The Effects of Working Memory on User’s Performance in Creative Drawing

Master Thesis (30hp) in Human-Computer Interaction

Qi Han

Supervisor: Stanislaw Zabramski | Examiner: Annika Waern
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Abstract

Creative thinking ability is increasingly valuable in the nowadays society, especially in the innovation industry. The way to evaluate and somehow measure human’s creativity deserved the plenty researches for decades. Among approaches for creation, drawing has been used as a support for ideation for centuries. A widely well-known creativity test was Torrance Tests of Creative Thinking (TTCT), in which creative drawing tasks took apart in. Additionally, it was proposed that creativity was a result of continuously repetitive processes of working memory and some neurophysiologists had discovered that working memory and our cerebellum collaborate to produce creativity and innovation. To expand our knowledge on the potential relationship of working memory and creativity, the problem - to what extent does a load on working memory affect creative performance in drawing tasks - therefore was addressed.

The exploratory study presented in this thesis was conducted as a continuation of a series of relevant previous researches investigating how multiple factors affect the outcomes of creative drawing tasks (Zabramski & Neelakannan, 2011) (Zabramski, et al., 2011) (Zabramski, et al., 2013). A controlled experiment investigating how the outcomes of a drawing creativity test are affected when the participants are given a load on visual working memory was launched. The computerized TTCT were performed in both the experimental group and the controlled group. The load on visual working memory – the so-called Trace Fade-out setting – was only loaded for the experimental group. The Trace Fade-out setting means that what the participant has drawn on the screen will fade out until disappear in 15 seconds.

This thesis presents the results of the study, which show no significant effect on creativity scores earned by the participants, in general. Specifically, relative significant differences were detected between the quality scores of the drawing outcomes obtained by the two groups. The results imply that creative drawing activities can be unaffected achieved in an interference of working memory, although the involved people may think they are affected during the activities and believe that they may perform better without the interference.
Acknowledgement

I would like to express my gratitude to my supervisor Mr. Stanislaw Zabranski. His guidance, instructions, support of the software and hardware used in the tests, invariable quick replies to my questions, and especially his encouragement, helped me a lot throughout the whole thesis work. I felt very lucky and happy to have a supervisor like him.

I also want to thank Prof. Else Nygren and Prof. Annika Waern for their guidance and comments, and the fellow students for their suggestions. I would like to thank our Human-Computer Interaction section in Uppsala University, for providing the lab and all the test equipment for me to perform the test.

Finally, I would like to thank all the participants came to my tests. All of them spent not a short time for the test and gave their best efforts. Without them, I was unable to conduct the test and write my thesis.
1. Introduction

Human and computer together form a problem-solving system with multiple output methods (e.g. screen display, sound effect) and multiple input methods (e.g. keyboard, mouse, stylus) providing the interface. Our visual thinking abilities and skills, which vary from the universal, are mainly responsible for interacting with the interface. Our visual memories are what we use to capture meaningful and useful information, either from the world or some sort of information display (Ware, 2008).

On the other hand, creative thinking is definitely increasingly valuable in the nowadays society, especially for designers and people working in the innovation industry, which contains the field of HCI. It is obvious that creative activities always involve visual tasks, which must be implicated with visual memories as well.

So far, hundreds of previous studies had explored on either human’s creativity or working memory. Moreover, it was proposed that creativity was a result of continuously repetitive processes of working memory. Vanderverta and his colleagues (2007), as neurophysiologists, had discovered how working memory and our cerebellum collaborate to produce creativity and innovation. Their study was concluded that working memory and cerebellar explanation of creativity and innovation could tie together from a neuroimaging and clinical perspective. And it was suggested that newly developed electromagnetic inverse techniques will be a necessary complement to functional brain imaging studies.

However, less research on exploring the influence of working memory on creative activities has been carried out. Therefore the focus of this study is addressing this gap by exploring the possible effect of working memory on one’s creativity, in the context of a controlled experiment on creative drawing tasks.

To be specific, this study was conducted as a continuation of a series of explorative laboratory-based usability studies on computer mediated creative drawing which had been performed by Zabramski and his colleagues (Zabramski, et al., 2011) (Zabramski & Neelakannan, 2011) (Zabramski, et al., 2013). The series of studies (which will be described in more detail in the Previous Work section) evaluated how particular software solutions (e.g. user interface) together with computer input devices (i.e. mouse, stylus, and touch input) affect the outcomes of creative drawing.
(idea sketching) that take place on the computer’s screen. The figured part of the Torrance Tests of Creative Thinking (TTCT) were used as the general method of these researches, and I assumed my study to be methodologically compatible with previous researches. Hence, to explore the idea of the influence of working memory on performance in creative activities, I decided to perform a controlled experiment of two versions of the computer-based non-verbal part of the Torrance Tests of Creative Thinking, which additionally offers a standardized measure of the participant’s creativity.
2. Problem Description

As the mentioned neurophysiology research (Vanderverta, et al., 2007) proved that working memory produces creativity and innovation by collaboration with cerebellum, a relationship between working memory and creativity was therefore established. Whereas, any other possible relationship between working memory and creativity was not found due to the less research besides the field of neurophysiology. In addition, as a continuative study of the previous researches investigating on multiple influence factors on creative drawing by Zabramski (Zabramski, et al., 2011) (Zabramski & Neelakannan, 2011) (Zabramski, et al., 2013), the idea that exploring whether and how one’s creativity will be affected when an interference of working memory is loaded, was come up with for this study.

2.1. Goal

Since it was not clear that the degree of possible influence of working memory on creative activities, and to attempt to address this gap, this thesis aimed to explore the factor of visual working memory involved in the process of creative sketching activities under a computer-mediated environment, and to assess the impact on the outcomes of the process. By investigating on this subject, this study could be assumed to be meaningful for supporting people create and explore ideas effectively. This is also done for minimizing the negative effects in creative activities.

2.2. Research Question

To expand our knowledge about the influence of working memory on the user’s performance in creative drawing tasks, the experiment was based on the following research question: 

*To what extent does a load on visual working memory affect one’s creativity in drawing tasks?*

2.3. Hypothesis

Although the fact of less relevant literature made it hard to give a valid hypothesis, I still hypothesized that a load on visual working memory would make a significant difference on one’s creativity in drawing tasks. I also had a guess that the participants might redraw their drawings or even lose their initial ideas during the activities.
3. Previous Works

3.1. Visual Working Memory

Alan Baddeley, a well-known British psychologist in his work on memory, suggested that (Baddeley, 1999)

Memory does not comprise a single unitary system, but rather an array of interacting systems, each capable of encoding or registering information, storing it, and making it available by retrieval.

