

Circadian rhythms and creativity

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Abstract

This writing presents empirical research using the Torrance Test of Creative Thinking to explore creativity and its relationship to circadian rhythms. Studies involved first year college students in design. Separate studies examined impacts of training on creativity and the variation of creativity at different times during the day. In one study, pre- and post- treatment evaluation showed improvement in measured creativity due to training. The second used repeated measures at different times of day to show significant differences, indicating a circadian influence on creative capability. Creativity, as a higher order cognitive function, appears to be affected by biological factors.

Introduction

Creativity, is quantifiable and can also be qualitatively evaluated for divergence, the internal and external differences of their ideas. Creativity is definable, measurable, and open for evaluation; measurement of creative actions provides a means to understand ways of training and paths to improvement in creativity. Creativity can be taught, developed, encouraged, and improved. Creativity requires cognitive effort which may be affected by context and abilities, including nutrition, social environment, and by the cycles of night and day.

Creativity, the development and adoption of new ideas is an important element in any domain. That skill is important at all levels of activity, from initial idea to finished product, and from nano scale inventions to city planning. Governments and businesses alike find value in increasing creativity.

Training people to be more creative is effective, and long term changes in ability are achievable. While people can become more creative, it is important to recognize that social, biological, and cultural structures can affect creativity as it is practiced (See, for example Puccio, 2006 and Amabile, 2003).

While substantial research has occurred on the training, development, and social contexts of creativity, less investigation has occurred as to the environmental aspects of creativity. Being creative requires substantial cognitive involvement, and elements that have an impact on the ability to think must be understood. Specifically, the time of day may have a significant impact on cognitive ability.

Here we will begin with an examination of standard aspects of creativity; definition, applicability and it's relationship to innovation and intelligence. The generation of new ideas is the most essential element of creativity which is measured by the Torrance Tests of Creative Thinking. Given a large data base of previous results, this standardized test allows comparisons with a wider population for creativity norms. Two studies using the TTCT that examine creativity and circadian rhythms will be presented followed by a brief examination of the environmental and personal impacts on creativity.

Creativity and intelligence

While there may be many popular explanations and examples of creativity, the generally accepted functioning definition of creativity is the cognitive ability to generate novel and applicable ideas. "Creativity is the generation of new ideas -- either new ways of looking at existing problems, or of seeing new opportunities..." (Cox, 2005, 8). "The creative process... refers to the sequence of thoughts and actions that leads to novel, adaptive productions" (Lubart, 2001).

Innovation is often used as a synonym for creativity, but it remains distinct from creativity: "'*Innovation*' is the successful exploitation of new ideas. It is the process that carries them through to new products, new services, new ways of running the business or even new ways of doing business" (Cox, 2005, 8).

Our focus here is on creativity, which could be described as the spark to the fire of innovation. Innovation is concerned with the adoption and use of new and different ideas. As fire needs air and fuel, so too does the innovation need social support, resources, and change (Florida 2002, Rogers, 1991); but still, metaphorically, the

igniting spark is provided by creativity. One can be creative without being innovative; one can have a spark without ignition. Not all ideas catch fire.

Creativity can be developed through a number of methods including motivational, cognitive, and social approaches (Bull et. al., 1995). This writing assumes some creative ability in all individuals and that training is effective in increasing measured creativity.

The Research Venue

This research was conducted in two regular offerings of a large introductory lecture course on design. Each study occurred over a separate semester of the course, and they were used to gather data on creativity from a large population of design students. The first study compared a control group with an embedded group receiving creativity training through a separate course. (Specific instruction in creativity was not included in the larger course.) The second study examined creativity at different times of day.

The smaller separate creativity course was a blend of theoretical instruction, application, and rapid idea generation, and was taught by the author. The nature of the course was consistent with recommendations inherent in Fasko (2001), and the findings in Scott, et. al. (2004).

Scott, et. al. (2004) said that "divergent thinking" was common in most training efforts for creativity. Divergent thinking is the development of multiple responses to questions, and the ability to provide numerous applicable answers.

