held constant. They found that the more successful group was "less moody, impulsive, conformist; they show more self-confidence, sociability, perseverance…show more good nature and emotionality, and are more popular" (as cited in Eysenck, 1995, p.64). Of the various personality characteristics, traits that most characterize high achievers and creative genius are persistence, perseverance, strong activation, strength of character, and forcefulness. The will to be self-motivated and to persist despite failure are key characteristics of

success for many; as Thomas Edison once said, “genius is one percent inspiration and 99 percent perspiration” (Martin, 1996-2008).

This leads to another common thought: the more creative the individual, the more insane. There is some truth to this notion. A number of studies on creativity have found positive correlations between psychopathology and creativity, and it is proposed that some genetic link exists between them. Hammer and Zubin (1986) and Jarvick and Chadwick’s (1973) studies sum it up to this effect; “there is a common genetic basis for great potential in creativity and for psychopathological deviation…it appears to be psychopathology in the absence of psychosis that is the vital element of creativity” (as cited in Eysenck, 1995, p.121). The emphasis here is that although psychopathology is evident, it is rarely actual destructive psychoses. So it is not true that the more creative individuals are more psychopathic, rather to a certain extent where characteristics of psychopathology surface in these individuals, their creativity can be aided. In addition, there are hypotheses concerning a mediating physiological-hormonal-enzymatic structure or substance, e.g. dopamine, which connects psychoticism with creativity. To counter this old age belief, we find that many creative individuals are self-actualizing. Although these two traits might appear contradictory, Eysenck (1995) suggests that creative people have an unusual combination of these two normally disparate traits. His diagram (see figure 1) shows that creative lies somewhere between self-actualizing and pathological traits.

When we speak of creativity, we cannot limit it to a single unit. It exists in various degree and type. By degrees, there is the range of everyday little “c” creativity, to big “C” eminent creativity. Prior researches have focused on eminent individuals with

high-level of achievement or expertise. However, the idea of creativity as used in day-to-day problem is receiving increasing attention (Runco, 2004). As for type, the technical term is "domain." Creativity is expressed differently when you are in the field of art, mathematic or politics. What has been uncovered about creativity in general is really domain specific, depending on the subject of study. Gardner (1983) explicitly listed seven of these: "musical, mathematical, verbal-symbolic, bodily kinesthetic, spatial, interpersonal, and intrapersonal," later adding "the naturalistic" (as cited in Runco, 2004, p. 678). To understand what creativity is, we need to distinguish the differences in creativity across domains and begin to approach the problem by domain. These initial divergence then needs to be converge again to given creativity a meaning in the general sense of the term.

Narrowing Down Creativity: The Neurobiological Perspective

Current research into creativity crosses numerous disciplines. Runco (2004) lists 11: behavioral perspective creativity, biology of creativity, clinical, cognitive, developmental, economic, educational, historiometric, organizational, psychometric, and social research. For the purpose of this paper, we will mainly focus on the biology of creativity, i.e. the brain. In general, it is said that creativity is not localized in the right-hemisphere, but requires both regions. Studies of creativity and the brain have focused on various regions of brain and their relationship to creative activities. Arieti (1976) proposed an association between creativity, the temporo-occipito-parietal cortex and the prefrontal cortex. Carlsson, Wendt and Risberg (2000) investigated creativity in terms of regional cerebral blood flow (rCBF) during a divergent thinking task. They found

increase rCBF during these creative tasks. Another study, Bekhtereva et al. (2001) found that highly creative performances were associated with higher CBF in both frontal lobes, especially the Brodmann's Area (BA) 8-11 and 44-47 (as cited in Chávez-Eakle, 2007).

Another area of focus is electroencephalography (EEG), arousal and creativity, which is also the core of this experimental project. EEG is the measurement of electrical activity in the brain as recorded by electrodes placed on the scalp. In the 1970s, Colin Martindale and colleagues conducted several creative studies related to EEG. In an article titled *Creativity, consciousness and cortical arousal* (1977-78), he argued for a relationship between creativity and level of arousal based on previous findings. The study of arousal goes back to Kris' theory (1952). He believed that the creative process involves an inspirational stage, where the individual regresses from secondary to primary process without being "overwhelmed by the latter," it then returns to the secondary process with the inspiration gained from the primary processes. Primary processes are seen as "free-associative, emotional, and 'illogical,'" as opposed to the deductive, analytic form of secondary processes. Empirical research also supports the notion that creative individuals have a higher frequency of primary regression experience. This state is said to more freely allow for novel combination that often preludes creative products. Martindale (1977-78) hypothesized that if creative subjects are more variable on the primary-secondary process continuum, then it should parallel the arousal continuum. Hence, low levels of arousal should co-occur with the primary process state. This extends to the idea that creativity, should be associated with high, but even more so with low arousal. This hypothesis relies on Lindsley's (1960) conclusion between cortical

activation as measured by EEG parallels state of arousal (as cited in Martindale, 1977-78).

Arousal is seen on a continuum that ranges from sleep alert wakefulness, normal wakefulness, to emotional tension and panic. Alert wakefulness is characterized by the alpha wave (8-12 Hertz), whereas normal waking conscious, tension, anxiety is represented by the beta wave (> 12 Hertz). Martindale and Hines (1975) measured alpha activity while participants took the Alternative Uses Test, the Remote Associates Test (RAT), and IPAT. The alternative uses measures creativity only, the RAT measures creativity and intelligence, and IPAT only measures intelligence. The results revealed that highly creative subjects exhibited the highest basal alpha level, or in another word, the lowest level of cortical arousal on creativity measures. Logically, the data (figure 2) shows decreasing in basal arousal alpha as the highly creative individual partakes in less creative activities, i.e. the RAT and IPAT. These results correspond to Kris' theory (1952) because the creative tests require unfocused attention and low arousal (high alpha), whereas the intelligence tests require secondary process of thought, the more alert and concentrated. Martindale (1977-78) then hypothesize that, "when a task calls for creativity, creative individuals exhibit a defocusing of attention and a decrease in the level of cortical activation." In light of the observed connection between low arousal and creativity, this experiment seeks to test for causal relationships between the two. I did not find any study that focused on the manipulation of the level of arousal to stimulate creativity, with the exception of Martindale and Greenough (1973). Martindale and Greenough's study (1973) is based on Hull's (1973) behavior law and Mednick's (1962) theory of creativity. Hull's behavior law says that increase in arousal makes behavior

more stereotyped and decrease in arousal makes it more variable. Mednick's theory characterized creative individuals as having a flat associative hierarchy (figure 2). A flat associative hierarchy means greater remote association and hence greater chance of novel combination. Not surprisingly, these were individuals who perform better on the Mednick's Remote Associative Test (RAT).

Using the RAT, Martindale and Greenough (1973) predicted that direct manipulation to increase arousal should decrease RAT performance and increase WAIS Similarity subtest performance. RAT as a function of creativity measured the stereotypical and novel responses as it relates to arousal level. The WAIS similarity subtest is a measure of intelligence. Significance was found only for effects of high arousal on creative performance. In other words, high arousal significantly decreased performance on RAT. Another key finding of the experiment was that the hypothesized trend- increasing arousal decreases RAT and the inverse for the similarity test- was evident. If an increase in arousal is detrimental to creative performance, would the reverse be true – would a decrease in arousal enhance creative performance?

