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Ai Shinohara
Lindenwood University

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Ai Shinohara[11]

Technology has had a great impact on education today. Computer skills are necessary in order to complete many school assignments, and typing on the computer has become a main writing method for younger generations (Burnhart & Goldinger, 2010). Many college students bring their computers in the classroom, and more and more students have started to take notes by typing on their computer instead of handwriting their notes. The question to this convenient society is whether the new writing method, typing, affects students' memory abilities in a classroom situation. The current study was conducted to determine if handwriting or typing was the better method of writing in order to memorize unfamiliar English words. Twenty-eight students were recruited from the Lindenwood Participant Pool (the LPP) for this study. The participants were asked to complete two sets of conditions; one to remember and type five unfamiliar words (meaning words that you may not encounter very often), to solve the Sudoku puzzle, and then to recall the words which they learned earlier; another condition to write down five different English words on the piece of the paper instead of typing. The paired sample t-test was used to examine the mean score of the test difference between the handwriting and the typing condition. The findings show that there was no significant difference between handwriting and typing for remembering the new words.

The human brain is highly developed compared to other animals, and it allows us to do many complicated tasks such as speaking, writing, thinking and making decisions. However, human memory is limited. Because people cannot remember all information surrounding them, they select what they need to remember and what they have to forget. According to the Atkinson and Schiffrin model, there are three types of memory: sensory memory, short-term memory, and long-term memory (as cited in Scott, 2009). Sensory memory is the first stage of memory storage in which all information is stored for less than one second. People receive new information through their senses, and the information goes into sensory memory, but if people do not pay attention to it, it quickly disappears. However, if people decide to pay attention to particular

[11] Ai Shinohara, Department of Psychology, Lindenwood University.
This research was supported by the Lindenwood Participant Pool.
Correspondence concerning this article should be addressed to Ai Shinohara, AS502@lionmail.lindenwood.edu.

information, the information will be placed into the Short-term memory where the selected information is held and remembered for 15-30 seconds. If people want to hold the information for a long period of time, that is, store the information into the Long-term memory, rehearsal is needed (Atkinson & Schiffrin, as cited in Scott, 2009).

Semantic memory, one type of the Long-term memory, refers to the information people learn and acquire as knowledge (Atkinson & Schiffrin, as cited in Scott, 2009). Thus, information which is learned in the classroom is considered semantic memory if the information enters a learner's Long-term memory. In addition to requiring repetitive activities, such as writing information down again and again, one of the best ways to hold semantic memory in long-term memory is elaborative rehearsal. Elaborative rehearsal is a technique in which people make a connection between the new information and their own knowledge (Atkinson & Schiffrin, as cited in Scott, 2009). For example, when people learn a new word, it is better for them to learn the definition of the word and know an example of how to use the word in a sentence, rather than to remember only the word itself.

The traditional rehearsal method for word recollection is writing it down on a piece of paper or notebook again and again. Today, however, typing on the computer has become a main writing method for younger generations (Burnhart & Goldinger, 2010). Many students, including younger children, have easy access to computer products. Schools also rely on computers to teach students fast typing skills, and this reduces the time in which students are actually involved in handwriting (Burnhart & Goldinger, 2010). The question for this convenience in society then becomes weather the difference in writing methods affects memory ability in a classroom situation.

According to Cunningham and Stanovich (1990), the difference in words produced between handwriting and typing is that handwriting is a type of graphomotorical activity while typing is not. When people write words down by hand, they have to produce shapes of each letter of the word. Although it takes time to write a letter by hand, people who prefer to handwriting access to kinesthetic movements while producing the letters, and their hands remember the shape of the letters. However, typing basically is void of graphomotorical activities as the letters are already present on the keyboard. Thus, when people try to memorize a new word, typing would be more difficult to recall it because people cannot access to their kinesthetic abilities during the rehearsal phase.

