



**Trinity College Dublin**  
Coláiste na Tríonóide, Baile Átha Cliath  
The University of Dublin

## Title:

Is handwriting or typewriting the better writing method for secondary level students to develop the skills of writing exposition along with memory? Or could both methods have a similar process in our brain as they are the same in our learning?

**Nga Sin, TSE**

A research paper submitted to the University of Dublin, in partial fulfilment of the requirements for the degree of  
Master of Science Interactive Digital Media

The year of submission: 2021

## Declaration

I have read and I understand the plagiarism provisions in the General Regulations of the University Calendar for the current year, found at: <http://www.tcd.ie/calendar>

I have also completed the Online Tutorial on avoiding plagiarism 'Ready, Steady, Write', located at <http://tcd-ie.libguides.com/plagiarism/ready-steady-write>


I declare that the work described in this research Paper is, except where otherwise stated, entirely my own work and has not been submitted as an exercise for a degree at this or any other university.

Signed: \_\_\_\_\_  
Nga Sin, TSE

Date: 04/06/2021

## Permission to lend and/or copy

I agree that Trinity College Library may lend or copy this research Paper upon request.

Signed: 

Nga Sin, TSE

Date: 04/06/2021

## **Acknowledgments**

I would like to thank my supervisor, Glenn Strong, for his support and guidance throughout the entire process. I am very grateful for his advice and feedback that allowed me to successfully complete this research paper consistently.

I would like to thank my friend, Victoria Horrobin, for her support, the time and the effort she put into proofreading this paper.

I would like to thank my best friend in life for his patience and support.

Finally, I wish to express my gratitude to my whole family for their understanding and for always being there for me.

Nga Sin, TSE

MSc in Interactive Digital Media 2020 – 2021

CS7044 RESEARCH PAPER

Title:

Is handwriting or typewriting the better writing method for secondary level students to develop the skills of writing exposition along with memory? Or could both methods have a similar process in our brain as they are the same in our learning?

Supervisor: Glenn Strong

Year: 2020 – 2021

Abstract:

This paper aims to guide people to study how both writing methods, handwriting and typewriting, assist our learning in academic writing by affecting our memory systems. Also, it can guide people to find out if there is a writing method that can override the other. This paper will introduce us to academic writing, handwriting, word processing, cognition, memory systems and the relations between them. After that, this paper will compare both writing methods, handwriting and typewriting, to give evidence by two hypotheses to prove that these two methods function the same in the brain, but the priming effect and number of rehearsals cause differences. The hypotheses are: (1) The first learned method of writing is the most useful mode for the author; (2) The more time involved in an automated movement, the more repeated rehearsal process will occur. After that, this paper can then prove that word processing can assist student learning.

## 1 Table of Contents

<b>1. Introduction .....</b>	<b>7</b>
<b>2. The writing methods .....</b>	<b>7</b>
<b>2.1 Definition of Handwriting.....</b>	<b>8</b>
<b>2.2 Definition of Typewriting.....</b>	<b>8</b>
<b>2.3 Definition of Word Processing .....</b>	<b>8</b>
<b>2.4 Conclusion .....</b>	<b>9</b>
<b>3. Definition of Academic Writing.....</b>	<b>10</b>
<b>3.1 The overview of writing .....</b>	<b>10</b>
<b>3.2 Academic Writing in Secondary level education .....</b>	<b>11</b>
<b>3.3 Academic Writing in tertiary level education.....</b>	<b>11</b>
<b>3.4 The Four characteristics of Academic writing .....</b>	<b>11</b>
<b>3.5 The purposes and development of academic writing in different stages .....</b>	<b>12</b>
<b>3.6 The Difficulties of Students in writing academic expositions.....</b>	<b>12</b>
<b>3.7 Conclusion .....</b>	<b>13</b>
<b>4. The Definition of Cognition .....</b>	<b>13</b>
<b>4.1 The Definition of Cognition .....</b>	<b>13</b>
<b>4.2 Piaget’s theory .....</b>	<b>14</b>
<b>4.3 The information processing approaches.....</b>	<b>14</b>
<b>4.4 The contemporary scientific approaches to study cognitive processes.....</b>	<b>15</b>
<b>4.5 The scientific process of cognition and the related measurement methods.....</b>	<b>15</b>
<b>4.6 Conclusion .....</b>	<b>15</b>
<b>5. The Definition of Memory.....</b>	<b>16</b>
<b>5.1 Sensory Memory.....</b>	<b>16</b>
<b>5.2 Working / Short-term Memory.....</b>	<b>16</b>
5.2.1 Short-term memory capacity.....	17
5.2.2 The Factors of the finding.....	17
5.2.3 Short-term memory duration.....	18
5.2.4 Supplement of the short-term memory with the term Working memory .....	18
5.2.5 Conclusion for short-term memory.....	19
<b>5.3 Long-term Memory .....</b>	<b>20</b>
5.3.1 Declarative Memory .....	20
5.3.2 Non-declarative memory .....	21
5.3.3 Forgetting curve and the interference effects.....	22
5.3.4 Consolidation and Reconsolidation .....	22
5.3.5 Conclusion for Long-term Memory.....	23
<b>5.4 Memory Section Summary and the link to Writing .....</b>	<b>23</b>
<b>6. Memory in Writing .....</b>	<b>23</b>
<b>6.1 Greater Capacity, Greater Writing Quality .....</b>	<b>24</b>