Scott, et. al. (2004) completed a meta-analysis of 70 studies of creativity training. A number of elements differentiated results. Time on task and extensive work were usually needed to develop skills in creativity. Courses that focused on specific structured techniques were usually more effective than courses that merely dealt with open ended creative exercises. The largest gains in measured creativity occurred by the use of these structured techniques, such as convergent thinking (focusing ideas on a given result), critical thinking (thinking about one's thought processes), and the identification of problem constraints.

Measuring creativity

Different psychometric measures of idea generation were developed and popularized by Guilford and Torrance, early researchers in the field of creativity. This research used the Torrance Tests of Creative Thinking (1974a), which has been described as "... by far the most commonly used test of divergent thinking and [which] continues to enjoy widespread international use" (Plucker & Renzulli, 1999, 39).

As with any testing method, there are limitations in validity and pragmatic concerns. The TTCT provides a good understanding of some aspects of creative abilities, focusing on the development of new ideas. The test can easily administered and can be scored by either the researcher or publisher, and the results can be compared with a large historical population.

The Torrance Tests center on the idea that creativity can be measured through generative output, that is, ideas set forth in response to stimuli. We understand that creativity can be enhanced through training and other educational factors. In addition, creativity, as a higher order cognitive function, is affected by context and biological factors.

There are two forms of the Torrance Tests (TTCT), figural and written. The written version was used in this research; it contains six sections in the test that ask for multiple written responses to illustrations and verbal prompts. Responses are sought over five or ten minutes. In addition, there are two full versions of the test which are designed to complement each other and be used in any order. The two versions were used as repeated measures.

Within the Torrance written tests, there are three scoring areas that provide detail on creativity; fluency, flexibility, and originality. **Fluency** is based on the understanding that creative people generate more ideas than non-creative people. The Torrance Tests pose a hypothetical situation and ask for responses. Participants are evaluated by the number of answers given. For example, if question asked what one could eat, responses could include, for example, pizza, a salad, or fish. Providing more answers would be indicative of a higher level of creativity.

Flexibility is a measure of how the answers of an individual vary among themselves. Creativity is a skill that focuses on the development of new and different answers; generating slight variations of one theme would not be as creative as generating different types of answers. Building on our previous example, minor changes in a food type would not be considered a different answer; different flavors of ice cream or different types of salad would not be considered different answers.

The Torrance measure of **Originality** compares answers to a common set of responses to the same question. In our example "salad" is an answer that could be received in many places around the world, but eating "crow" or one's own words would be less expected responses in any culture. New, novel, and unexpected answers outside of societal norms are, by definition, more creative.

Testing

The venue for the testing was a large lecture class on design thinking. This class is required of all new design students at the university and also includes students from other areas of study as well. It consists of lectures, readings, and projects dealing with design. While all students in the class took the TTCT, in this study, only design students were scored and evaluated.

The test was administered twice over the semester, separated by about 14 weeks. 53 first year students were scored for this study, and were selected because they were majoring in design. 46 of the participants were female, and 7 were male, a gender breakdown that is generally consistent with design students registered at the university.

Scholastic Testing Services, publisher of the Torrance Tests was used for test scoring to insure reliability and accuracy.

Results

There was no measured gain in creativity by students in the lecture course between the two testings. The fluency score increased by 2.5%, an insignificant change. The score for flexibility increased by 2.9%, and this change was also not significant. In contrast, the originality score increased by 16% which was statistically significant.

Table 1: Scores and comparisons

	RS – A mean	RS – B mean	Difference	t-test A:B
Fluency Control [n = 51] [SD]	88.40 [27.08]	90.56 [33.04]	102.45%	0.49
Fluency Treatment [n = 9] [SD]	94.67 [26.81]	109 [33.73]	125.44	122
Flexibility Control [n = 51] [SD]	49.40 [11.16]	50.84 [12.77]	102.92%	0.36
Flexibility Treatment [n = 9] [SD]	48.33 [10.84]	111 [10.29]	63.89	133
Originality Control [n = 51] [SD]	59.19 [22.73]	66.16 [26.60]	116.35%	0.017*
Originality Treatment [n = 9] [SD]	66.00 [23.41]	116 [31.87]	98.56	124

RS = raw score. SD = standard deviation. * = significant at .05

Scores of students within this group that received training significantly increased their scores for fluency, flexibility, and originality by over 30%. There was not significant difference between the treatment and control groups prior to treatment; after treatment the training group had measured significant comparable gains (Hokanson, 2007).