Longcamp et al. (2008) found that the brain activities were different when people wrote with their hand and when they typed on the screen. In his experiment, functional magnetic resonance imaging, fMRI, showed that the Broca's area, which is a particular brain area in the left frontal lobe for language production, was more active when the participants wrote down letters on the piece of paper, than when people typed the letters on the a computer. Thus, it could be concluded that the connection between handwriting and the Broca's area might play an important role in word recollection.

The idea of the motor-perceptual interactions also explains why handwriting affects memory ability as well. The motor-perceptual interaction is an idea that the combination of body movement and perceptions are highly efficient at recalling the particular object or a target item (Longcamp, Zerbato-Poudou, & Velay, 2005). Handwriting involves complicated motor-perceptual interaction as people move their hands, wrists, and arms, while perceiving visual stimuli. On the other hand, typing also involves moving people's fingers, but they cannot look at the screen and the keyboard at the same time. Therefore, from this perspective, because typing

does not involve motor-perceptual interaction, handwriting would be better to recall information than typing.

The present experiment was conducted to determine if handwriting or typing is a better method of writing in order to memorize unfamiliar English words. Based on the study of cognitive activities and neural activity in the brain, the hypothesis of this experiment was that people would be able to recall more words accurately when they write down the words than when typing the words.

Method

Participants

The Lindenwood Participant Pool (LPP) was used to obtain the participants for the study. The LPP is considered a convenience sampling technique, and it is an ethical way of recruiting participants at Lindenwood University. Students, who registered for at least one of the classes which were selected by LPP with an agreement with the professors during the spring semester of 2013, voluntarily signed up on the recruiting time sheets on the LPP bulletin board. Twenty-eight undergraduate students at Lindenwood University, 12 men, 16 women (mean age= 19.5), received extra course credits as compensation for their participation in the study.

The breakdown of participants' year of school showed that 12 freshmen, 6 sophomores, 9 juniors, and 2 seniors participated in the study. Eighteen students spoke English as their first language, and other students spoke different languages, including in Spanish and French, as their first languages.

Materials

The basic materials, such as informed consent forms, the debriefing statement, and the extra credit slip were provided to all participants who came in to take the experiment. Ten

English words, which were considered important for those students who plan to pursue graduate-level education, were randomly selected from http://www.grevocabulary.org/gre-word-list-1.html. Two sets of word learning packets were created, each with five sheets. One learning work packet was for the typing condition, so that the packet was created in the excel sheets. Each sheet had a word, its definition, and the example of how to use the word in the sentence. There were six blank boxes to ask participants to type the word, definition, the example once, and type only the word three times. Another word learning packet was for the handwriting condition, so that participants were given five word sheets (see Appendix A for an example of word learning packets). Corresponding to the word learning packets, two sets of word tests, word test 1 and 2, were created through a Microsoft PowerPoint slideshow (see Appendix B for examples of word tests). The word definitions and sentence examples appeared on the screen one at a time, and the participants were asked to identify the proper word and spell it out verbally. Their responses were recorded on the answer sheet (see Appendix C). The participant's responses were scored using two different scoring systems. The spelling score was when participants were able to recall spellings of the word correctly and matched the correct definitions of the word. Another score was if the participants remembered the word which matched the definition of the word, but they could not recall the spelling correctly. Both scores were out of 5.

In order to have a 1 min and 30s, interval time between the learning phase and the testing phase, two sets of Sudoku puzzles (from http://www.sudokukingdom.com/very-easy-sudoku.php) were given to the participants (see Appendix D). Sudoku is a logic puzzle consisting of a 9x9 grid, subdivided into nine smaller grids. Each smaller grid contains nine cells, and the objective of the puzzle is to fill each cell with an individual digit (from 1-9) so that each column row and smaller grid contain all of the numbers from 1-9.

A demographic survey consisted of five questions to gain the participants' general information (see Appendix E). Those questions on the demographic survey were participants' age, gender, year of college, first language, and if the participants were familiar with any of the words which appeared in the experiment. The participants were informed that they did not have to answer any questions if they did not want to answer.