6.2	Limited Capacity, inefficient processing would take up some space.....	25
6.3	A skilled writer can activate the brain better .....	26
6.4	Conclusion .....	26
7.	<i>The hypothesises</i> .....	27
7.1	The method of writing that is first learned is the most useful one .....	27
7.2	The more time involved in a movement, the more repeated rehearsal circles occur..	29
8.	<i>The Summary</i> .....	30

## **1. Introduction**

Nowadays, people prefer to write through word processors instead of writing by hand. In today's society, technology has become a necessity for us. Smartphones have replaced a lot of paperwork in our lives, for example, we prefer to type our grocery list on a phone, rather than write it down on paper. Students now have access to typewriting beginning in primary school or even earlier, while a lot of school work needs to be submitted through online platforms in PDF or Word format. Under these circumstances, the number of concerns that word processing may replace handwriting increases among us. This paper aims to study how both writing methods, handwriting and typewriting, assist our learning in academic writing by affecting our long term and short-term memory. This paper aims to guide us to find out if there is a writing method that can override the other to assist students to learn and study. In other words, to discover whether we should prioritize one over the others. This paper starts with a definition of handwriting and typewriting. Then, we will learn the definition of academic writing, which this paper focuses on. This paper will introduce us to the characteristics of academic writing, the purpose of writing, and the difficulties students are facing when they write. After that, this paper will study human cognition and connect it with the purpose of academic writing. In this cognition part, the definition of cognition, Piaget's theory (Piaget, 1976) and the approaches to studying cognition will be elaborated. One of the cognitive processes, the memory, including sensory memory, short-term memory and long-term memory, will then be addressed. Next, this paper will deliberate the relationship between memory and writing. This section will guide us to find out if there is a writing method that is greater than the other. To find out the answer, this paper will question whether both writing methods expand our working memory capacity, reduce inefficient processing and activate more brain areas. These three questions will lead to two hypotheses of this paper. (1) The first learned method of writing is the most useful mode for the author. (2) The more time involved in an automated movement, the more repeated rehearsal process will occur. This paper would like to explore how word processing assists students in typewriting, with the supports of these hypotheses. While clearly beyond a research paper such as this, as early use of keyboards in schools becomes more common, evidence for or against this proposition is likely to come. This paper can hopefully inspire people to consider their writing preference and therefore find the best way for them to write to learn.

## **2. The writing methods and Word Processing**

The main focus of this paper is to find out if there is a writing method that overrides the other one, therefore, this section is going to provide a clear insight into what these two methods, handwriting and typewriting, are and what are the main focus of each.



## **2.1 Definition of Handwriting**

Handwriting is a cultural writing skill implemented by hand with any writing instrument, for instance, from writing on clay in ancient time to using handwriting input device nowadays. It is a skill that is taught by predecessors and in use in any region with any language, letters or symbols. For example, the cuneiform from Mesopotamia is a type of handwriting. The history of handwriting can be traced back to clay writing in Mesopotamia from 3000 BC. The earliest texts are broadly recognized that they came from Sumer. The history of contemporary handwriting, using metal pens to write in the western world, can be traced through Roman times and beyond (Sassoon, 1999). Also, it is broadly recognized as a complex neuromotor skill that involves cognitive and motor processes synchronously (Hurschler Lichtsteiner et al., 2018). When people are doing handwriting, it will activate their cerebellum to have motor control over the hands while the brainstem and cerebrum are encoding information (Hurschler Lichtsteiner et al., 2018). That means there are two types of learning, motor learning and informatics learning, processing in a person's brain when writing. Learning is a process of how we acquire new knowledge from information. When learning of information has persisted over a period, it becomes a memory. Therefore, handwriting is a complex skill that can strengthen learning, and it needs to be practised.

In this paper, any form of letters, such as cursive or printed letters and symbols written by hand, is classified as handwriting. Calligraphy is a type of writing that writers focus on its outline and appearance rather than the contextual meaning of the letters and words. Therefore, any kind of calligraphy, an art form of handwriting, will not be included.

## **2.2 Definition of Typewriting**

Typewriting is the writing skill in using keyboards, which are “QWERTY” keyboards, or other typewriters to input words to any word processors that can free users from any physical effort of handwriting (Nisbet et al., 1999). It is strongly aligned with the development of word processors. People believe that typewriting involves more implicit learning than explicit learning because people remember the spatial information of the keyboard rather than the representation of letters. Experienced keyboard users often type without looking at the keyboard itself but the screen. The reasoning behind that is they associate letters with the keys' positions of the keyboard as a natural motor memory (Eysenck & Brysbaert, 2018). We will discuss more information about implicit and explicit memory with typewriting in the long-term memory section.