A side order: Breakfast

A few additional contextual elements were informally examined during the first study. It had been hypothesized that gender, dominant-handedness, and nutrition could have an impact on creative performance as evidenced by the Torrance Tests. As other research had indicated that cognitive abilities are influenced by similar factors, a series of adjunct questions were added to the TTCT. Specifically, participants were asked if they had had breakfast prior to the 930am testing.

Breakfast, for the purposes of this study, was defined as "something more than coffee". 27 of 51 participants said they had eaten breakfast prior to research, and no data was gathered on food intake. On all three measures, those students eating breakfast scored significantly higher than those who did not. This informal investigation clearly hints at a direction of future research, and indirectly led to the research on creativity at different times of the day.

A study of circadian rhythms and creativity

The Torrance Test of Creativity was also used to investigate the influence of time of day on creativity.

Circadian rhythms, the daily rhythmic changes of a 24 hour day, affect a variety of biological functions. While most people are familiar with larger seasonal effects due to changes in length of day, the daily changes of circadian rhythm are more subtle or noticeable. Jet lag is the most well known disruption of circadian rhythm.

Humans, like most life forms, have a regular, daily schedule of biological rhythms. The most evident cycle is the sleep-wake cycle, but over 24 hours, heart rate, metabolism, urine production, cognition, body temperature, and receptiveness to certain medicines all vary.

Research into circadian rhythms began with body temperature measurements on subjects isolated from daylight in underground caves by research/subject Norman Kleitman (1939). He found that body temperature, which may be connected with cognitive activity reached a low point early in the morning (6am) and peaked in early evening.

In subsequent research, cognitive capability has been found to be at its lowest on waking in the morning through the use of dexterity, mathematics, and drawing to evaluate mental skills over a normal daily cycle (Kreitzman, 1963). Performance generally peaks at noon or shortly thereafter, declining gradually, with some variation until late evening. Colquhoun (1972) also found a daily rhythm of mental ability. He held that changes in body temperature paralleled mental ability, and was not causative, per Kleitman (1939). (see also Folkard, 1990).

...rhythms include our body temperature, which is higher during the day than at night, as is our heart beat and blood pressure; we have a clear sleep/wake cycle; our cognitive ability change rhythmically over a 24-hour period. Tooth pain is lowest after lunch; proof reading and sprint swimming are best performed in the evening; labour pains more often begin at night and most natural births occur in the early hours; sudden cardiac death is more likely in the morning (Foster & Kreitzman, 1965, 11).

Folkard found that mental ability is dependent on a range of variables including circadian time; it also is affected by waking hours (time awake) and type of task. Some tasks, such as those involving short term memory are significantly better performed in the morning, while some tasks, such as editing are better undertaken in the early evening (Folkard, 1990). Creativity, as a relatively complex mental task, would be expected to follow the general curve of abilities of body temperature, and should be more evident later in the day.

Within this study, the age of the study participants was anticipated to also affect the results of the study. Young adults have a daily circadian rhythm that is less defined than older adults and the general cycle occurs later in the day by 2-4 hours. This could mean that early morning cognitive testing of younger subjects could result in lower scores than with more mature adults. In response to this phenomena, many school districts in the United States have reacted pragmatically and changed start time for high school students (aged 14-18) to one to two hours later in the day.

Method and venue

142 undergraduates were tested within a large lecture class using the verbal Torrance Test of Creativity at the regularly scheduled class time of 9:30am. Eight weeks later, volunteers, solicited through extra credit, were retested using the TTCT. 57 volunteers completed the test at 4 pm on one of two days; 56 participants had taken the test in the classroom morning session, and were scored for this study. The two different forms of the verbal TTCT were used for this study.