Also, participants were able to read the instructions for each task through a Microsoft PowerPoint slideshows in addition to explaining the instructions verbally by the experimenter (see Appendix F).

Procedures

Students from LPP voluntarily signed up for the experiment on the LPP bulletin board. There was an experiment description form and the sign-up sheet on the board, so that students were able to read the description and briefly understand the process of the study. The study was conducted at Lindenwood University in one of the psychology labs where there was a computer (Young Hall 105), and the participants were tested individually. Once they arrived at the appointed time, they were asked to read and sign the informed consent form if they agreed to partake in the experiment.

After the participants signed the informed consent form, they were given a word learning packet for handwriting and asked to remember 5 words, the definitions, and the examples of the words for 20 s. After 20s., they were asked to write down each word, definition, and sentence example once and to write down only the word three more times on the work sheet. They were then asked to try to solve a Sudoku puzzle for 1 min and 30s., as an interval period between the learning phase and the testing phase. After the Sudoku task, they were tested to recall the words which they learned earlier in the experiment. When they saw the definition of the word, they

were asked to speak aloud the spelling of the word. They saw the definition of the word on a piece of the paper one at a time. The experimenter wrote down the spellings participants said aloud.

The participants then were asked to remember another 5 words and the definition of the words from the leaning work packet for typing on the computer screen. This time, they were asked to type each word, definition, and sentence example once and type only the word three more times on the computer screen. Then they tried to solve Sudoku puzzle for1 min and 30s. Three minutes after they tried the Sudoku puzzle, they were tested to recall the words which they learned in the second trial. Once again they saw the definition of the word, and they were asked to speak aloud the spelling of the word. They saw the definitions of the words on the screen one at a time. The experimenter wrote down the spellings that the participants said aloud.

Because it was a within-participant design, the order of the two conditions: handwriting and typing was counterbalanced as well as the 5 words associated with each condition. Thus, 15 participants started with typing task with word learning packet 1 and word test 1, and 13 participants started the handwriting task with word learning packet 2 and word test 2.

After both tasks were completed, the participants were asked to take a demographic survey. At the completion of the session, the participants were told about the purpose of the study, were given the feedback letter, and were given the participant receipt in order to get their course credits through the LPP office.

Results

The research question of this experiment was how writing methods, either handwriting or typing, affected an individual's memory ability. From the last question in the demographic survey in which the participants were asked if they already knew any words before the

experiment or not, 25% of the participants knew a word "zenith" from word test 1, and 54% of them knew a word "exonerate" from word test 2. These two words from test 1 and test 2 were excluded the data analysis to keep the amount of the participants for this study. Thus, the score was ended up out of 4 points for each test. Moreover, to prevent skewed data in the result, people who were able to identify at least one of the words except "zenith" and "exonerate" on the word learning packets before taking the experiment were excluded the data analysis. To compare the mean scores of word tests (spelling accuracy and word retention) between the handwriting condition and the typing condition, the paired sample t-test was used. The mean scores of the spelling accuracy of the handwriting condition and the typing condition were 1.57 (SD= .28), and 1.8 (SD=.25), respectively. The mean scores of the word retention of hand writing and typing were 1.71 (SD=1.27), and 1.90 (SD=1.09), respectively. The results show that there are no significant difference between handwriting and typing, $t(20)=-.631$, $p>.05$ (spelling accuracy), and $t(20)=-.525$, $p>.05$ (word retention). They also suggest that there are no score differences between spelling accuracy and word retention.

Discussion

The prediction of the experiment was that handwriting would be better to recall the words than typing, which would be interpreted that handwriting would be easier to access to Long-term Memory than typing. However, the results show that there is no significant score difference between handwriting and typing. The procedures were thoroughly followed the concept of the memory; the elaborative rehearsal was used to maximize the participants' memory ability. Before the participants started to practice the words, they had 20s., to understand the meaning of the word and how to used the word by reading the example. Even though the elaborative method was used for rehearsal, the mean scores of the word tests of both handwriting and typing were

very low. Thus, it would be said that memory ability for word recalling is not affected by writing methods. However, there are some possible explanations why the results did not support the hypothesis.