During the 1960s, intense studies on memory models appeared. The results came to a similar form and were represented by the models made by Atkinson and Shiffrin (Atkinson & Shiffrin, 1968). They assumed three kinds of memory - sensory memory, short-term memory and long-term memory. Among these memory, short-term memory was a system for storing information over brief intervals of time. A limited capacity short-term store was fed by sensory memory, and was in turn responsible for encoding material into a more durable long-term store (Baddeley, 1999).

But what is short-term memory for? A man with a low memory span could also have a good life. There was agreement that its function was to serve as a working memory, a system that actively holds multiple pieces of transitory information in the mind, where they can be manipulated. Working memory includes subsystems that store and manipulate visual images or verbal information. Baddeley proposed that the subsystem for visual images was for maintaining and manipulating visual images, and as such it was useful in taking advantage of imagery for learning (Baddeley, 1999).

Capacity

When people try to remember something, for instance, a random series of numbers (e.g. 415, 63, 890, 2, 702), the capacity of short-term memory is determined by the number of chunks (there are 5 chunks of the instanced numbers) rather than by the number of digits (12 digits). This phenomena is called chunking, which is also true with other types of materials to be remembered. Chunking is what memorizers in our brains do by themselves with the material presented. A large number of studies investigated on the capacity of visual working memory. George Miller suggested that human short-term memory
has a memory span of approximately seven items plus or minus two (Miller, 1956). Luck and Steven also came to the conclusion that visual working memory stored integrated objects rather than individual features. As long as the individual features were confined to a small number of objects, the capacity for retaining the features was large. Their results indicated that at least four features could be joined with no cost in terms of storage capacity (Luck & Steven, 1997). Years later, the best overall estimate of short-term memory capacity was about four pieces or chunks of information (Cowan, 2010). Although Cowan still believed that it had been difficult to determine the capacity limit of working memory.

**Durability**

One study suggested the durability of visual working memory is very limited. It lasts seconds to minutes and is resistant against visual interference (Luck & Steven, 1997).

Some but not many previous studies involved the durability of visual working memory, and they investigated the storage time, or the encoding time. The storage time was assumed to be less than 1 second (Averbach & Coriell, 1961). Among the relevant studies, Phillips assumed that short-term memory deteriorated greatly within 10-20 seconds (Phillips, 1974).

**Retrieval**

Forgetting was thought to be, actually, a reflection of the decay of the short-term memory trace. However, it was later shown that initiative interference took an important role on forgetting. Baddeley suggested the last few items presented were very well recalled, if recall is immediate—what showed the so-called recency effect. In addition, good retrieval depends on good encoding (Baddeley, 1999).

### 3.2. Creativity and the TTCT

The definition of creativity could vary on literal expression, but a general agreement had been reached by creativity researchers in recent decades. An idea was said to be creative when it fulfilled two requirements. One was the idea must be original, novel or surprising. The other one was the idea must be functional or effective, which meant, it must work (Simonton, 2009).

The Torrance Tests of Creative Thinking (TTCT) was a well-known test for individual’s capacity of creativity. The
tests, created by Ellis Paul Torrance, an American psychologist, in 1960s. The tests were originally built on Guilford’s works (1956) and involved divergent thinking, which reflects one’s ability to generate multiple solutions to a problem, in other words, reflects one’s creativity ability. The tests were firstly conducted in Minnesota to several thousands of school children and were conducted and developed by Torrance and his associates in the following decades for use in all cultures, from kindergarten through graduate and professional school. Till now, several longitudinal studies had also been conducted to follow up the elementary school-aged students who were first administered the tests. The tests therefore were regarded as the most systematic assessment of creativity for elementary school children. Once again, a definition of creativity in Torrance’s understanding (Torrance, 1966) was as

"a process of becoming sensitive to problems, deficiencies, gaps in knowledge, missing elements, disharmonies, and so on; identifying the difficulty; searching for solutions, making guesses, or formulating hypotheses about the deficiencies; testing and retesting these hypotheses and possibly modifying and retesting them; and finally communicating the results."

The tests had three categories of tasks - verbal tasks using verbal stimuli, verbal tasks using non-verbal stimuli and non-verbal tasks. Specifically, there were three activities of the non-verbal tasks, which basically were tasks on creative drawing (Torrance, 1990):

- **Picture construction task** (Activity 1): the participants were asked to draw a novel picture in which the given shape is an integral part. And they were required to name the picture.

- **Picture completion task** (Activity 2): the participants were asked to draw novel objects based on the ten given different stimulus figure.

- **Circles and lines task** (Activity 3): the participants were asked to draw objects based on forty two circles or pairs of straight lines with the requirement that circles or lines should be the major part.

A streamlined scoring system described in the scoring manual (Torrance, et al., 1992) was underwent years of
developmental work and provided a maximum of information about the creative functioning of a child or adult with a minimum of scoring effort. The five norm-referenced subscales were given credits individually. Each was scored for one, or two, or all the three activities. According to the manual, the drawing results by participants were scored on five subscales:

- **Fluency** (scored for Activity 2 and 3): Represents the participant’s ability to produce large numbers of images. The total number of different relevant responses is counted as this score; nonsense and inappropriate responses to the given stimuli are not counted.

- **Originality** (scored for Activity 1, 2 and 3): Represents the ability to produce novel and uncommon responses. The most common responses (shown on the lists of every given stimuli) are scored as 0 and all other reasonable responses showing creative strength as 1.

- **Abstractness of Titles** (scored for Activity 2 and 3): The level of abstraction given to the titles of the pictures drawn. This requires one to know what is truly essential in a problem.

- **Elaboration** (scored for Activity 1, 2 and 3): Reflects the ability to develop, embroider and elaborate ideas. The number of added details is estimated by the scorer within six sets of limits determined by normative data.

- **Resistance to Premature Closure** (scored for Activity 2): The degree of psychological openness; based on the general belief that creative behaviour requires a person to consider a variety of information and to keep an “open mind.”

Scoring resulted not only in the five norm-referenced measures above, but also in thirteen criterion-referenced measures. The criterion-referenced measures represented a series of creativity strengths, and were scored as bonuses. In general, any appearance of a strength was scored for 1 bonus credit. If a strength appeared three or more times, 2 credits were given as the bonus. The measures were:

- Emotional expressiveness (in drawings and titles),
- Storytelling articulateness (draw context or environment),
- Movement or action (running, dancing, playing, etc.),
- Expressiveness of titles,
- Synthesis of incomplete figures (for Activity 2) (combination of two or more figures),
- Synthesis of circles (for Activity 3) (combination of two or more circles),
- Unusual visualization (above, below, at angle, etc.),
Internal visualization (inside, cross section, etc.),
Extending or breaking boundaries (in titles, captions, drawings, etc.),
Humor,
Richness of imagery (variety, vividness, strength, etc.),
Colorfulness of imagery (excitingness, earthiness, etc.),
Fantasy (pictures in myths, fables, fairy tales, science fiction, etc.).