As the biological daily clocks vary between young adults and more mature, 30-year-old adults, the age of the participants was an important concern. The average age of the participants was 19.6, and the age of the participants ranged from 19 to 29. It was hypothesized that this comparative youth would help reveal cognitive differences in retesting, and that the later testing would demonstrate gains due to circadian rhythms. As noted in the previous study, simple retesting, without treatment does not demonstrate significant gains. (e.g. 9:30 a.m. to 9:30 a.m.).

In all areas, subsequent afternoon testing revealed significant differences in performance. See table 2.

Table 2: Time of day scores and comparisons

Group [n=56]	RS B 9:30am mean	RS A 4:00pm mean	Percent A/B	t-test B:A	SS - B mean	SS - A mean	Diff in SD
Fluency [SD]	73.94 [21.34]	114.86 [28.64]	155.34%	0.000*	102.57	122.20	19.63
Flexibility [SD]	39.90 [8.17]	60.96 [10.74]	152.79%	0.000*	99.61	131.14	31.75*
Originality [SD]	44.98 [19.21]	79.96 [23.91]	177.77%	0.000*	102.10	127.02	24.92*

RS = raw score. SS = Standardized score SD = standard deviation. * = significant at .05

While there were differences between areas of testing, the strength of change in each area was substantial. The mean for Fluency, the ability to generate a large number of answers to a prompt, increased by 55%, which was significant at .05. Standardized scores, a distillation of raw scores in comparison with the broader society, increased by 19.64. As the mean for TTCT standardized scores is 100 and the standard deviation is 20, this may not be significant.

The mean scores for Flexibility and Originality both increased significantly. Flexibility increased by 53%; Flexibility is a measure of the divergence of individual participants' responses. Originality, the ability to generate uncommon responses increased by 78%.

Discussion

Time of day would appear to be an important consideration in the application of creativity, or with any other substantial cognitive effort. At the least, creativity is a challenging mental activity, and one which cannot be viewed as equally available every hour of the day. The mental effort of creativity needs to be treated as a sensitive aspect of the human mind, and specifically addressed with the resources of time and nutrition.

This may mean that individuals should recognize their own personal circadian cycles and seek to work with their own inherent biological variances.

These findings support the concept that challenges that involve creative and cognitive efforts must address the time of day when tests were administered. This could have an impact of forms of standardized testing such as college entrance or graduate exams. For example, this could mean that examinations directed at 18 year olds, such as the Scholastic Aptitude Test, should not be given at 8am. This and other research may also affect class and curricular scheduling of courses in creativity, design, and throughout the university.

Those taking examinations at a standardized time may be more successful that if they were attempted at a time better suited to their own circadian rhythms. As is well known, each individual also has variances in their circadian cycle. During this research, each participant was asked about their own description as a "night" or "day" person. These are coarse measures of personal performance, and are only anecdotally accurate. In addition, given the complex variations found by Folkard (1979), there may be multiple peaks and troughs of cognitive ability during a 24 hour cycle.

The ability to perform specific cognitive tasks also varies throughout the day; e.g. as short term memory peaks during the early morning it may mean that didactic class sessions work well in the morning, which is consistent with many college lecture classes. Analytical tasks are better performed later in the day or early evening, which may indicate that those times are more applicable for active learning. At the least, student performance could be improved by lecturing in the morning and testing in the afternoon.

This may also be a strong argument for online asynchronous learning. Students and faculty are both able to adjust their schedules to be more effective, in contrast with current practices, with wide-awake faculty and bleary-eyed students joined an 8am class.

Conclusion

This research measured creativity in two large groups of undergraduate design students. Students receiving training showed significant improvement of a large control group, demonstrating strong gains in all measured areas. In repeated measures, participants tested at different times of the day demonstrated significantly greater creative ability in afternoon examinations.

It can be concluded that circadian rhythms can have significant effects on measured creativity, and it could be hypothesized that other cognitive functions would be similarly affected. Other biological impacts could also affect creative performance including recent nutrition.

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