## **2.3 Definition of Word Processing**

Word processing refers to the act of using an electric device or computer to input or output texts. Word processing is a writing method that involves word inputting, planning and editing with an e-platform. It implies cognitive and motor processes synchronously as it requires hand movement,

which is a skill of procedural memory. A specialized software, which is known as a word processor, is fundamental to word processing. We need a medium for a word processor to input letters and words by the users, and it can be a traditional keyboard or a touch-typing keyboard, e-pen, etc. Typewriting is the major way to write to produce words with word processors. We might consider typewriting as the main method for word processing. However, we should also consider digital handwriting as the other methods for word processing. The first digital handwriting device, Stylator, was invented in 1957 which was invented closely with the IBM *Selectric* electric typewriter (Li, 2018). Therefore, this paper will focus on the word processors with the traditional keyboard and a graphic tablet as tools. Word processors allow users to edit, draft and redraft work, print out or share documents with others, without large amounts of work such as rewriting and transcription. This kind of software contains many functions, with the editing and formatting functions being the primary ones. Yet, nowadays, the tool that can only allow editing and creating plain text documents is merely recognized as a text editor rather than a word processor. Humans have been trying to improve life with the invention of tools and technology. We have been working hard on the automation of writing and editing since the end of the Middle Ages when the invention of printing and movable type was created (Kunde, 1986). Word processing has been developing since 1867 from typewriters that had no screen, to a digital typewriter introduced by IBM in the early 1900s (Kunde, 1986), until it reached today's standard. Smith and Jones classified word processors into three levels in the book, "*Computers, Cognition, and Writing Instruction*" (Montague, 1990). First, at the basic level are the programs that allow editing and revision, the functions most word processing software can manipulate. The minimum requirement of a word processor is that it has to be accessible for revision. Then, the second level is that word processors have to aid users to write texts and achieve a proper writing style. For instance, Google Doc aids users with the algorithm to write text when they are typing something. When processing this paper on Google Doc, some predictions, e.g., "word processing", are made if the word "Word" is typed on the body area. The word processor, ProWritingAid, is a tool that assists users to write in a correct tone and style with its database which has over 1000 writing styles. The third level is that they have to accommodate users with functions of generating ideas, organizing content and revising texts. For example, Trello allows users to write in a card system, in which users can rearrange the order of the writing cards. This system is handy for users to generate better ideas during the writing process.

## 2.4 Conclusion

In conclusion, handwriting and typewriting are the most common ways that people apply to produce writing. We implement handwriting with pens and papers, while typing with keyboards. In this paper, the definition of handwriting covers all kinds of writing written by hands with any writing instrument, except for any kind of art form created by hand, such as calligraphy. As for word processing, it involves word inputting with a keyboard or a graphic tablet and implementing electronic devices.

Owston, Murphy and Wideman (1992) had conducted a paper “*The Effects of Word Processing on Students’ Writing Quality and Revision Strategies*” and conveyed that papers written through word processors were rated significantly higher than those just written by hand. However, it would not be fair to directly compare handwriting and word processing together, because handwriting is merely a motor skill when word processing is an entire process involving motor skills and progress with help from technology. Therefore, this paper would like to explore how word processing assists students, with the assumption that typewriting and handwriting contribute in the same way to the quality of writing. Finally, this paper aims to encourage us to properly use word processors.

### **3. Definition of Academic Writing**

As this paper aims to encourage people to make excellent uses of writing methods to improve their writing quality, it is necessary to give people a clear insight into writing. Writing is a broad area that can cover different genres and purposes, thus, this paper will focus on academic writing, specifically writing for secondary level students. This section will define the categories of academic writing in secondary and third-level education, the characteristics of academic writing, the purpose of it in different stages, and the difficulties students are facing when they write.

#### **3.1 The overview of writing**

Writing is a process to produce words and sentences from a draft and an editing piece to a final publication. The entire writing process includes prewriting, drafting, revising, editing and publishing (Lincoln Learning Solutions, 2020). The prewriting stage is the process that allows a writer to consider the purpose and goals for writing, get some ideas and logically connect them. Then the writer can produce words according to the ideas jotted down previously. The revising stage aims to improve the writing quality by checking the organization, word choice, and sentence variety. After that, the writer goes through all the mistakes and corrects them in the editing stage. Finally, writers publish the writing. The process might involve back-and-forth changes to shape and arrange the product. It requires developmental experience and knowledge of writing, therefore, it is cognitively demanding. Writing implies cognitive involvement, which is thinking about some related information of writing that has a specific genre, goal and purpose. According to the paper, “*An Investigation of Academic Writing in Secondary School to Inform the Development of Diagnostic Classroom assessments*” conducted by Lorena, Sarah and Cecilia (2011), cognitive processes can enrich the textual features of academic writing. When students need to make an effective argument, they have to analyse things with their experience and cognition to convey to readers. Also, according to the “*Kinds of knowledge-telling: Modelling early writing development*” (Hayes, 2011), the writing quality highly depends on the writer’s long-term memory because it allows the writer to write according to knowledge.

### **3.2 Academic Writing in Secondary level education**

Academic writing at the secondary level is straightforward when it is compared to university academic writing. According to the book, *“The Language Of Schooling–A functional Linguistics Perspective”* by Schleppegrell (2008), there are three major categories in secondary level education; personal, factual and analytical. The recount and narrative genres are under the personal category. Students write these two genres with their personal experience, perspective and imagination. The factual category involves two genres, which are procedure and report. Both genres are used to describe some information. To be specific, the procedure genre is related to orders and sequence of events, and the report genre is related to a set of facts. In most cases, the personal and factual categories appear more often in the early years of schooling. The last category is the most essential writing type in the secondary level of education because it is the foundation of the 12 types of academic writing in university, as listed below. This category includes three genres, account, explanation and exposition, with exposition being the most influential one. The account genre is the complemented version of the recount genre in the personal category. It is because it also explains the reason behind the experience that students have. An explanation is used to clarify or define a specific phenomenon. We broadly know exposition as an argument that is used to present a perspective and provide evidence to readers.