The points of the five norm-referenced measures was summed into the Raw Scores. Point of each subscale was corresponded with a Standard Score which could be checked in the lists of the manual (Torrance, 1990). The Creativity Index were then calculated by adding the Standard Scores and the bonuses of creativity strengths, representing one’s overall creative performance in the tasks.

3.3. Related Works

Nowadays, people spend increasing time on interacting with computers, sometimes for creative activities (e.g. designers use computer or touchpad for sketching ideas). Unsurprisingly, there were some previous attempts of creating a version of the non-verbal TTCT tested by computer-based method instead of pen and paper. A series of relative latest researches investigating the role of different input methods and user interfaces in creative drawing tasks in computerized versions of the TTCT had been conducted as follows:

- Three different computerized input methods (mouse, stylus, and touch-input) made no significant differences between the results of drawings produced in the tests. (Zabramski, et al., 2011)
- Using computerized input method (stylus and screen) instead of traditional method (pen and paper) in the tests did not affect the drawing results. (Zabramski & Neelakannan, 2011)
- The difference between using a simple and a more complex user interfaces was significant for the quantity of ideas produced. (Zabramski, et al., 2013)

In these previous study, a simplified UI software to minimize any potential effect of UI and to minimize differences between paper-based and computer-based version of the TTCT was created (see Figure 1). The stimuli shapes were given in 5-pixel thick solid-black lines and displayed on a white background which took the whole screen.
Figure 1. A screenshot of the simple GUI used in the studies showing Activity 3 of the TTCT. (Zabranski, 2014)
4. Methods

The experiment was designed and launched based on the framework of the TTCT. Indeed there were multiple choices of framework for answering my question, the reason I chose the TTCT was that firstly it was a well-known and typical creativity test which had a rich developed history by the inventor himself and many other researchers; secondly, that my study was assumed to be methodologically compatible with the previous mentioned studies which used the framework of the TTCT.

4.1. Test Design

In order to answer the question about the influence of visual working memory on the one’s creativity performance in the TTCT, I designed a load on visual working memory – the Trace Fade-out setting – to be embedded in the non-verbal tasks of the TTCT. Hence, my test had to be a computerized TTCT with the help with a software embedded Trace Fade-out setting, though the original test asked the participants to draw with paper and pens. I decided to perform a controlled experiment where every participant use either the timed version (with Trace Fade-out setting) or the regular version (without the Trace Fade-out setting) of the TTCT.

4.1.1 “Trace Fade-out”

As my understanding of the conclusions of the previous studies on visual working memory, 1 second (or even 600ms or 800ms) is enough for encoding 7±2 (or 4) chunks into the working memory, which lasts for several seconds and deteriorates greatly within 10-20 seconds. Since principle form of the experiment would be drawing tasks, it could be considered that participants would have enough time for encoding. So what I need to design was a load on working memory where information had to be retrieved from the storage to complete the tasks.

After considering different options, I decided to use the idea called Trace Fade-out, which was originally called “Disappearance”, into the regular TTCT drawing tasks. Trace fade-out means that what participants have drawn will fade out until disappears in 15 seconds. That is, each touch of drawing trace would fade out along with the participants drawing. Each drawing trace by the participants would start to fade out in the fifth second after the starting point (the point that the stylus touched the drawing area on the screen) and completely disappear in the fifteenth second after the starting point. If a drawing stroke itself lasted for more than 5 seconds, it would
immediately start to fade out and disappear in 15 seconds. If a drawing stroke lasted for more than 15 seconds, it would immediately disappear once the stylus left from the screen.

Why “Trace Fade-out”?

At the beginning, several different ideas were come up with:

- “Delay”: the system has 2 or 3 seconds delay on the output of what has drawn.
- “Disappearance”: what users have drawn will only display for a fixed time, then it begins to disappear. Or, the drawing traces will gradually fade-out until disappear.
- “Invisibility”: nothing is shown on the screen during drawing; all things come out at a time when the users done.

Finally the second idea was chosen. I think in this way it involves the factor of working memory, which might influence participants’ creativity and storytelling on the drawing tasks. At the same time, it much easier for the participants than the last idea.

Why 15 seconds?

Previous studies on the duration of working memory were not as many as studies on the topic of the capacity. Some studies explains the duration of short-term memory in vague words, like “seconds” or “short periods of time”. Phillips mentioned in one of his studies (1974) that the visual memory is called short-term because it deteriorates greatly within 10-20 seconds. Therefore I choose the mean time of 15 seconds for the Trace Fade-out setting.

Through this approach, participants had to encode what they had drawn on the screen into their working memory store. I also have the assumption that they might redraw their drawings or even lose their initial ideas.

4.1.2 Controlled Experiment

The participants were randomly assigned into two groups – an experimental group and a control group. The tests for the both groups were designed to be completely the same other than the single variable – trace fade-out.
The Experimental Group (The Timed Group) – the test for this group was a TTCT embedded Trace Fade-out setting as described above. The participants in this group were informed about Trace Fade-out by the moderator (me) before their tests.

The Control Group (The Regular Group) - the test for this group was a regular computerized TTCT without trace fade-out. Participants were able to see their drawings on each page all the time during the test.

4.1.3 Input method
As a computerized TTCT would be conducted, an input method need to be selected. Mouse, digitizer, stylus with touchscreen and finger-touch on screen were possible choices. Among them, a mouse was the most common input device for everybody, but obviously it was not a good tool for drawing. A digitizer was a good and precise tool for digital drawing but practice and adaption would be necessary for first-time users. Using fingers to draw on a touchscreen always got low accuracy. After all, a PC equipped touchscreen and stylus came to be the best choice as this combination is the most similar with pen and paper. Besides, the previous studies had shown that different input methods did not affect the results of creative drawing, so I assumed stylus with touchscreen would work for my study.

4.2. Test Conditions
4.2.1 Environment
The test was launched at the usability test laboratory in Ekonomikum, Uppsala University. The lab consisted of one testing room and a control room separated from the testing room by a one-way mirror. A laptop was used by the participants for conducting the test and recording the participants’ progress. An additional PC located in the control room was used for observing during the test session.