Enhancing Creativity

So can creativity be enhanced? Torrance (1972) and Torrance and Presbury (1984) reviewed 384 studies that examined the effectiveness of creativity training (as cited in Puccio, 1999). The majority of these studies concluded that creativity can be enhanced through formal training. Parnes and Noller (1972) conducted an extensive four semester sequence of college courses which focused on creative problem-solving, synectics, creative analysis, and awareness. They found significant improvement for the

students in terms of creative applications and performances for both academic and non-academic settings (as cited in Puccio, 1999). The importance of fostering creativity in the young is at the root of enhancing creative output in society. This is not to say that creative young adults will remain creative later in life, it merely implies that fostering creativity helps to increase the possibility of generating greater creative output. This is obvious because of the detrimental affect of the lack of resource and mentors for potentially creative youths. Despite perceived importance of creativity, Adams and Hamm (1989) points out that, "there has been little serious attention to creative behavior and advances in the area are not materialized." A survey by Mack (1987) demonstrated this exact disparity. It was found that for teacher educators and student teacher, the importance of ranking for creativity was 85% and 90% respectively. However, when asked how important it is to include it in teacher educations program, it was only 48% for teacher educators and 52% for student teacher.

An additional technique that has been studied in creativity research is meditation. One of the better-known is Transcendental Meditation (TM), which became popular in the mid 1970s. TM is a technique introduced in 1958 by Maharishi Mahesh Yogi. Their promotional literatures claim TM as a technique to improve health, wellness, creativity, intelligence, happiness and so forth. There was a vast amount of study on the physiological benefits of TM, and some benefits are well documented. However, claims of psychological changes remained uncertain. As for studies on the relationship between and TM, there were mixed findings on its effectiveness. Some studies that have investigated the difference between TM and non-TM participants found a positive effect on creativity score (e.g. So & Orme-Johnson, 2001; Jedrczak et al, 1983; Travis, 1979),

while other didn't (Gowan, 1978; Domino, 1977). Upon closer examination, the flaw of studies appeared to be the different way which creativity is assessed in individual studies. A latter study (Travis, 1979) found that TM had an effect on figural but not verbal measures of creativity. This clarifies some of the mixed findings in previous studies. It appears that those that found creative enhancement had tested their participants for figural creativity, whereas those that didn't mainly scored them for verbal abilities. The obvious downside with TM and meditation in general is that it requires extensive resources, and time, not to mention a serious commitment from the practitioner. To circumvent some of these issues, I used a computer game which assists in meditative practices and allows the individuals to be monitored through biofeedback.

The Logic of the Biofeedback Game

Biofeedback is any device which gives individuals immediate feedback to their inner physiological states; involuntary bodily functions individuals would not normally be aware of (e.g. heartbeat, brain activities). Biofeedback is generally used in clinics to help decrease stress, control pain, prevent high blood pressure, paralysis and so forth. As opposed to TM, biofeedback mechanism allows for immediate monitoring of one autonomic process. This feedback mechanism will be useful for the purpose of this experiment, which is to induce low arousal or relaxation given the constraints of time.

The *Wild Divine* is a computer game that measures heart rate variability (HRV) and skin conductance level (SCL) through three finger sensors (index, middle and ring finger); these parameters are used to change the gaming environment for the player. HRV is a measure of the variations of heart rate from beat-to-beat. SCL expresses the

sympathetic activity through our dermal sweat glands; it has a positive correlation with cortical arousal. Martindale's study used EEG measurements, mine does not. The relationship between EEG and SCL, however, is a close one. Underlying both measures is the shared reticulo-thalamo-hypothalamo-cortical network, which would support an immediate connection between EEG and SCL. In support of this, Lim et al. (1994) reported a strong relationship between cerebral function, as measured by EEG total power and band powers (beta, alpha and theta), to be associated with autonomic (SCL) activities. Wild Divine Wisdom Quest consists of individual activities where the gamer is asked to either lower their arousal or increase their arousal in order to pass the activity. For this experiment, three activities that require the lowering of arousal were chosen. Martindale's studies and numerous others biofeedback related studies (e.g. Hull, 1943; Martindale 1990; Martindale & Hines 1975; Martindale & Hasenfus, 1977-78) measures the participant before, during or after they are performing a creative/ non-creative task. A literature search did not show any result for the use of biofeedback as an enhancer for creativity. If it is the case that highly creative individuals show lower arousal during periods of creative process, would it also be the case that a reduction in arousal level would be reflect by changes in creativity or creativity score?

The Pilot Study

Due to the unknown nature of the computer-based biofeedback software, and being unsure of the direction of this experiment I decided to conduct a pilot study. The goal of the pilot study is to provide a preliminary assessment of the procedure, feasibility and to obtain initial results on the experiment.

Participants

Five participants (3 male and 2 female) affiliated with Syracuse University volunteered to participate in the pilot study without any compensation.

Measures

Torrance test of creative thinking

Torrance Test of Creative Thinking was administered for both sessions to measure the creativity levels of participants. This was the determinant factor in assessing any changes in the participants' creativity level. Due to time constrain, I selected three activities from the TTCT-figural and two activities from the TTCT-verbal. According to the TTCT manual, the result of these activities alone has proven to be good measurements of creativity score when compared to the TTCT score obtained from all activities. This experiment's TTCT-figural set included activity 1, 2, and 3. Activity 1 and 2 are picture construction of a random shape, e.g. a line, circle, curve and construct a title for the picture. Activity 3 consists of repeated lines or circles and participants were asked to come up with novel ways of constructing pictures/stories with them. TTCT-verbal set included activities 4 and 7. Activity 4 is product improvement, participants were asked to come up with new ideas of improving the toy shown on the activity. Activity 7 describes an unusual situation where participants were asked to write down possible consequences of that particular situation, e.g. "if strings exist on clouds, what would happened?" The measures of creativity for the figural TTCT that I was concerned with are as follows (Kim, 2006):

- Fluency: The number of relevant ideas; shows an ability to produce a number of figural images.

> • Originality: The number of statistically infrequent ideas; shows an ability to produce uncommon or unique responses. The scoring procedure counts the most common responses as 0 and all other legitimate responses as 1. The originality lists have been prepared for each item on the basis of normative data, which are readily memorized by scorers.
>
> • Elaboration: The number of added ideas; demonstrates the subject's ability to develop and elaborate on ideas.
>
> • Abstractness of Titles: The degree beyond labeling; based on the idea that creativity requires an abstraction of thought. It measures the degree a title moves beyond concrete labeling of the pictures drawn.
>
> • Resistance to Premature Closure: The degree of psychological openness; based on the belief that creative behavior requires a person to consider a variety of information when processing information and to keep an "open mind." (p. 5)

The Verbal TTCT was scored for Fluency, Originality and Flexibility. Flexibility is the ease which the individual can change a mind set; the extent to which he can reach out into new "channels of thought" (Guilford, 1950, p. 543).