### **3.3 Academic Writing in tertiary level education**

Academic writing is a formal type of writing for educational purposes. It is the variety of academic English to convey research in writing. We can call any writing that can deliver messages to persuade people, academic writing. Although it covers a wide range of categories, people always recognize academic writing as the formal writing of university. On page 87 of the book *“Academic Writing and Genre: A Systematic Analysis”*, Moore and Morton classify 12 categories of university academic writing. Those 12 categories are essay, review, literature review, experimental report, case study report, research report, research proposal, summary, exercise, short answer, written argument and others. However, only three of them are the mainstreams, which are essay, case study reports and exercises, accounting respectively for 58%, 10% and 8% of academic writing (Ian & Bruce, 2010).

### **3.4 The Four characteristics of Academic writing**

Although academic writing has a lot of categories, it normally contains four fundamental characteristics (University of Leeds, n.d.). First, academic writing has to be focused on particular questions depending on the type or genre. Second, to convey insight, it has to contain a clean structure that can contextually and grammatically express comprehensive opinions. Then, to make the academic paper formal and concise, it has to be accomplished and supported with facts rather than

feelings and vibes. Finally, the proper tone and style and lexical choices, play an important part in academic writing.

### **3.5 The purposes and development of academic writing in different stages**

Academic writing is a type of knowledge, while it is also a tool that assists learning. Students write to gain knowledge and merge it along with cognitive involvement. We gain and apply unique knowledge in different stages of our cognitive development. As a tool to assist their learning, the purpose of academic writing tasks is frequently changing to help children develop into adolescence. According to Piaget's theory (1976), we need to go through four stages of cognitive development to reach full human intelligence. These four stages are the Sensorimotor stage, Pre-Operation Stage, Concrete Operation Stage and Formal Operation Stage. That is the reason schools focus on the personal and factual categories of academic writing in the early years of schooling. We enter school to have structural learning at the preoperational stage when we learn to write and recognize the information. Children's early writing is mostly written in the same way as they speak and talk (Schleppegrell, 2008). The personal genre is the priority of academic writing in the early stage of schooling. The purpose of this type of academic writing in this stage is to expose children to letters and sentences and also encourage them to express their feelings. Then, children will learn to use grammar and organizational structure to form academic writing pieces. When children reach their concrete operational stage, they learn how to merge simple sentences into complex sentences. Children learn how to transform predicate adjectives into prenominal adjectives at around age 9-10. For instance, they place the adjective behind the subject rather than place it after a linking verb until 13 -14. The purpose of academic writing is frequently changing according to the stages of cognitive development. Therefore, this paper will only focus on the formal operational stage, which occurs when children are at 12 years or older, which is the stage where students have mostly developed their cognition. In light of this, the formal operational stage is the ideal option for this paper to study if handwriting or word processing affects students' cognition and memory.

### **3.6 The Difficulties of Students in writing academic expositions**

The paper, "*An investigation of academic writing in secondary schools to inform the development of diagnostic classroom assessments*" (Llosa et al., 2011), investigated the writing difficulties of students aged 14-16. They reported that there were 22 challenges experienced by students, and translating was the most prevalent one at 85%. Translation referred to "articulating ideas in the conventions of written English." (Llosa et al., 2011, P256) Students find it hard to use accurate words and sentences to express thoughts and have grammatical and spelling difficulties. Making grammar mistakes or misspelling a word can be one difficulty under this item, however, the primary concern is students do not know how to think and write. The second challenge was generating. Approximately

50% of the participants found they did not have enough ideas to write because they could not recall their knowledge of a specific topic and use it well. According to table 6 on the paper, other common difficulties that over a quarter of the participants had were related to memory, interpreting task demands, audience needs and revising (Llosa et al., 2011).

### **3.7 Conclusion**

To conclude, the writing process involves prewriting, drafting, revising, editing and publishing. This paper will only focus on the exposition of academic writing at the secondary level because it is the foundation of further academic achievement. At age 12 or above, students mostly have a structured development of cognition, therefore, this age range would be the ideal option for this paper to study if handwriting or word processing affects students' cognition and memory. While there are 22 difficulties of students in academic writing, translating and generating ideas were the major difficulties to over half the class of students. "Swanson and Berninger proposed that children learning to write are mainly constrained by working memory demands of transcription and text generation during translation." This paragraph states that memory and cognitive processes have a direct and influential effect on children's writing skills, therefore, the paper will next define and explain cognition and memory.

## **4. The Definition of Cognition**

The previous section of academic writing has listed the difficulties of students in academic writing, therefore, it reveals that cognition has a direct and influential effect on children's writing skills. This section aims to explain what cognition is and its relation to memory as well as how it influences our learning and writing. In this section, a basic definition of cognition and how our brain processes pieces of information will be elaborated on. Also, the approaches that scientists take to study cognition will be introduced in this section.

### **4.1 The Definition of Cognition**

Cognition is a term that describes the mental process of gaining information and generating it into knowledge and comprehension. To simplify the meaning, cognition is the internal process of us making sense of something. Cognition involves knowing, remembering, understanding, communicating, problem-solving, and learning and memory (Eysenck & Brysbaert, 2018). These processes help us form concepts of things and the related prototypes, which are mental images of some specific items or activities. Normally, cognitive processes occur in our mind first, and then we have some behaviours based on our cognition. Memory is one of the most important roles in cognition and involves learning that has persisted over a period (Eysenck & Brysbaert, 2018).