4.2.2 Hardware
The participants used a HP TouchSmart tm2 laptop with a 12.1-inch, 1280x800-pixel touchscreen with a stylus. An external keyboard was connected with the laptop. The stylus was used as a tool by the participants to sketch on the screen. The external keyboard was used only for the control of progressing to the next page. An external camera focusing on the participants was used for recording participants’ actions.
4.2.3 Software

The laptop ran Microsoft Windows 7 (Intel Core 2 Duo, 4GB of RAM). The Flash program of the test ran in the laptop. The participants were allowed to use the stylus to draw 5-pixel thick black trace over the full touchscreen in white background. The Form B of the non-verbal TTCT was chosen to use in the software. All the user’s actions, system events, computer’s screen view were recorded by the software TechSmith Morae Recorder 3.3.3. The observing in the control room was with the help of TechSmith Morae Observer 3.3.3. There was no eraser function in the software. By using the stylus, the participants were able to draw in single line type and only in black colour.

<table>
<thead>
<tr>
<th>Questions</th>
<th>Timed</th>
<th>Regular</th>
<th>Both</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 My painting skill is…</td>
<td>2</td>
<td>1.5</td>
<td>2</td>
</tr>
<tr>
<td>2 I use a computer/tablet…</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>3 My previous experience of using a stylus is</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>4 My previous experience of drawing by computer/tablet is</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 1. Median responses of the Likert scale in the pre-questionnaire (Appendix B).

4.2.4 Participants

The test was conducted on 16 participants, who were collected volunteers in Uppsala University. Their ages ranged between 22 and 27. Most of them had completely no idea about the TTCT before the test and only 2 of them were not sure whether they had previous knowledge of it. They were all acquainted using a computer, but they had not much experience on using a stylus (see Table 1 & Appendix B). The participants were randomly assigned into the two groups and each of them attended the test alone. All of them were rewarded homemade desserts and snacks after their test session.

4.3. Procedure

Each test took around 40 minutes totally following the procedure described below.

4.3.1 Introduction

First, the participant was greeted and asked to fill up the consent form (see Appendix A). By signing the consent form, the participant indicated that he or she had read and understood the information informed on the form (e.g. the test was voluntary participation, the process of the study will be video recorded and hand written notes of
participants will be taken, all recordings will be erased after the study is completed).

Then I, as the moderator, informed the participant about the following things:
✧ Brief introduction of the test: the participant is expected to draw pictures based on given features, using imagination to think of the most interesting and unusual ideas.
✧ The procedure: one pre-test questionnaire, a warm-up, three activities, one post-test questionnaire.
✧ When the participant had any questions during the test, he or she could raise hand up and I would come for help.

4.3.2 Pre-test Questionnaire
Pre-test arrangements included signing consent forms by the participants and filling a pre-test questionnaire (see Appendix B). The pre-test questionnaire was regarding the previous experience about computer and stylus, drawing.

4.3.3 Warm-up
In order to avoid the unfamiliarity of both the hardware and the software influencing the participant's drawing performance, especially for those who is a first-time user of a stylus, the participant had a warm-up phase before the three activities. They had some time to try freely with the stylus in the software MS Paint until they felt they were ready to start the real test. Mostly, this phase only lasted for less than one minute.

In addition, the participants of the experimental group had a chance to see what will exactly happen with trace fade-out by doing some drawings on the welcome page of the software. And they were explained by me that all their drawings would be recorded by the system so that they did not have to redraw any lines, but in other words, they had to remember what they had drawn.

4.3.4 Three Activities
After all above, the participant was asked to complete the three tasks of the TTCT in the original order as described in Chapter 3.2. The tests were performed based on the TTCT directions manual (Torrance, 1990). The instructions also basically followed the manual and kept the same for each participant (see Appendix E). When the participant was doing on the tasks, the moderator moved to the control room in order to prevent any disturbing. The
participant was allowed to ask the moderator for help when he or she has any questions during the test.

The test performed all three activities of the non-verbal part of TTCT – Form B in the original order:

✧ **Activity I. Picture Construction Activity** - required the participant to draw a picture based on a given shape as part.

✧ **Activity II. Incomplete Figures Activity** - where the participant was provided with 10 different incomplete figures (one screen with first 6 figures and then 4 figures on another screen) was required to draw as many pictures as possible with each shape as an integral part.

✧ **Activity III. Repeated Figures Activity** - 30 circles distributed over 2 screens for a participant to make and draw multiple associations to a single stimulus.

In each activity, participants had to write the titles of their drawings by writing on an additional sheet of paper using a regular pen. These titles were later used for scoring purposes.

### 4.3.5 Post-test Questionnaire

When the participant has completed all the activities, a second questionnaire (see Appendix C and D) will be answered by regarding the feedback of the test and the participant’s perception of their performance. The post-test questionnaire is based on The New Creativity Support Index (Carroll, et al., 2009).

#### 4.3.6 Post-test Interview

After filling up the post-test questionnaire, the participants had a chance to give comments about the test. There was no designed questions for the interview, the participants were allowed to say anything they wanted.

#### 4.4. Scoring and Data Analysis

What the participants drew on the screen was recorded by Morae. The screen snapshots of the participants’ drawings in the regular group were taken as their drawing results. However, since the drawings of the participants in the timed group would fade out as time went by, there was no way for me to screen shot their drawings. So for the timed group, I took snapshots every 5 seconds of each screen recording video and converted the snapshots of each activity into one picture. The pictures showed the whole
drawing traces of each activity by the participant, and were considered as their drawing results.

All the drawing results were scored by me according to TTCT scoring manual (Torrance, et al., 1992). According to the manual, five subscales representing different abilities of creativity were given credits respectively as Raw Scores. They are, as described in Chapter 3.2., –
- Fluency,
- Originality,
- Abstractness of titles,
- Elaboration,
- Resistance to premature closure.

The 13 creative strengths as described in Chapter 3.2 (i.e. Emotional expressiveness, Movement or action, Synthesis of incomplete figures, Unusual visualization, and Humor, etc.) were also scored as bonuses.

Then a Standard Score was given to each Raw Score according to TTCT norms-technical manual (Torrance, 1990). Finally, the Creativity Index was derived by adding the Average Standard Score and the creative strengths score.