Raven advance progressive matrices

The Raven Advance Progressive Matrices (APM) is a measurement of higher mental ability. The test consists of 36 items total, 18 questions in form A and 18 in form B, each successive item being more difficult than the former. It is used as a measurement of problem solving, analytic and fluid intelligence (Hamel & Schmittmann, 2006). Though frequently used, the drawback is that the APM usually takes 30-40 minutes to carry out and complete. It takes longer in the untimed version. Shorter versions of the APM have been developed, but the validity of its measurement of problem-solving or educative ability might have been compromised. On the other hand, Hamel & Schmittmann (2006) reported a high correlation ($r = .74$) between scores of the untimed version of the APM- and after the 20 minute timed version. For the untimed version,

participants were asked to underscore the question they were working on after a 20, 30, 40 minute interval. This is different from the timed version because they were still allowed to continue with the test. Hamel & Schmittmann's (2006) data also showed that the means scores after the successive intervals were increasing but negatively accelerated. This means the first interval had better predictability than those closer to completion. This point gave us the confidence to allocate only 10 minute for the APM, seeing that the beginning of the APM were relatively good indicators of the APM score as a whole. There were two parallel versions of the APM (A and B, each set consists of 18 items) administered to the participants, counterbalanced for order effect. All 18 items were given to our participants during their session and they were asked to complete as many items as possible within 10 minutes.

Procedure

Participants (n=5) were randomly assigned into a category of control or experimental for a two-session experiment, two in the control group and three in the experimental group. The experiment was conducted on an individual basis; each participant was given 1.5 hours to finish the task given per session. For session 1, the tasks were identical for both groups. The participants were instructed to play a "time-filler" computer game (Tetris) for 30 minutes. They were then administered the two activities. They were to complete selected activities from the TTCT-figural and TTCT-verbal, followed by the APM. Each activity was given 10 minutes of working time, resulting in one hour of time for the six activities-the APM counted as one activity. The 10-minute interval was signaled through an intercom by the experimenter.

At session two, the control group repeated the same procedure as session one. Meanwhile, the experimental group was given the biofeedback activity (Wild Divine) in place of Tetris. These participants were instructed to complete the designated Wild Divine activity and inform the experimenter after each completed activity. The experimenter then dictated the next game activity to be completed. These participants were not working under time constraints for the Wild Divine games, however, most if not all the participants were able to complete the three activities around 30 minutes, which is the amount of time given the control group to play Tetris in Session two. A parallel version of the TTCT and the APM was again given after the 30-minute game activities. For both sessions, all participants were hooked up to the biofeedback software at all time, except for the short interval where they switched from the game to pen and pencil measurements.

Pilot Study Results

Multivariate analysis was conducted to test for effects between sessions and groups across the various TTCT subscales. No significant effects were found for the TTCT-verbal Fluency, $F(1,32)=.24$, *ns*; Flexibility, $F(1, 32)=.00$, *ns*; and Originality $F(1, 32)=.16$, *ns*. No significant effects were found for the TTCT-figural fluency, $F(1,32)=.28$, *ns*; Originality, $F(1,32)=1.06$, *ns*; Abstractness of Title, $F(1,32)=.99$, *ns*; Elaboration, $F(1,32)=.00$, *ns*; and Resistance, $F(1,32)=.12$, *ns* (see figure 4). However, a few trends are worth mentioning. For all verbal scores there was a consistent decrease for both groups, more so for the control group than the experimental group. This is contrary to what we would have expected to find. For the figural scores we observe

mixed results. For the Fluency score the experimental group did better than the last control group, but only slightly. Originality decreased for both groups, but the experimental group decreased less. A score increase was observed in Abstractness of title, elaboration and a decrease for resistance to premature closure for the experimental group. The control group increased their scores across these three subscales (see figure 5).

T-test analysis revealed no significance for APM score across Sessions for the control, $t(2)=.14$, *ns*, and experimental group, $t(4)=-1.41$, *ns*. Neither was there significance across Version for control, $t(2)=-1.14$, *ns* and experimental group, $t(4)=.48$, *ns*. Two outliers were presented in the APM data. Eliminating of the two outliers resulted in three sets of data, which is far too insufficient for further discussion of the the pilot APM scores results.

The Experiment

Participants

The study consisted of 34 participants, a mix of students and nonstudents from the Syracuse University area. Participants received either course credit or $10 in cash in return for their participation. Students were mostly taken from the Introduction to Psychology subject pool.

Measures & Procedures

Two parallel versions of both Verbal and figural Torrance Test of Creative Thinking (TTCT) and two parallel version of Raven Advance Progressive Matrices

(APM). Please refer to the pilot study for further details on the measurements and procedures.

Results

From the Torrance Test of Creative Thinking

Scoring is the same as the pilot study. This time we again did not find any significant interaction for the eight variables. For the TTCT-Verbal, the results were Fluency, F(1, 3)=1.23, *ns*; Flexibility, F(1, 3)=2.10. *ns* and Originality, F(1, 3)=7.16, *ns*. For the figural the results were Fluency, F(1, 3)=.23, *ns*; Originality, F(1, 3)=1.84, *ns*; Abstractness of Title, F(1, 3)=.11, *ns*; Elaboration, F(1, 3)=.60, *ns* and Resistance to Premature Closure: F(1,3)=.20, *ns*. Similar to pilot study, there was a consistent decrease for the verbal measures (fluency, flexibility, originality) across all groups (see figure 6). On the other hand, for all the figural scales, the control group and experimental diverged in respect to their scores. The control group increased their performance across all figural subscale (except elaboration) whereas the performance of the experimental group decreased or remained the same for the second session (figure 7).

Raven Advance Progressive Matrices

T-test analysis revealed no significant effects across Session for the control, $t(32)=.12$, *ns*, and experimental groups, $t(32)=.11$, *ns*. But as figure 8 shows, the control group increased their performance at session two, while the experimental group decreased in performance. As expected, a T-test showed no significant effects between Version A and B for the experimental, $t(32)= -.73$, *ns,* and control group, $t(32)= -.1.30$, *ns*. If anything, the control group performed only slightly better on session two than

session one (figure 6). Furthermore, no correlation was found between the APM and the verbal or figural TTCT subscales. The supports previous findings that there is no causal relationship between intelligence and creativity, and that the correlation is generally low (Simonton, 1994). Intelligence can be viewed as a dispositional variable; it gives the individual the ability to achieve but does not guarantee success. For example, Marilyn Vos Savant is cited in the Guinness Book of World Records under the highest IQ, but she writes a Sunday column where she solves puzzles and questions from readers (Simonton, 1994).

Discussion

The lack of significant findings may be due to some of the limitations of the design of my study. The most important of these is that the study was short. In spite of mounting evidence that creativity can be enhanced, it is usually the result of a series of mental training and exercise that takes place over a given span of time. Second, there is also the difficulty of manipulating arousal to impact creativity. The arousal level and creativity studies conducted by Martindale and colleagues (1974, 1795, 1977-78) only showed that highly creative individuals had low arousal compared to non-creative and medium creative individuals during periods of inspiration. Their result did not indicate a causal relationship. Similarly, Martindale (1977-78) concluded:

> The question arises as to whether these physiological differences are causes or effects of different modes of thought in more and less creative individuals…So, at the moment, we have no way of knowing if we are measuring "noise" thrown off by different states of consciousness or the biological activities causing these different states (p. 83).

Even though Martindale and Greenough's (1973) study indicated trends that increasing arousal would lead to increase creativity (as measured by the RAT), the reverse might not necessarily be as plausible. We also have to consider that most of their results were based on observations in trends rather than levels of high statistical significance. It seems more likely that an interference acting to decrease the RAT score is more likely to succeed than one which acts to increase creativity. Further, the RAT and the TTCT measure different aspects of creativity; their relationship needs to be further studied in order to give a better sense of our results in relation to Martindale and Greenough's (1973) results.