One of the biggest problems of this study was that the number of the participants was relatively small. A Total of 28 participants were recruited of this study, and 7 were excluded from data analysis due to having knowledge of at least one of the words on the learning phases. In order to get an accurate result, at least 30 sets of data were needed. Because of the small amount of the data collection, the possibility of getting the Type-II error increased. Thus, using unfamiliar English words was not good idea because some data were discarded and thus, only 21 sets of data were used for the analysis. Moreover, not many people signed up for the study because it took 30 min to complete the experiment due to the within-participant design. Other studies from the LPP were mostly 10 -15 min experiments, so the students might avoid signing up for the longer studies. The within-participant design is more powerful than the between-participant design because it reduces the individual differences of each condition. However, it takes longer to complete the session because the participants have two conditions to complete.

Another possible explanation is that this procedure of the experiment did not reflect the class room situation for college students. Although word retention and spellings of the word are very important for children, understanding the information quickly in the class is more important for college students. Thus, if the participants were college students, the research questions should have been how writing methods, either handwriting or typing in class, influence the understanding of the materials.

In order to gain the participants more effectively and meet the need of the college students, the procedures and materials should be revised for future study. Instead of

remembering words, it would be better to recall the contents of the materials after the participants engage in either typing a short paragraph on the computer screen or writing the passage on a piece of paper. Thus, individual differences in initial knowledge base would not factor in if the passage itself is unfamiliar to the participants. Also, recalling of the content of a passage is more analogous to the classroom setting for college students, so it would be better to use this new idea to examine if writing methods, either writing down on the notebooks or typing on the computer during the lecture, affect their test scores. Although the between-participant design has some problems, such as individual differences, using this design would be better to get more participants from the LPP.

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Appendix A

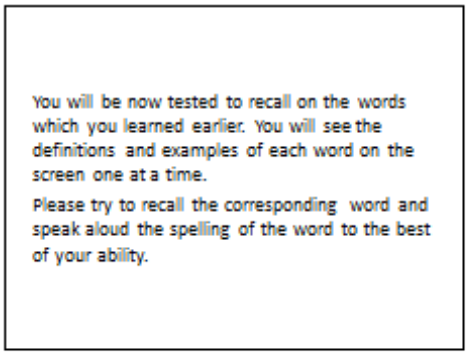
Word Leaning Packet

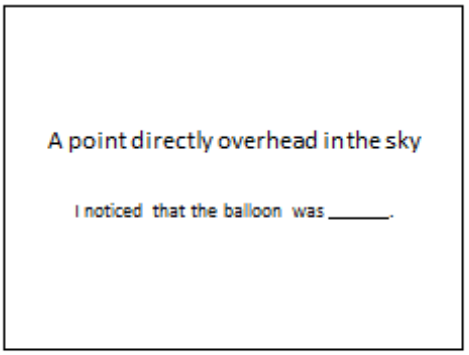
Word	**Lexicon**
Definition	A dictionary
Example	I used the lexicon to discover definitions of terms I did not know.
Word	
Definition	
Example	
Practice 1	
Practice 2	
Practice 3	

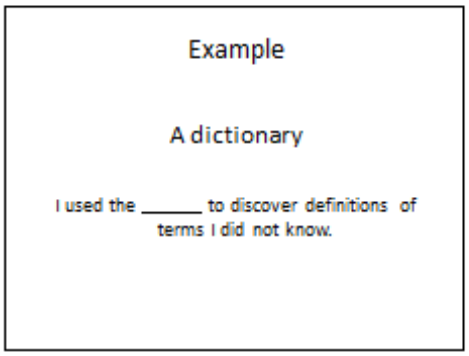
	A	B
1		
2	Word	**Lexicon**
3	Definition	A dictionary
4	Example	I used the lexicon to discover definitions of terms I did not know.
5		
6	Word	lexicon
7	Definition	A dictionary
8	Example	I used the lexicon to discover definitions of terms I did not know.
9	Practice 1	lexicon
10	Practice 2	lexicon
11	Practice 3	lexicon