The values in different sorts (e.g. Creativity Index, Raw Score, abilities of creativity) were respectively compared and analyzed between the two groups. Multiple ANOVAs were done with an alpha of 0.05. Box plots and bar charts were created for different comparisons to visualize the data analysis.
5. Results

An ANOVA of the participants’ Creativity Index scores showed no significant differences between the results of the two groups (see Figure 2; F=0.1790; p=0.6787). Similarly, difference of the Raw Scores between the two groups were not significant (see Figure 3; F=0.7130; p=0.4126). These implied that weak correlations were found between the working memory and creativity.

The average Raw Scores of each creative ability were also compared (see Figure 4). It indicated that there was a relative significant difference between the Originality scores of the two groups, but nearly no difference was shown between the Fluency scores, while minor differences between each one of the three other scores.
The Fluency scores represented the numbers of qualified images produced by the participants, and the rest of the abilities were actually related to the quality of the pictures or titles produced. Although this approach for analysing the results was not provided by the original TTCT, some previous studies separated the scores into quantity and quality scores as well (Zabramski, 2014) (Jackson, et al., 2012). Moreover, since no credits would be given to a picture for Originality, Abstractness, Elaboration or Resistance if it got 0 in Fluency, the four subscales indeed reflected quality of the picture which was counted as effective. It implied that the attempt of grouping the four abilities and analysing separately was reasonable and feasible.

As no difference was found between the quantities of pictures produced by the two groups, an ANOVA of the quality scores (the sum score of the Raw Scores of Originality, Abstractness of titles, Elaboration and Resistance to premature closure) obtained by the participants of both of the groups was made (see Figure 5). It showed a relative significant difference between the quality scores of the two groups (F=3.0037; p=0.1050).

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Figure 4. Average Raw Scores of the creativity abilities scored for the two groups.

Figure 5. Quality scores (sum of the Raw Scores of Originality, Abstractness, Elaboration and Resistance) of the two groups.
The post-test questionnaires (see Appendixes C and D) were based on The Creativity Support Index Survey (Carroll, et al., 2009) with some minor changes and showed participants’ positive or negative responses to evaluation statements in the 5-point Likert scale where 1 = “strongly disagree” and 5 = “strongly agree”.

The median response of each question answered by each group were shown in the Table 2. The median responses of the both groups were also calculated. The last three questions were answered by the participants of the timed group only.

<table>
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<tbody>
<tr>
<td>1 It was easy for me to explore many different ideas, options, designs, or outcomes.</td>
<td>3</td>
<td>3</td>
<td>3.0</td>
</tr>
<tr>
<td>2 I focused my attention on the activity and I neglected the system/tool I was using.</td>
<td>4</td>
<td>4</td>
<td>4.0</td>
</tr>
<tr>
<td>3 I was very engaged in this activity.</td>
<td>4</td>
<td>5</td>
<td>4.5</td>
</tr>
<tr>
<td>4 I enjoyed this activity and would do it again</td>
<td>4</td>
<td>5</td>
<td>4.5</td>
</tr>
<tr>
<td>5 The trace fade-out affected me while I was drawing.</td>
<td>5</td>
<td>N/A</td>
<td>5.0</td>
</tr>
<tr>
<td>6 During the test, I was getting used to drawing with the trace fade-out.</td>
<td>4</td>
<td>N/A</td>
<td>4.0</td>
</tr>
<tr>
<td>7 Without the trace fade-out, my drawing would be much better.</td>
<td>5</td>
<td>N/A</td>
<td>5.0</td>
</tr>
</tbody>
</table>
6. Analysis and Discussion

The software used in this study had been previously tested also with stylus (Zabramski & Neelakannan, 2011) and it had been found equivalent to the original version of the TTCT with paper and pen. Hence, the load of visual working memory (the Trace Fade-out setting) might be expected to influence one’s creative performance.

However, the result showed that the difference between the scores, either the Raw Score (p=0.4126) or the Creativity Index (p=0.6787), obtained by the participants from the two groups was not significant at all (see Figure 2 and 3). Since an alpha of 0.05 – a widely used value by the scientific community - was set as the significance level for the multiple ANOVAs, both of the p-value (p>0.05) could be interpreted as no presumption against the null hypotheses (i.e. no differences between the data of the two groups). In other words, the probability of assuming that the null hypothesis is true was around 41% and 68% for the Raw Score and Creativity Index respectively.

Since each TTCT’s activity was scored differently, the comparisons of the Raw Scores between activities did not make sense. Nevertheless, the Raw Score summarized per creativity ability showed that the Originality was mostly affected in the case of timed version, and minor differences happened on the scores of the Abstractness of titles and the Elaboration (see Figure 4). Furthermore, when considering four creative abilities (Originality, Abstractness of titles, Elaboration and Resistance to premature closure) at the same time, the most significant difference between the results of the two groups was found in this study. Quality score was called for the total Raw Score of the four abilities (see Figure 5). That meant, the participants in the regular group produced pictures and titles with slightly better quality. It also could be seen that the quality score of the timed group was more discrete than the one of the regular group. Although the difference between the quality scores of the two groups was the most distinct difference (p=0.1050) that I could found among the analyzed data, it could not be called “significant” since p>0.05 still. To be specific, this result indicated a one in ten chance of assuming no difference between the quality scores of the two groups. Although the result failed to show significant differences between the outcomes of the two groups, I cannot ignore the fact that the load on working memory still affected the outcomes in a lesser extent. One of my assumption was that that the study did have limitations on
the small sample size might lead to hinder a greater extent of the differences.

Meanwhile, the quantity of qualified pictures produced by the participants was nearly not influenced by the load of visual working memory. This result may suggest that an interference of working memory did not significantly influence the participants’ ideation ability. The Fluency scores were only given to the pictures of Activity 2 and 3, where several small pictures were drawn by the participants in ten minutes respectively, not as in Activity 1, where only one full-view picture was drawn in the whole ten minutes. It could be inferred that the time spent on each picture in Activity 2 and 3 was less. I assumed the Trace Fade-out setting for this reason did not affect much on the ideation process of each pictured drawn by the participants.

The results that the differences between the two groups varied among the five subscales also reflected the way of construction of the TTCT scores. Torrance and his associates deliberately tried to use activities that are models of the creative thinking process, each involving different kinds of thinking and each contributing something unique. By integrating the data into analysis and comparison, an overall creative ability of the participant therefore can be illustrated.

Besides the limitation of the small sample size, another limitation was the individual differences on drawing skills, previous experience of using stylus, etc., among the participants. I had hypothesized the difference between the two groups would be significant, but actually, the results of the timed group were surprisingly better than my expectation (see Figure 6 as an example).