## **4.2 Piaget's theory**

According to Piaget's theory (1976), there are the Sensorimotor stage, Pre-Operation Stage, Concrete Operation Stage and Formal Operation Stage of cognition development. This theory explains how humans acquire knowledge and respond to stimulus in these stages. Piaget believed that children are curious about the world and they actively explore the world rather than taking a passive role to learn. At the sensorimotor stage, children between birth to two years old develop their experience and knowledge through five senses, which are sight, hearing, touch, smell and taste. When they reach about five months old, they will have a basic knowledge of the world and they can understand that things continue to exist even though they cannot see them. This is the earliest stage of cognitive development. At the concrete operational stage, between the ages of 2 to 7, children learn to speak and respond to people and things. They are very curious about everything, therefore; they ask a lot of questions and love to play pretend play. However, they are still egocentric in this stage because they have not developed the skills to see things from another perspective. During the concrete operational stage, children between 7 to 11 think logically and become organized. They develop their thinking with logic and consider other people's feeling. Finally, children can have a concrete cognitive development at the formal operational stage when they reach 12 years old or above. They can process abstract thinking and feelings while they also have a concrete understanding of logic and can use deductive logic for problem-solving. This is the stage that we have to develop our cognition. The age of 12 is the age that our working memory fully develops. Therefore, it would be the most appropriate stage for this paper to focus on.

## **4.3 The information processing approaches**

There are different information processing approaches to generate information in our cognition system. Psychologists first believed that the main approach humans adopted to deal with information was bottom-up processing 45 years ago (Eysenck & Brysbaert, 2018, P.10). This processing, caused by environmental stimulus inputs, was assumed as serial processing in which only one process was happening at a time. Once the one process is completed, the next step can then begin. This approach might merely work for the infant because they have no experience on anything so they can only receive stimulus inputs to explore the environment according to Piaget's theory. However, this approach was judged as oversimplified because it did not align with reality. After that, this processing was compromised with an alternative approach which is Top-down Processing (Atkinson & Shiffrin, 1968), a process influenced by an individual's experience and knowledge. Also, Atkinson and Shiffrin (1968) proved that there should not be only serial processing but also parallel processing. For example, when we read an article written with some synonyms, our brains connect them with the same meaning while understanding the article.

#### **4.4 The contemporary scientific approaches to study cognitive processes**

Nowadays, scientists have come out with four approaches to understanding human cognition, they are: experimental cognitive psychology, cognitive neuroscience, cognitive neuropsychology and computational cognitive science (Eysenck & Brysbaert, 2018). Experimental cognitive psychology is the approach that is based on experiments on healthy individuals. The accuracy of the research depends on the quantity of data. Cognitive neuroscience is also based on experiments, however, they are designed and observed under scientific evidence from brains. Cognitive neuropsychology is closely linked to the previous approach, but the participants of this approach are not healthy individuals. The last one, computational cognitive science, is the approach based on simulated computer models to explain human cognition. In this paper, healthy human participants will be the major focus.

#### **4.5 The scientific process of cognition and the related measurement methods**

Our brain processes information from the lower brain regions to the higher brain regions. The process starts with transduction, which can be understood as the receiving and filtering process in the brainstem and cerebellum areas. Having received the information, our brain will encode the information in the thalamus, and then send it through neurons to the cerebrum. Then the higher part of our brain, the frontal lobe, parietal lobe, occipital lobe and temporal lobe, will collect the information and go through the integration process. After that, the information will be passed into the cognitive and executive function. In the end, the message will be modulated so an act will be made. These procedures can now be captured and observed under fictional magnetic resonance imaging (fMRI) by detecting the magnetic changes in brains. To tell if there is any activity occurring in brains, scientists can measure the changes of oxygenated red blood cells. The other way to measure brain activities is through the electroencephalogram (EEG) recording (NDLab, 2014). The electrical activity going on in brains can be measured through the wave and movement of neurons. To learn about the brain activities of handwriting and typewriting, some research that has applied fMRI or EEG will be analysed.

#### **4.6 Conclusion**

To conclude, cognition is the mental process of gaining and generating information to make sense of that information and possibly respond to it. The sensorimotor stage, pre-operational stage, concrete operational stage, and formal operational stage are the four stages of cognitive development. There are four approaches to study cognition and they are experimental cognitive psychology, cognitive neuroscience, cognitive neuropsychology and computational cognitive science. The higher cognitive systems develop more comprehensively with the support system of verbal language, which involves speaking, hearing, reading and writing. Different from the natural processes of speaking and hearing,



reading and writing must be learned in a long-term learning process. Therefore, the memory will be discussed next.

## **5. The Definition of Memory**

Memory is the learning process, one of the cognitive processes, that has persisted. This process involves three things which are recall, recognition and relearning. If a person has no information about one thing before, that person cannot have the memory of that specific thing. Memory only functions when the information has been stored previously. Atkinson and Shiffrin (1968) brought up a theory that there are three stages of transforming information into memory. This section is written based on the Atkinson and Shiffrin model of memory, therefore, any inline referencing will not be added one by one. First, information is input into our sensory memory and then our brain will encode this memory. If you try to remember the information, the working/ short-term memory will access it. Short-term memory lasts in our brain for a short time, for example, 30 seconds. If a person practices this short-term memory repeatedly for a period, it could become a long-term memory.