Another limitation of this experiment is that the participants were tested for their creativity after the arousal-decreasing activity. Although EEG data indicated high correlation between creativity and arousal, we must stress that these measurements were taken only during creative performance (Martindale, 1977-78). It is possible that the state of arousal only impacts creative activity during and not after an arousal-decreasing manipulation.

At the beginning of the paper, I noted that arousal exists on a continuum. It might be important to determine the point on this continuum that the correlation between low arousal and creativity would be seen. In other words, it would help to quantify the amount of arousal when relating it to creativity; instead of being only descriptive about it. Martindale also noted the effect of different affect of arousal on different points of the spectrum. He stated that, "A moderate amount of primary process thinking, as in fantasy or reverie may facilitate discovery of creative ideas, but extreme primary process thinking-such as dreaming-does not produce creative ideas" (Martindale, 1990a, p.258).

Although *Wild Divine*'s activity requires low arousal to pass, it doesn't limit how low. The question then arises whether the accumulation of the activities perhaps lowered arousal to a point where it became difficult for the participants to express creativity because they have slipped toward extreme primary process.

We also need to consider that the length of the experiment may have been detrimental to motivation and hence performance. Although not explicitly measured, it was noted that majority of the participants were somewhat bored at the thought of a parallel version. The task might have appeared redundant, so that the second performance deteriorated as compared to the first. It is interesting to see that our control group appears to have done much better on the figural TTCT than our experimental group. Being that everything else is identical, this calls into question the alternative game, Tetris. In of itself, Tetris can lead to increase arousal, depending on the level that the player is working on. We are unsure of its effect, but even if it did increase arousal, it still wouldn't be able to explain the increase in figural creativity scores. Previous studies only mentioned an inverse relationship between creativity and arousal. This increase arousal might explain the decrease AMP score for the experimental (low arousal) group and increase APM score for the control group (Tetris-arousal) group. Although the change in score is insignificant, this trend is consistent with Martindale and Greenough's (1973) study, increased arousal will lead to better performance on intelligence test while decrease arousal will result in a decrease in creativity test.

The shortcomings of the design may have contributed to the null-results. It is, however, also possible that the manipulation of arousal might not have a direct impact on creativity. There are so many more variables to consider when we aim to enhance

creativity that a short-term change in arousal might not be sufficient in of itself to affect changes in creativity. Creative individuals, even when not partaking in creative processes, have a low basal level of arousal. It is unknown whether this basal level is amenable to change. Perhaps long-term training would produce such a physiological effect.

Finally, not only do we need to consider the effectiveness of the biofeedback intervention at inducing low arousal, but we also face the possibility that the induced state is evanescent. The impact of the manipulation might not have carried over at all because arousal states can easily be altered by minimal disruptions. Ironically, it has been noted that creative people tend to perform worst on biofeedback task than non-creative individual (Martindale, 1977-78). It would be interesting to see if their poor performance on biofeedback tasks had anything to do with the result of their creative performance in this experiment.

The non-significant finding in this experiment is trivial in comparison to the mounting evidence that creativity can indeed be enhanced. More studies on arousal manipulation need to be conducted to gain a better understanding of the effects of arousal on performance. Intuitively, we might begin with a replication of Martindale and Greenough's (1973) study, but go in the opposite direction; instead of increasing arousal as they did, we can investigate a reduction of it in the exact state. Being that we have so little understanding of the cause and effect relationship with cortical arousal, the leap to biofeedback might have been a step too far.

Conclusion

> It is not the fruits of scientific research that elevate man and enrich his nature but the urge to understand, the intellectual work, creative or receptive.
>
> –Albert Einstein

So we must not be discouraged by a lack of fruition in the endeavor, the (re)search must go on. We need to continue empirical studies on the subject in order to better understand the vital elements that have contributed to human greatness. Researches in the past fifty years have attributed a good deal of information to guide further creativity researches, but we must not fall behind.

Creative individuals have always sought ways to enhance their own creativity, and they often have unique ways of doing it. In *Essay on the Creative Imagination*, Theodore Ribot described a series of them:

> The most frequent method consists of artificially increasing the flow of blood to the brain. Rousseau would think bare-headed in full sunshine; Bossuet would work in a cold room with his head wrapped in furs; other would immerse their feet in ice-cold water (Grétry, Schiller)…some require motor excitation; they work only when walking or else prepare for work by physical exercise (Mozart)…On the opposite side are those requiring retirement, silence, contemplation, even shadowy darkness, like Lamennais…[or] Leibniz, who could remain for three days almost motionless in an armchair. (1906, p. 73)

These descriptions were written more than a century ago, however, the practice themselves probably had been around for a longer period of time. Whether they worked or not we can not be certain. From a modern perspective, their practices might appear silly or extreme, but perhaps a careful study of their behavior would lead to more reasonable conclusion. It may very well be that they have unknowingly stumbled upon methods which hold more logic than one might assume.

The psychological study of creativity aims first to understand these potentials in highly creative individuals, but more importantly, how it can relate to the rest of the population. Not considering special conditions, all of us are endowed with the basic physiological makeup. But there is something more which marks the distinction between the non-creative and the highly-creative person. This *something* is what psychologists want to grapple with. In addition to great individuals, psychologists have also argued that the zeitgeist in which these individuals lived in played a key role to their success. In the end, it is necessary that we make better contributions to the understanding of creativity. It is hoped that newly generated knowledge will cross to and be integrated into our culture, so that in return it can further nourish the creative minds and fuel new ones.

Capstone Summary

The experiment discussed above involved two main elements: Creativity and arousal. The goal of the study was to investigate a cause and effect relationship between these two elements. An extensive amount of information obtained from previous studies had confirmed the existence of a relationship between creativity and physical arousal. The relationship is that those individuals labeled to be highly creative exhibited less electric activity in the brain, at rest and during creative activities. This low level of activity is what we refer to as low arousal.

Based on these findings, the study went a step further to test for a cause and effect relationship between the physiological state and creative abilities. Before I began the actual experiment, I did a pilot study. A pilot study is a mini version of the experiment conducted in order to find flaws, make adjustments and obtain preliminary data for the

actual experiment. Being that the pilot study is similar to the actual experiment, I will focus the summary on the latter.

The experiment was conducted in two sessions. Participants were measured for creativity and intelligence scores during the first session using the TTCT and APM. At the second session, Wild Divine was introduced to the participants. The participants were again measured for creativity and intelligence using parallel versions of the tests from session one.

The experimenter divided the participants into two groups, each consisting of 17 individuals. The control group is used as a baseline to measure the experimental group against to compare for any changes. The only difference in procedure that set them apart is the biofeedback game, Wild Divine, used by the experimental group at session two. The Wild Divine game consists of meditative activities, which is said to decrease arousal. The game achieves a low arousal state with the help of a biofeedback mechanism that collected measurements through three-finger sensors. The experimental group uses their state of arousal to interact with the game activity on the screen. The selected activities for this experiment required the experimental group to decrease their arousal in order for them to pass. Though it would be optimal for the control to do nothing while the experimental group played Wild Divine, we had to equalize the time for both groups, so in lieu of Wild Divine, the control group played Tetris.