Figure 6. A drawing result in Activity 2, by one participant of the timed group.
On the other hand, the feedback from the participants themselves could be regarded as qualitative data. For the time group, the result of the post-test questionnaire indicated that, the participants felt strongly that they were affected by Trace Fade-out setting while drawing (see Table 2, Question 5, median=5). At the same time, they also agreed that their drawings would be better without Trace Fade-out setting (Question 7, median=5). It could be easily understood that the participants would have these feelings because it was so abnormal that what they had drawn disappeared while drawing. The Trace Fade-out setting made the sketching process quite unusual than a common use of pen and paper. So feedbacks like mentioned above were basically predictable.

However, why did the participants strongly think they were affected but the scores said no? This phenomenon might be explained by some participants’ comments. In the free-talk interview phases, two participants of the timed group mentioned to me that they were rather affected by Trace Fade-out setting when they were drawing on the screen, but it did not affect them when they were thinking what to draw. And they said they were able to draw what they supposed to draw. This also might be a good explanation of why the Fluency scores obtained by the two groups were no difference. Meanwhile, two participants mentioned that, during the activities, they were learning to remember what they had drawn but disappeared on the screen. This also can be seen in the post-test questionnaire (Question 6, median=4). In addition, one participant explained that she could add more ideas and enrich her drawings without Trace Fade-out. With it, she could only draw what she had envisioned in mind before starting to draw.

Even though the vast majority of the participants in the timed group expressed their ideas clearly on the screen, the quality scores still varied from the one of the regular group. A componential theory of organizational creativity (Amabile, 1995) (Amabile & Gryskiewicz, 1989) proposed five stages. Two of the stages were response generation (conceiving of what to do) and response execution (doing it). I considered either of the stages affected, one’s creativity could be regarded as affected. According to what presented above, visual working memory was inferred to affect both the generation stage and the execution stage of creativity to a lesser extent.

Besides, some unexpected situations appeared on the participants of the timed group. In Activity 1, three
participants were drawing continuously for a series of different pictures in one page, even though they were informed to draw only one picture on that page. Overlapped pictures were shown eventually after image processing (see Figure 7). I took effort to figure out different panels of pictures in chronological order (see Figure 8). For the scoring, credits were given to each decipherable picture which was also relevant to the titles they made. But in fact, as Activity 1 was only scored for Originality, Abstractness of Titles and Elaboration, the scores obtained under this situation were nearly no differences comparing with the ones obtained by those who drew a single picture as required.

This phenomenon was a consequence of Trace Fade-out setting, but I judged it to be actually equivalent to using an eraser. Since no eraser function was provided in the software, the participants were expected to anticipate their errors or work with the consequences of drawing errors, and had to incorporate errors into their drawings. However, in the case of the timed group, Trace Fade-out setting was just similar as an automatic eraser. It gave participants the chance to add more ideas, but it by no means affect their scores in the end.

Figure 7. An example of the overlapped pictures produced in Activity 1.
Figure 8. Different pictures were extracted from Figure 7, in produced sequence. The title for this was “A boy is walking his dog in a beautiful park”.
7. Conclusion

This study investigated the effects of Trace Fade-out on the performance in the computerized TTCT drawing task using stylus. A 15-second Trace Fade-out setting was regarded as a load on visual working memory. The research question is reviewed:

*To what extent does a load on visual working memory affect one’s creativity in drawing tasks?*

The result showed that the Raw Scores and Creativity Indexes with the load were not significantly different from those without the load, while the quality scores (the sum score of the Raw Scores of Originality, Abstractness of titles, Elaboration and Resistance to premature closure) had relatively significant differences between the two versions of the test.

Therefore, a conclusion that a load on visual working memory had no significant effect on one’s creativity in drawing tasks could be reached. But still, it affected the quality of creative activities to a lesser extent. The results could infer that creative drawing activities can be performed well even with an interference of working memory. Although people might have the thought of being affected when performing, the results could turn out to be basically unaffected.
8. Future Work

In consideration of the limitations of this study, a larger numbers of participants can be tested in future studies. As no differences between the overall scores of outcomes of the two groups were found in the presented results, a larger sample size might powerfully verify this finding again, but it might happen as well that the p-values decrease. On the other side, as the p-value of the quality scores in this study reached 0.1050, a bigger difference might be found with a larger sample size which will indicate a significant difference between the quality scores, or especially the Originality scores.

Furthermore, to estimate the effect of participants’ individual differences (e.g. drawing skills, previous experience of using stylus for drawing), some methods can be added. For instance, a pilot test using a part of Form A of the TTCT (which will not be used in the main study) can be done and the results will be scored, then the participants could be distributed relatively fairly into two groups based on their scores; the individual differences between the two groups could be therefore balanced.

Experiments on whether and how participants getting used with the interference factor during the tests, would also be interesting to conduct. Quantitative studies can be done with different period of Trace Fade-out setting (e.g. 5 seconds, 10 seconds, and 20 seconds) among more than two groups of participants. Loads on visual working memory other than Trace Fade-out setting can be designed for further analysis.
Appendices

A: Consent Form

This study is conducted by Qi Han under supervision of Stanislaw Zabramski at Uppsala University. The study is conducted for a master thesis project.

- Participation in this study is voluntary.
- Participants may immediately raise any concerns or areas of discomfort during the session.
- The process of the study will be video recorded. Handwritten notes of participants will be taken.
- All personal information will be treated with confidentiality and discretion.
- All recordings will be erased after the study is completed.
- Summary data may be used in publication for educational/research purposes.

Please sign below to indicate that you have read and you understand the information on this form and that any questions you might have about the study have been answered.

__________________________________________
Signature and Printed Name

_________________________________________
Date
B: Pre-test Questionnaire

Age? ___________  Gender: □ Female □ Male

Circle a number that best describes you.

1. My painting skill is…
   1  2  3  4  5
   ---
   Very limited  Very good

2. I use a computer/tablet…
   1  2  3  4  5
   ---
   Very barely  Very often

3. My previous experience of using a stylus is...
   1  2  3  4  5
   Very limited  Very rich

4. My previous experience of drawing by computer/tablet is
   1  2  3  4  5
   Very limited  Very rich
C: Post-test Questionnaire (for the Timed Group)

Do you have any previous knowledge about TTCT (Torrance Tests of Creative Thinking)?
☐ Yes, I know it well  ☐ Yes, I’ve heard about it
☐ Maybe/Not sure  ☐ No

Circle a number to indicate to what extent you agree or disagree with the statements below.