### **5.1 Sensory Memory**

The information engendered through bottom-up processing, one of the information processing approaches stimulated by outer environmental inputs to generate information in our cognition system, is kept as sensory memory. There are sense-specific sensory stores to keep different senses of stimulation from the environment separately. Sight and sound are the dominant senses among our five senses. Visual stimulated information is stored in the visual sensory store, which is known as the iconic store. The aural information is kept in the auditory sensory store known as the echoic store while the sensory stores have a large capacity to store all five types of sensory information, however, it decomposes expeditiously. Iconic memory decays in less than 0.5 seconds while echoic memory decays after three to four seconds. Because sensory memories decompose rapidly, only a segment of them can be successfully lifted to short-term memory.

### **5.2 Working / Short-term Memory**

Short-term memory can be explained as a type of memory that lasts for several hours or days after learning and receiving knowledge. However, psychologists define this term as a type of memory that can only last for a much shorter period, as mentioned in the definition of memory section, for just a few seconds. Short-term memory was regarded as a store that can retain information for a period. However, psychologists realized it was not merely a store, but it could recall information from long-term memory simultaneously. Therefore, short-term memory is supplemented with the idea of working memory. Suppose you have to write an exposition about cyberbullying. Here, you will need to plan your writing into three key parts: introduction, the body and conclusion. You will need to

remember what to write in these sections, what you have written, and what you are going to write. This kind of combined processing is working memory.

### **5.2.1 Short-term memory capacity**

Different from sensory memories, short-term memory has a relatively small limited capacity to store information. Before Atkinson and Shiffrin brought up their theory and evidence, the belief that short-term storage already existed. Jacobs (1887) was the first one to measure the capacity of short-term memory with an experimental approach showing a random sequence of digits or letters to participants. Memory span, “the number of items that an individual can recall immediately in the correct order” (Eysenck & Brysbaert, 2018, P147), was the information that could be recalled accurately. Jacobs found out that the mean number of the digit span one could recall is 9.3 items while the letter span one can recall is 7.3 items. However, George Miller (1956) argued that this number was higher than the actual capacity number because some sequences presented to the participants in Jacobs’ experience assisted them with some meaningful connections. People can easily remember sequences if they are formed meaningfully, for instance, APPLE. Therefore, he brought up the number “seven, plus or minus two” as the number of pieces of information that one can hold at a time. He believed that the number of spans should not vary whether the units are digits, letters or words. Rather than measuring the sequence of digits and letters, he claimed we should pay attention to chunks, which mean the stored units formed from consolidating pieces of information. Even though the number “seven, plus or minus two” is highly recognized by psychologists, Cowan (2010) argued that this number was still ideal to have. He believes that this number can only be reached when people have given adequate time to remember spans. When a lecturer is teaching a lesson for 30 minutes non-stop, can students still receive a 7+- span in a period? Cowan et al. then applied the running memory task, which presents digits rapidly, to find out the number of spans one can recall. The number was merely 3.9. After that, Chekaf et al. (2018) tested participants with sequences of pictures. He found participants found out that four to five items for the sequences were easy to chunk. Therefore, in the latest experience, the short-term memory capacity might only be four plus or minus one.

### **5.2.2 The Factors of the finding**

Miller's stand, the number of spans of unique items should remain the same, was argued by some authors that there were differences between digits and letters in Jacobs' experience. We can explain this problem as the number is easy to re-chunk. A number itself can form meaning. For example, the number 2 can refer to 2 o'clock, 2 pages, etc., when it is combined with another word like 24, we can associate it with a date. However, a letter itself is merely a letter. Therefore, there was a difference between words and numbers because of re-chunking. Not only does re-chunking affect the capacity, but the word length also influences the memory capacity. Simon (1974) studied memory span with

different length word phrases and found out that there is a word-length effect in remembering span. Phonological information also influenced the ability to remember spans. Shorter pronunciation time allows the speaker to have a greater digit span to remember more items. Chen et al., (2009) found out that shorter pronunciation takes up less space to store phonological information, therefore Chinese Mandarin speakers have a greater digit span when it compares to English speakers. Larsen et al. (2000) also discovered the phonological similarity effect. People recall the words in order better if it is with different phonological words. As the example from the book *Fundamentals of Cognition*, it is harder for people to remember the order of the list formed by the words, FEE, HE, PEA, KEY, ME and SKI; when it compares to the list with the words BAY, HOE, IT, ODD, and SHY. The recency effect also influences how a person remembers spans, for example, people remember the first items and the last few items in a list more than those in the middle of the list. Ageing is the factor that influences memory spans the most. According to Gathercole et al. (1999), the short-term memory span increases from four years old and becomes stable at fourteen. However, when people reach the age of 25, the memory spans decrease until 85. We need to know that when processing requires more capacity, working memory can only store less information because of the limitation of capacity. In this case, can we assume that writing with hands takes up more memory capacity, influencing the writing quality?