All tests were hand scored and compiled by the experimenter. The test scores were then analyze using the statistical software SPSS. The result of the experiment did not indicate anything that was statistically significant. The results of the experiment did

not support the experiment's hypothesis. This indicates that the induced low arousal state did not change the creativity score of the experimental group.

In one sense, we can treat the experiment as a pilot study for new methods of creativity enhancement. No study was found in the literature search to have directly decreased arousal through manipulation and correlating that to creativity. The only other study found to manipulate arousal and its relationship to creativity was conducted by Martindale (1973). Even then, it was to increase arousal. The finding that high arousal acts a detrimental factor to performance has been well documented. This is evident from individual experience. For example, being too nervous or not worry at all about an exam will tend to decrease your performance. On the other hand, a medium level of arousal is optimal for test taking. It was also indicated that high arousal negatively affects creativity scores.

So, is there a causal relationship between our autonomic, neurophysiological activity and creative output? The results of this experiment did not support one, but the result is far from conclusive or satisfactory. In the case that significant results were observed, further research and study is needed in order to establish a causal relationship. What we are investigating is the notion that a change in the physical can produce a change in something abstract. Although the answer is that a short-term intervention is unlikely to produce such a change, perhaps it is worth it to look at longer-term interventions. Again, we are assuming that this long-term conditioning will produced something qualitatively different in the mind in terms of output quality.

To a greater extent this question touches on the mind-body problem first postulated by René Descartes. Descartes said that the mind and body are distinct entities.

The mind is superior because it is the only things that which enables him to confirm his existence. The body is in his perspective, a mere extension. We know that our thoughts control our body, e.g. I want an apple, I reach out for one, but my body can sometimes act without my thoughts, e.g. reflexes, impulses. The mind-body problem is one of interaction. There is no focal point where the mind meets and body, hence how does something immaterial control something material, i.e. how does the mind control the body?

Our experiment probes the other question; to what extent does our body alter our mind. So to what degree can a change in neural physiological arousal induce a change in creativity? Here we associate arousal with the body and creativity with the mind. One can always argue that the state of arousal was produced first by a change of mind, but we will refrain from this circularity. The biggest concern here is: does the possibility of such physical manipulation resulting in a change of creativity even exist? Unlike the mind-body problem, which remains an enigma to this day, we hope the objective of our experiment will travel a merrier fate in the future.

The path is a difficult one because creativity is itself a wild path. Where does it come from? Should we despair that we have discredited our muses in the process of scientific studies? Far from it, we have begun to credit our own abilities more. Although we still do not understand much of the underlying working of creativity, much less its causes, we do admit that it is something inherent in us. Creativity and greatness does not bestow us by chance, Louis Pasteur famously said, “chance favors the prepared mind.” Pasteur emphasized that chance is not a spontaneous happening. It requires extensive work, knowledge and dedication to be able to generate novel and creative ideas.

Hence, this investigation adds, even if insignificantly, to the growing inventory of works on creativity. Time is required for good work and patience is required to complete extensive ones. Given more time and patience in the study of creativity, the field of creativity may concoct something worthy for chance to favor.

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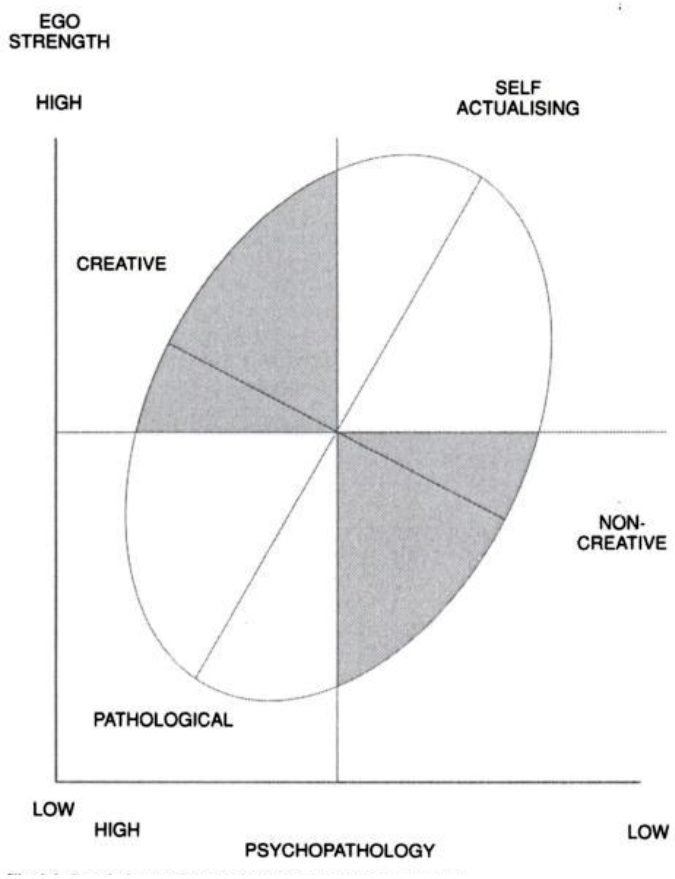
List of Figures

Figure 1. Correlation surface of psychopathology and ego-strength. [1]



[1] From *Genius: The Natural History of Creativity* (p. 121), by Eysenck, H.J. 1995. New York: Cambridge University Press. Copyright 1995 by Cambridge University Press.

Figure 2. Percentage of basal alpha exhibited by high, medium, and low creative groups during creative and intellectual performance. [2]