1- Strongly disagree
2- Disagree
3- Neutral
4- Agree
5- Strongly agree

1. It was easy for me to explore many different ideas, options, designs, or outcomes.
   ------ 1 ------ 2 ------ 3 ------ 4 ------ 5 ------

2. I focused my attention on the activity and I neglected the system/tool I was using.
   ------ 1 ------ 2 ------ 3 ------ 4 ------ 5 ------

3. I was very engaged in this activity.
   ------ 1 ------ 2 ------ 3 ------ 4 ------ 5 ------

4. I enjoyed this activity and would do it again
   ------ 1 ------ 2 ------ 3 ------ 4 ------ 5 ------

5. The trace fade-out affected me while I was drawing.
   ------ 1 ------ 2 ------ 3 ------ 4 ------ 5 ------

6. During the test, I was getting used to drawing with the trace fade-out.
   ------ 1 ------ 2 ------ 3 ------ 4 ------ 5 ------

7. Without the trace fade-out, my drawing would be much better.
   ------ 1 ------ 2 ------ 3 ------ 4 ------ 5 ------
D: Post-test Questionnaire (for the Regular Group)

Do you have any previous knowledge about TTCT (Torrance Tests of Creative Thinking)?
□ Yes, I know it well □ Yes, I’ve heard about it
□ Maybe/Not sure □ No

Circle a number to indicate to what extent you agree or disagree with the statements below.

1- Strongly disagree
2- Disagree
3- Neutral
4- Agree
5- Strongly agree

1. It was easy for me to explore many different ideas, options, designs, or outcomes.

2. I focused my attention on the activity and I neglected the system/tool I was using.

3. I was very engaged in this activity.

4. I enjoyed this activity and would do it again
E: Test Plan

1. Test Conditions

1.1 Environment

The test will be launched at the usability test laboratory in Ekonomikum, Uppsala University. The lab consists of one testing room and a control room separated from the testing room by a one-way mirror. A laptop will be used by the participants for conducting the test, and an additional PC located in the control room will be used for monitoring and recording the participants’ progress during the test session with the software Morae Observer and Morae Recorder.

1.2 Hardware

The participants will use a HP TouchSmart tm2 laptop with a 12.1-inch, 1280x800-pixel touchscreen and a stylus. The participants are expected to use the stylus to draw on the screen and also for common controls (e.g. go to the next page).

1.3 Software

The laptop runs Microsoft Windows 7 (Intel Core 2 Duo, 4GB of RAM). The test program will run in the computer. All the user’s actions, system events, computer’s screen view will be recorded with TechSmith Morae. The whole test progress will also be recorded by an external video camera focusing on the participants.

2. Participants

The test will be conducted on 20 participants, who are randomly collected volunteers in Uppsala University. They are supposed to be aged between 18 and 30. They should not have any previous knowledge of the TTCT experiment. They should be acquainted using a computer. Having experience of drawing software is preferred. The participants will be tested one by one and they will be rewarded with some snacks.

3. Method

The test evolves from the non-verbal tasks of the TTCT with some changes. The original test asked participants to draw on paper using pens, while my test will change to run a Flash program in computer and it will be launched
at a usability test lab. Besides, as I want to study the influence of working memory on one’s creativity in drawing, I decide to embed the following idea into the test: *Trace Disappearance* - what participants have drawn will only display for 15 seconds, then it will begin to disappear in the screen as time goes on. That is, the drawing trace will disappear along with the participants drawing. For instance, what they draw at the *starting point* (00:00,00) (the point that the stylus touch the drawing area on the screen for the first time on each page) will disappear by the tenth second (00:00,10), and what is drawn at the first second (00:00,01) will disappear in the eleventh second (00:00,11). So that the participants have to remember what they have drawn, otherwise they might repeat their drawing or lose their idea.

The test is a controlled experiment. The participants will be randomly assigned into two groups – an experimental group and a control group. Each group will contain 5 males and 5 females. The tests for the both groups are designed to be the same other than the single variable – “trace disappearance”.

**The Experimental Group** – the test for this group is a TTCT embedded the trace disappearance variable.

**The Controlled Group** - the test for this group is a regular TTCT without trace disappearance. Participants can see what they draw all the time during the test.

4. **Procedure**

4.1 **Introduction**

The participant will be greeted and asked to have seat by the desk in the centre of the room (not the one which they will perform the test). I will begin with the following words extracted from the original Directions Manual (Torrance, 1990) with minor changes:

“I believe you will have a lot of fun doing these activities. We are going to do some things that give you a chance to see how good you are at thinking up new ideas and solving problems. They will call for all of the imagination and thinking ability you have. And I hope you will enjoy yourself.”

Then I will ask the participant to read through the consent form and sign it. After this, I will inform the participant about the whole procedure - one pre-test questionnaire, a warm-up, three activities, one post-test questionnaire.
4.2 Pre-test Questionnaire
The pre-test questionnaire will be answered by the participant and will consist of a limited number of questions regarding earlier experience with computers and stylus, drawing experience, etc. This questionnaire will be used to determine the validity of the test and furthermore the possibility to generalize the results.

4.3 Warm-up
In order to avoid the unfamiliarity of both the hardware and the software influencing the participant’s drawing performance, especially for those who is a first-time user of a stylus, the participant will have three minutes for practice. For those in the experimental group, the participant can get to know what will happen with trace disappearance and try to adapt it.

4.4 Test
The instruction of the test will basically follow the original guide of TTCT. If the participant has any questions during the test, he or she can raise hand up and I will come for help, the participants will be asked to complete the three tasks of the TTCT. When they are doing on the tasks, the moderator will leave in order to prevent disturbing. If the participants have any problems during the test they can ask for help.

4.4.1 Activity 1, PICTURE CONSTRUCTION
In this activity, a curved line is given in the page. The participant will be asked to draw a picture based on the given line.
Instructions:
❖ Think of a picture or an object which you can draw with this shape as a part.
❖ Try to think of a picture that no one else will think of.
❖ Keep adding new ideas to your first idea to make it tell as interesting and exciting story.
❖ Make up a name or title for it and write it at the bottom of the page. Make the title as clever and unusual as possible to tell your story.
❖ You will have ten minutes.

4.4.2 Activity 2, PICTURE COMPLETION.
In the second activity, six incomplete figures are shown on the page. The participant will be asked to add lines and sketch some interesting objects or pictures.
Instructions:
❖ Think of some picture or object that no one else will think of.
✧ Try to make it tell as complete and as interesting a story.
✧ Make up an interesting title for each of your drawings and write it at the bottom of each picture.
✧ You will have ten minutes.

### 4.4.3 Activity 3

In the last activity, the participant will see 15 circles and will be asked to add lines to complete the picture.