### **5.2.3 Short-term memory duration**

According to the study conducted by Peterson and Peterson (1959), memory performance decreased after 6 seconds. Also, after 18 seconds, the participants almost forgot all the consonants there were asked to remember. Jonides et al. (2008) found out that forgetting happens at speed because of two reasons. The first one is that there is decay undergoing and the second one is that there is interference from the task. Nairne et al. (1999) argued that the study conducted by Peterson and Peterson involved interference because it required participants to remember consonants and simultaneously present the order. Therefore, he brought up a study that only required participants to remember the order information. Here, the memory span could last even longer than 96 seconds. This finding suggests that forgetting is more likely to be caused by interference.

### **5.2.4 Supplement of the short-term memory with the term Working memory**

In 1974, two psychologists, Allan Baddeley and Graham Hitch brought up the theory of working memory (1974), which is a system combining short-term memory and processing of information. Baddeley and Hitch argued that short-term memory can carry out more complex tasks that require various processes to complete, rather than only storing information. The book, *“Fundamentals of Cognition”*, explained this theory with an example. “Suppose you were given the additional problem  $13 + 18 + 25$ . You would probably add 13 and 18 and keep the answer (31) in short-term memory. You would then add 24 to 31 and produce the correct answer of 55 (Eysenck & Brysbaert, 2018).” In

this example, we can understand that working memory refers to a comprehensive system that can handle processing and store information at the same time. Baddeley and Hitch have brought up a newer version of the working memory theory in 2012. This version comprises four components which are phonological loop, the visuospatial sketchpad, central executive and episodic buffer. The phonological loop is a component of working memory that stores and processes phonological information in a limited number and time (Allen et al., 2012). It is an essential component for us to learn new words that are formed with unrelated sound and syllables in an arbitrary sequence. The number of words a person can add to their vocabulary highly depends on this component. The visuospatial sketchpad is the component of working memory that stores and processes visual and spatial information in a limited number and time. This component also orthographically assists people to remember word spans according to Logie et al.'s model (2000). The central executive is the most important component of working memory because it is used to control events happening within the other components. While important, the central executive itself cannot store information. The central executive is the attentional controller that controls the cognitive skills of various executive functions. Miyake et al. (2000) brought up the idea that we can classify all executive skills into three functions. The first function is mental set-shifting, which means switching between tasks. The second function is to update and monitor representations going on within working memory. The last function is inhibition or the prepotent response, which is used to stay focused on the relevant tasks, achieving a goal. The episodic buffer is used to assist the whole working memory model because it is a storage system that keeps information from the other components and the long-term memory.

### **5.2.5 Conclusion for short-term memory**

Short-term memory is a kind of memory that can store limited information in a short time. George Miller brought up the number of spans that people can recall is seven, plus or minus two in 1956. Then, Chekaf et al. (2018) brought up the number four plus or minus one in 2016. Some factors influence the number of spans that one can remember. First, we can remember things better if they are easy to re-chunk. Second, we can remember more short words than longer words. Third, words that have shorter pronunciations can take up less space in our brain. If there are a bunch of words to remember, it would be easier for us to remember them if they are pronounced differently. Then, the recency effects, which are like the interference effects on the long-term memory, also influence the memory span a lot. Finally, what influences our memory the most is the ageing factor. Short-term memory duration is about 18 seconds while the memory performance decreases after 6 seconds. However, short-term memory is not merely storage for us to store information, it can also recall information from long-term memory. Therefore, scientists use the term working memory to supplement the short-term memory theory. Working memory has four components which are the phonological loop, visuospatial sketchpad, central executive and episodic buffer. Visuospatial sketchpad and phonological loop are used to store and process different types of information, while

the central executive acts as a controller and also recalls information from the long-term memory. The episodic buffer is used to store the data for the entire process.

### **5.3 Long-term Memory**

Long-term memory is a system that can store information, which is encoded through learning processes, for a long period in its unlimited capacity. As mentioned in the introduction of memory, memory can only function when information is learned and stored in the memory capacity. Long-term memory ensures that information stored in it is retrievable, and rehearsal can help us remember the information. Learning and long-term memory are inseparable because of that. In most cases, we think that learning is processed consciously. For instance, we study some mathematics equations for the coming examination. However, there is also a type of learning happening without our awareness. To distinguish those types of memory, long-term memory is mostly divided into two major groups which are declarative memory and non-declarative memory (Eysenck & Brysbaert, 2018). There are three types of declarative memory which are episodic memory, semantic memory and autobiographical memory. Non-declarative memory is classified into two groups, which are procedural memory and other forms of implicit memory. Even though the hippocampus is used to deal with and manipulate explicit learning and memory while the striatum is the area to deal with implicit learning and memory, both types of memory are in line with each other during the learning process. However, scientists have proved that these two types of memory have their unique system according to some extreme cases of patients who have different types and levels of brain damage.

There are three ways to access information from our long-term memory, which are recall, recognition and relearning. Some scientists divide the recall method into free recall and cued recall (Course Hero, 2019). Free recall is how we retrieve any information that we would remember for a purpose, while cued recall is how we intentionally access our memory with some cues. Recognition is the method whereby we find out the correct information among some other information through identifying the correct one. Relearning is how we access knowledge that we had previously and receive it again to strengthen our memory of that information.

#### **5.3.1 Declarative Memory**

Declarative memory is also named explicit memory, and it refers to the memory that a person gains with intention. It can be divided into three types which are episodic memory, semantic memory and autobiographical memory. This section is written according to the book "*Fundamentals of cognition*" (Eysenck & Brysbaert, 2018), therefore, any inline referencing would not be listed in every sentence.