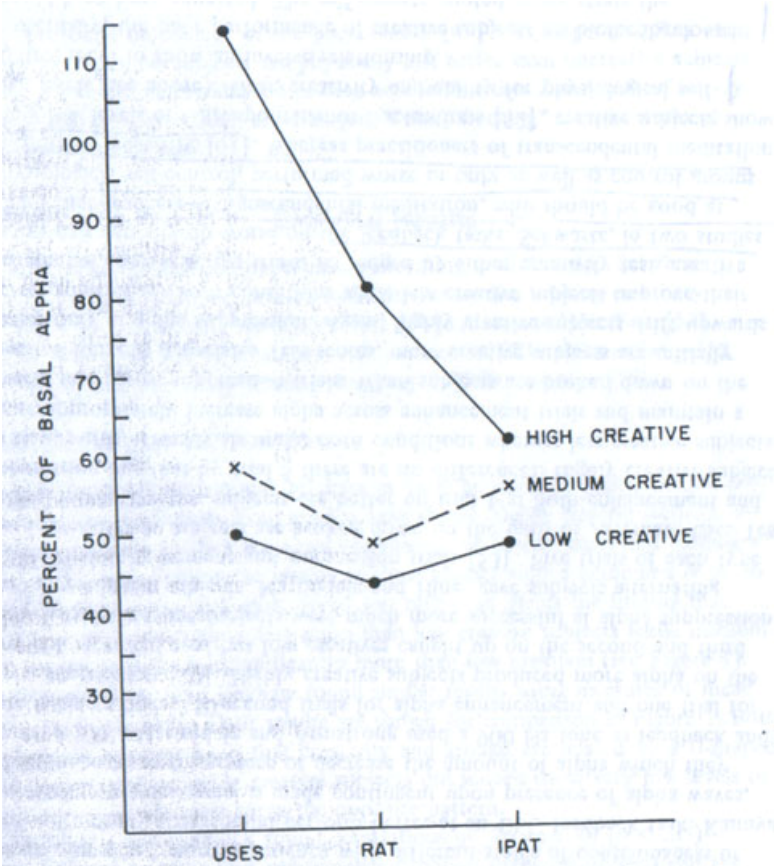
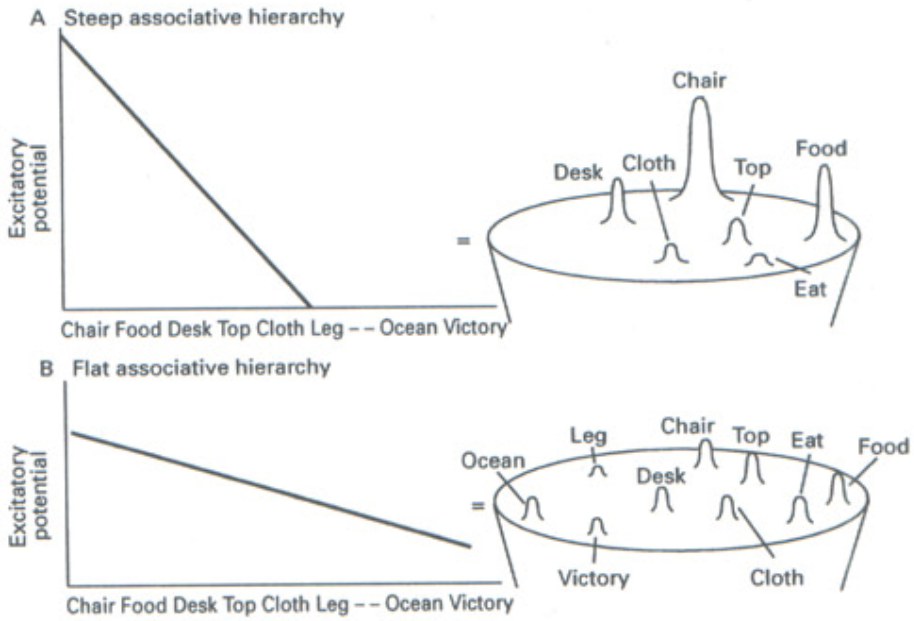


Figure 2. Percentage of basal alpha exhibited by high, medium, and low creative groups during creative and intellectual performance.

[2] From "Creativity, consciousness, and cortical arousal," by C. Martindale, 1977-78, *Journal of Altered States of Consciousness,* 2, p.78. Copyright 1977 by the Baywood Publishing Co., Inc.

Figure 3. A graphic visual of steep and flat associative hierarchies: A is characteristic of low RAT scorer and B is characteristic of high RAT scorers. [3]



[3] From "Creativity and Connectionism," by C. Martindale, 1995, *The Creative cognitive approach*, edited by S.M. Smith, T.B. Ward and R. A. Finke, p. 257. Copyright 1995 by the Massachusetts Institute of Technology.

Figure 4. Results from Pilot Study: TTCT verbal displaying decreasing trends in verbal scores for subscales: fluency (top), flexibility (middle), and originality (bottom).

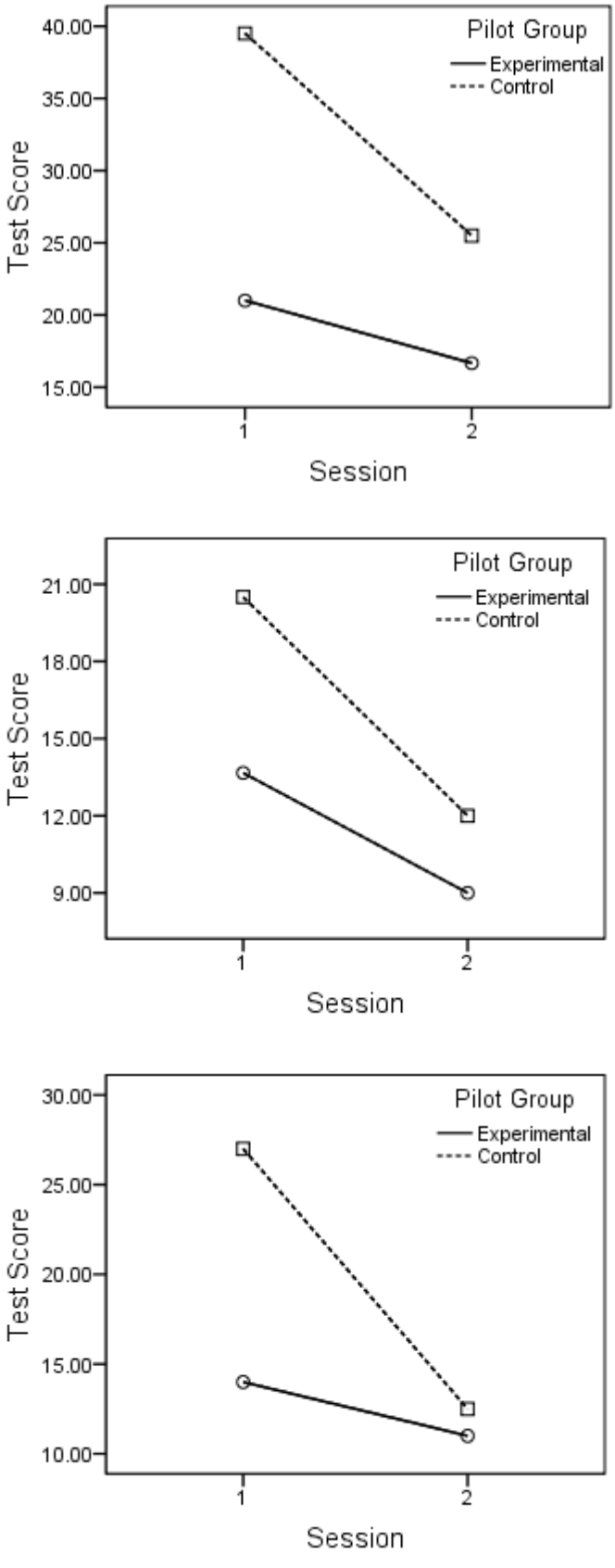
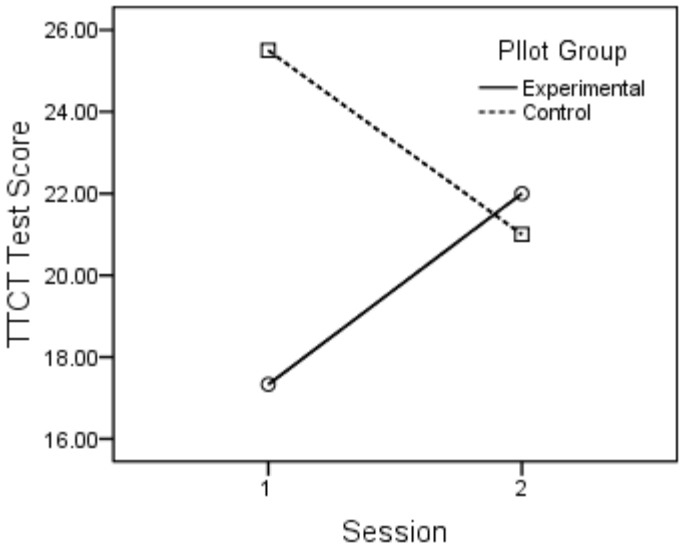