**Instructions:**
✧ The circles should be the main part of whatever you make.
✧ You can draw inside the circles, outside the circles, or both inside and outside the circles-wherever you want.
✧ Try to think of things that no one else will think of.
✧ Make as many different pictures or objects as you can and put as many ideas as you can in each one.
✧ Make them tell a completed and interesting story.
✧ Add names or titles below the objects.
✧ You have ten minutes.

### 4.5 Post-test Questionnaire

When the participant has completed all the activities, a second questionnaire (see Appendix C and D) will be answered by regarding the feedback of the test and the participant’s perception of their performance. The post-test questionnaire is based on The New Creativity Support Index (Carroll, et al., 2009).
Table 3. The scores obtained by the two group (Timed Group participants 1-8; Regular Group participants 1-8)

| Participants | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|--------------|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Fluency 2    | 6 | 10| 10| 10| 10| 10| 7 | 9 | 5  | 8  | 9  | 10 | 10 | 7  | 10 | 3  | 8  | 10 | 7  | 10 | 3  | 8  | 7  | 3  |
| Fluency 3    | 2 | 4 | 9 | 18| 2  | 5 | 16| 20| 11 | 7  | 12 | 23 | 21 | 3  | 8  | 0  | 7  | 12 | 23 | 14 | 3  | 8  | 0  |
| RS           | 8 | 14| 19| 28| 12 | 15| 23| 29| 19 | 15 | 21 | 33 | 12 | 23 | 10 | 14 | 2  | 8  | 0  | 7  | 12 | 23 | 14 |
| SS           | 69| 94| 107|129|87 |96 |118|132|107|96 |112|139|87 |118|78 |94 | 1  |
| Originality 1| 1 | 1 | 0 | 1 | 0  | 1 | 1 | 0  | 1 | 0  | 1 | 0 | 1  | 0  | 1 | 0  | 1 | 0  | 1 | 0  | 1 | 0  | 1 |
| Originality 2| 4 | 5 | 6 | 9 | 7  | 9 | 2 | 4  | 6 | 7  | 7 | 7 | 9  | 6  | 5 | 6  | 1 | 2 | 3 | 2 | 2 | 3 | 1 |
| Originality bonus 2 | 6 | 0 | 0 | 0 | 0  | 0 | 0 | 0  | 8 | 6  | 0 | 0 | 0  | 0  | 0 | 0  | 0 | 0  | 0 | 0  | 0 | 0  |
| Originality 3 | 1 | 3 | 1 | 4 | 0  | 1 | 8 | 10 | 0 | 1  | 4 | 5 | 3  | 7  | 0 | 3  | 1 | 2 | 3 | 2 | 3 | 1 |
| Originality bonus 3 | 5 | 6 | 8 | 0 | 6  | 3 | 0 | 1  | 9 | 7  | 7 | 7 | 8  | 4  | 0 | 1  | 1 | 2 | 3 | 2 | 3 | 1 |
| RS           | 17| 15| 15 |14 |13 |13 |11 |16 |22 |21 |18 |12 |20 |18 |5  |21 |3  |2  |3  |3  |3  |3  |3  |3  |
| SS           | 106|100|100 |96 |93 |93 |86 |103|118|116|109|89 |114|109|59 |116|
| Abstractness 1| 3 | 0 | 3 | 1 | 0 | 1 | 1 | 0  | 1 | 1  | 2 | 3 | 2  | 2  | 1 | 2  | 1 | 2 | 3 | 2 | 3 | 1 |
| Abstractness 2| 3 | 4 | 8 | 5 | 3  | 4 | 1 | 10 | 2 | 3  | 5 | 6 | 5  | 5  | 1 | 3  | 1 | 2 | 3 | 2 | 3 | 1 |
| RS           | 6 | 4 | 11| 6 | 3  | 5 | 2 | 10 | 3 | 4  | 7 | 9 | 7  | 7  | 1 | 4  | 3 | 1 |
| SS           | 87 |74 |114 |87 |68 |80 |63 |109|68 |74 |93 |104|93 |93 |127|68|
| Elaboration 1| 1 | 2 | 2 | 1 | 0 | 1 | 2 | 1  | 1 | 3  | 2 | 3 | 2  | 2  | 1 | 2  | 1 | 2 | 3 | 2 | 3 | 1 |
| Elaboration 2| 2 | 2 | 3 | 4 | 2 | 1 | 3 | 2  | 1 | 2  | 3 | 4 | 3  | 3 | 3  | 3  | 3 | 3 | 3 | 3 | 3 |
| Elaboration 3| 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1  | 2 | 1  | 1 | 1 | 1  | 1 | 0 | 1  | 1 | 0 | 1 | 1 | 1 | 0 |
| RS           | 4 | 5 | 6 | 7 | 3  | 3 | 6 | 4  | 4 | 6  | 6 | 9 | 6  | 5 | 4 | 3  | 2 | 3 | 2 | 3 | 2 |
| SS           | 72 |84 |96 |106|59 |59 |96 |72  |72 |96 |96 |118|96 |84 |84 |72 |72 |72 |72 |72 |72 |72 |72 |
| Resistance 2 | 9 | 15| 17 |17 |16 |15 |10 |11 |12 |15 |14 |13 |15 |12 |15 |11 |
| SS           | 90 |123|136 |136|129|123 |95 |100|106|123|117|111|123|106|123|100|
| Raw Score    | 44 |53 |68 |72 |47 |51 |52 |70  |60 |61 |66 |76 |60 |65 |49 |53 |
| Bonus        | 10 |8 |18 |12 |8 |10 |13 |14 |13 |10 |12 |11 |8 |13 |6 |10 |
| Average SS   | 84.8|95|110.6|110.8|87.2|90.2|91.6|103.2|94.2|101|105.4|112.2|102.6|102|94.2|90 |
| CI           | 94.8|103|128.6|122.8|95.2|100.2|104.6|117.2|107.2|111|117.4|123.2|110.6|115|100.2|100 |
| Quantity     | 8  |14 |19 |28 |12 |15 |23 |29 |19 |15 |21 |33 |12 |23 |10 |18 |
| Quality      | 36 |39 |49 |44 |35 |36 |29 |41 |41 |46 |45 |43 |48 |42 |39 |39 |
Table 4. The bonus scores of the Creative Strength obtained by the two group (Timed Group participants 1-8; Regular Group participants 1-8).

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<th>A2</th>
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<th>B2</th>
<th>B3</th>
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<th>B5</th>
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<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
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<td>2</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
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</tr>
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<tr>
<td>Synthesis of circles (Activity 3)</td>
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<td>2</td>
<td>0</td>
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References