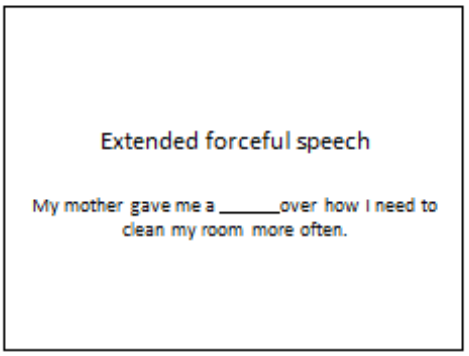
Appendix B

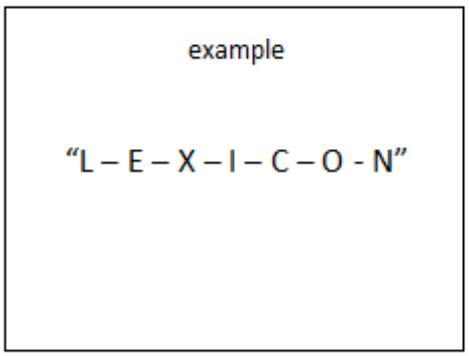
Word Test

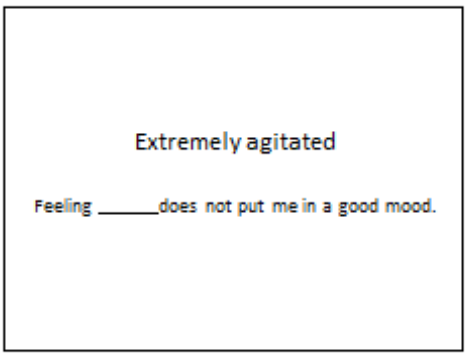












Appendix C

Answer Sheet

Answer sheet (1) Subject No: _____

Points (Spells) _____ Points (Word similarity) _____

1. Answer: Z e n i t h

   Response:
2. Answer: T i r a d e

   Response:
3. Answer: O v e r w r o u g h t

   Response:
4. Answer: S a t o r i

   Response:
5. Answer: O b d u r a c y

Appendix D

Sudoku Puzzle 1 &2

		4		2	1	6	5	
	9				6	1	7	4
1	6	8	5	4				
8			1		4		6	9
	5	6	7			4		1
4		9		6	2		3	
6	8	1	2				4	7
3				1			9	2
	2		4	7	3	8		

		7	2		9	8		1
		6	4			2	9	5
5	9	2	8		6			
	7	5		3		9		2
9	6			4			1	8
		8	1	9	5		7	
2	5			6			8	
6	8			2	4	7		
7			5		1	6	2	9

Appendix E

Demographic Survey

1) Are you MALE FEMALE?

2) How old are you? ( )

3) Are you Freshman Sophomore Junior Senior Other

4) What is your first language? ( )

5) Which writing style do you prefer?

Handwriting Typing

6) Are there any words which you already knew before the experiment? YES NO
Please circle:

Word	definition
Overwrought	Extremely agitated
Tirade	Extended forceful speech
Zenith	A point directly overhead in the sky
Obduracy	Stubborn persistence
Satori	The state in which a person suddenly acquires enlightenment.
Abeyance	Temporary suppression or suspension
Nostrum	A quack medicine or remedy; an untested cure
Pejorative	Negative in connotation; Having a belittling effect
Exonerate	Absolve from blame
Augury	Event seen as a sign of thing to come

Appendix E

Instruction (Writing first)