Figure 5. Results from Pilot Study TTCT figural: Fluency (top), Originality (bottom),



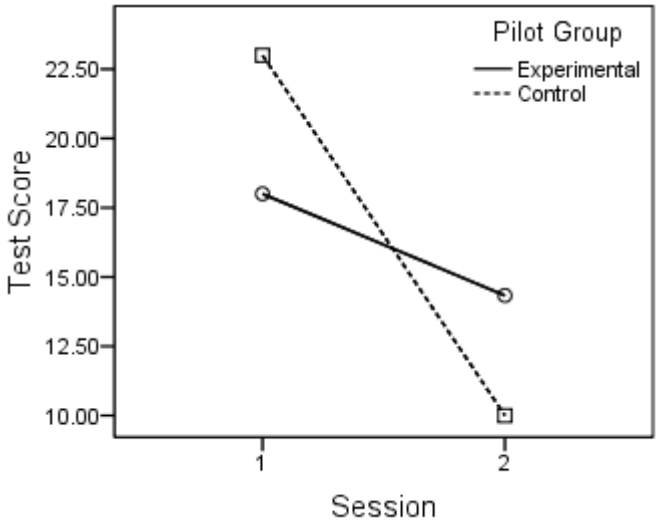
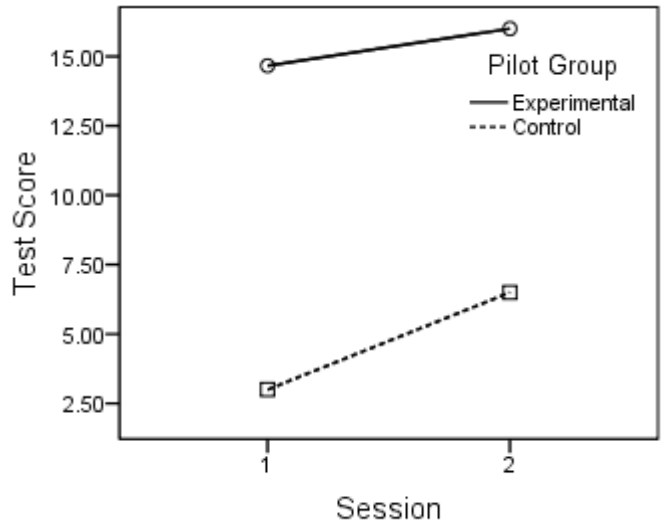
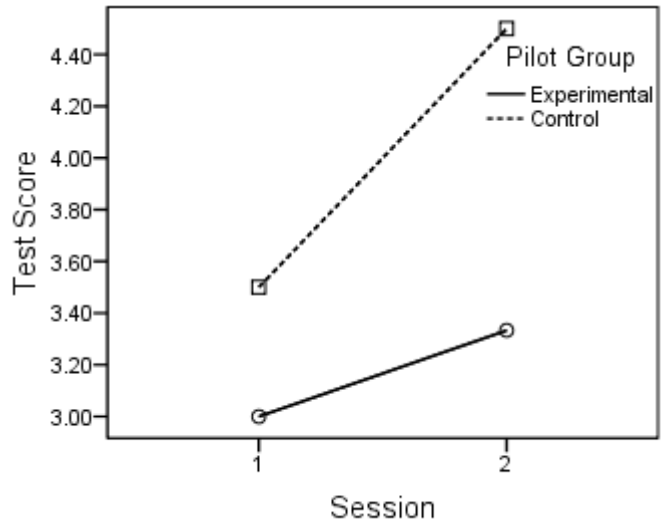


Figure 5. (continued) Abstractness of title (top), *Elaboration* (middle), and Resistance to premature closure (bottom).





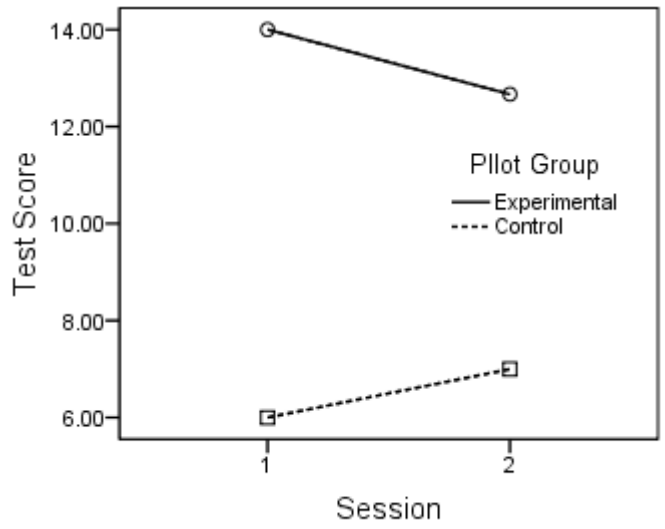
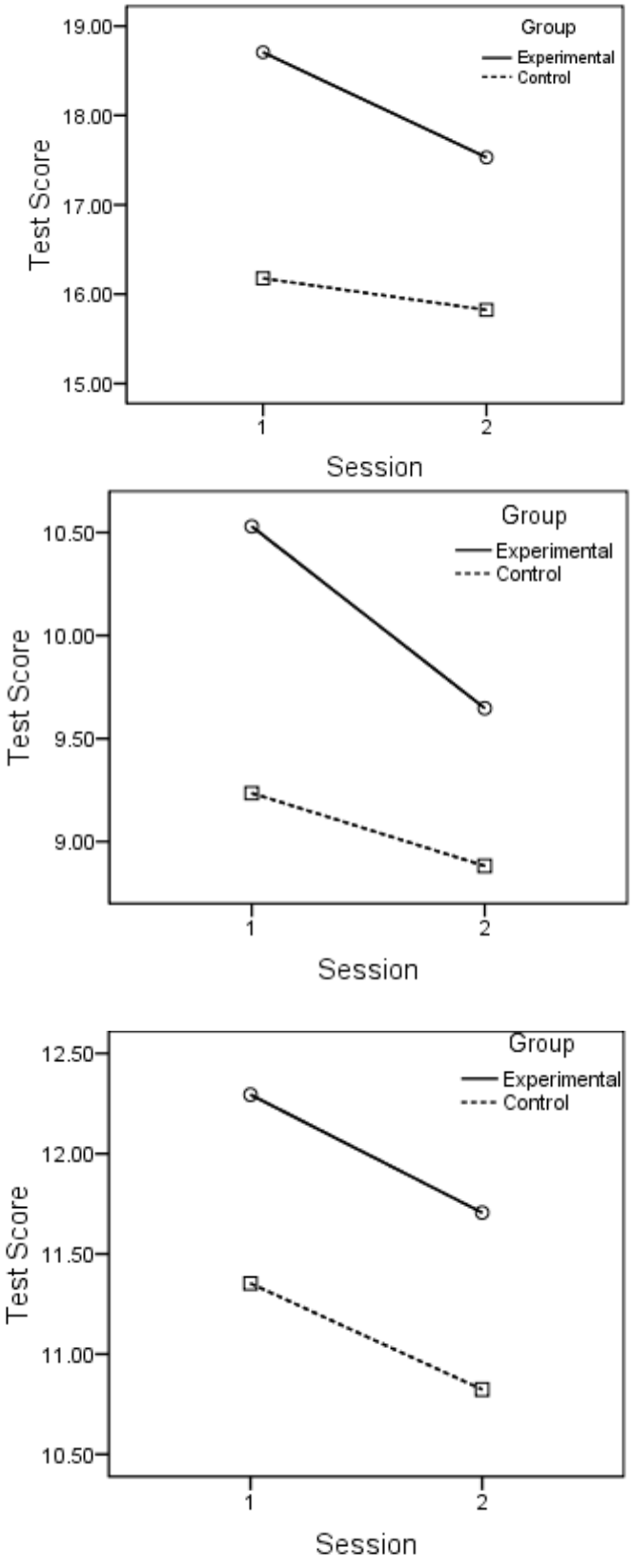


Figure 6. Results from the Experiment: TTCT verbal displaying decreasing trends in verbal scores for subscales: fluency (top), originality (middle), and flexibility (bottom).



Figural 7. Results from the Experiment: TTCT-verbal shows the divergence between the control and experimental group, with the control group doing consistently better. Fluency (top), Originality (bottom).

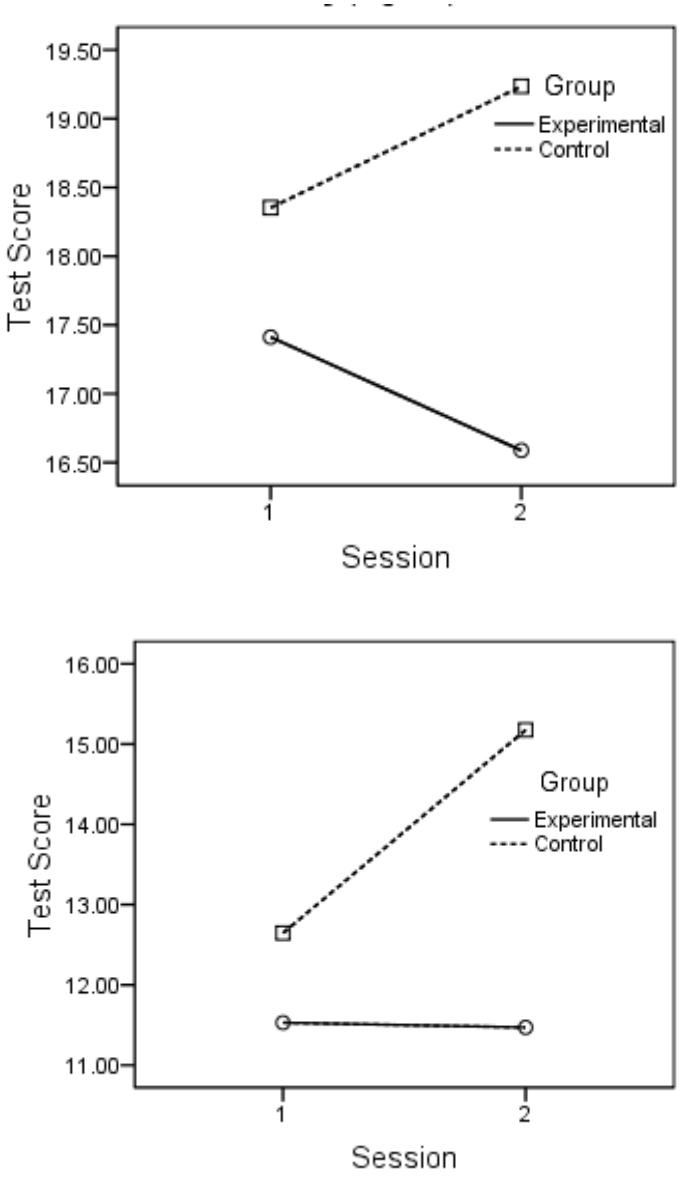


Figure 7. (continued) Abstractness of title (top), Elaboration (middle), Resistance to Premature Closure (bottom).

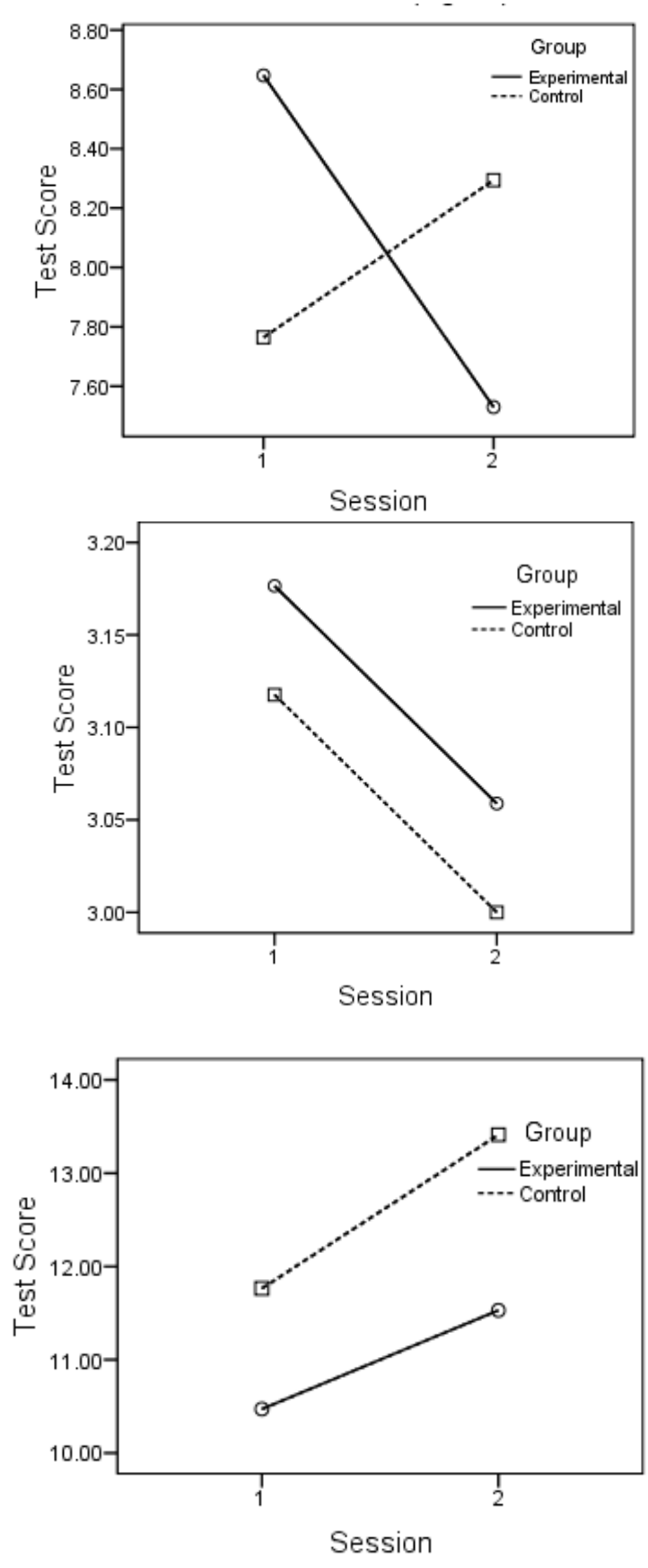


Figure 8. Minimal difference in score for experimental and control group across Sessions (top) and Version (bottom).