### **5.3.1.1 Episodic memory**

Episodic memory is the type of memory that we use to remember events and affairs happening in the past. This memory allows us to remember the details, including the background information, the location and the time of events, and these are highly related to our experiences. This type of memory often contains errors and illusions because it manipulates and processes a lot of information to form our daily experience. Episodic memory undergoes either recollection or familiarity, which means people can remember an event by recollecting related information or feeling familiar with some stimulus.

### **5.3.1.2 Semantic memory**

Semantic memory is the memory that stores general facts, concepts, ideas, and information. Sometimes we may not be able to tell where and when we gained that information from, but it is already in our semantic memory. This type of memory could be processed synchronously with episodic memory. For example, we learn how to write an essay in class, and we gain knowledge of what makes good content from the teacher. The knowledge we learn during class is a type of semantic memory, while the class activities and how the teacher teaches us are types of episodic memory.

### **5.3.1.3 Autobiographical memory**

Autobiographical memory is also similar to episodic memory because it is also related to experience. However, autobiographical memory is about our life experience while episodic memory is about daily experiences. Because this memory is about life, it is more stable and therefore it is more likely to be remembered without errors or illusion. Some people who have experienced trauma in their childhood could never forget that experience, causing them to be depressed. Therefore, this type of memory can be lifelong (Eysenck & Brysbaert, 2018).

## **5.3.2 Non-declarative memory**

Non-declarative memory is also known as implicit memory, which you process and store without an intention. There are two types of this memory and they are procedural memory and the other forms of implicit memory.

### **5.3.2.1 Procedural memory**

Procedural memory is also known as motor memory, which is the memory for movements produced by muscles or nerves. According to page 195 in the book “*Fundamentals of Cognition*” (Eysenck & Brysbaert, 2018), cycling, driving, playing a musical instrument, etc., can be examples of this type of memory. Interestingly, the book pointed out that many people access this memory when they type their password on the keyboard. One study (Snyder et al., 2013) found out that keyboarding is related to procedural memory the most instead of the explicit learning of letter position. Some college typists

with approximately 10 years of experience in typing were asked to fill in the correct locations of all the letters on a blank keyboard. Surprisingly, they could only reach 57% of accuracy. Then they were asked to identify the letter position with no finger movement. The result was even worse than the previous experiment. These two experiments showed that keyboard typing is related to procedural memory the most.

### **5.3.2.2 Other forms**

The other forms are those implicit memories that are not procedural memory. There is one form of non-declarative memory under this category called priming. Priming refers to the situation that an event that can be practised efficiently because there was an event that a person performed with a similar or same method.

### **5.3.3 Forgetting curve and the interference effects**

Even though the information is stored in our long-term memory, we may not retrieve it successfully for many reasons. We recognized this unsuccessful retrieval as forgetting. According to Hermann Ebbinghaus's data of the forgetting curve, information stored in our memory has been decaying since we encoded it. Our memory of a piece of information decays most rapidly in the first hour after learning, however, the rate of forgetting then decreases steadily. Interference effects, which are proactive interference and retroactive interference, often accompany forgetting (Eysenck & Brysbaert, 2018). Proactive interference refers to any disruption of memory caused by previous learning, while retroactive interference means any latest learning interferes with the previous learning. These two effects can happen at the same time. The most common example is that we remember the first variables and the last variables on a list and forget those lay in the middle of the list.

### **5.3.4 Consolidation and Reconsolidation**

Consolidation is a physiological process that happens in our brain that moves information from short-term memory to long-term memory (Wixted, 2004). This process can last for a long time, it could be months or even years, for a chunk of information to be concreted. There are two main major phases in consolidation. The first phase happens in the hippocampus for a relatively short period of hours, while the second one takes days or even years to process information. The latter phase mostly takes place during sleep and is activated in the hippocampal region and the neocortex. Consolidation could be the reason we forget things most quickly the hour after learning and the newly formed memories are fragile and easy to have interference (Wixted, 2004). Sometimes, we need to update some information that we have learned before and therefore we could retrieve and activate that information and replace it with a new one to supplement it. This new consolidation of formed memories is reconsolidation. For example, students in Hong Kong primary school learn to write a simple sentence in English following the structure of subject word agreement. When students get into secondary school, they

learn about the sentence inversion which is to place a verb before the subject. Reconsolidation can cause misremembering in this case, because the stored information is now in a delicate state that it is newly formed. Take the sentence inversion case as an example: it is easy for students to misremember that they can write every sentence in this way or, they misremember the correct order and conditions of an inversion.

### **5.3.5 Conclusion for Long-term Memory**

Long-term memory can store unlimited information for a long period and we can retrieve that information. Rehearsal can strengthen our long-term memory. There are two categories of long-term memory which are declarative memory and non-declarative memory. Declarative memory includes episodic memory, semantic memory and autobiographical memory, which are processed with consciousness. While procedural memory and other forms of implicit memory that are hard to describe precisely are non-declarative memory. We can access information that is stored through three methods which are recall, recognition and relearning. However, it is not always possible to retrieve it from our long-term memory because there are forgetting issues caused by consolidation and interferences. There are two types of interference, which are proactive and retroactive interference. Consolidation is the process that transfers information from short-term memory to long-term memory and reconsolidation is the new consolidation of stored information.

### **5.4 Memory Section Summary and the link to Writing**

Long-term and short-term memories are highly connected to learning. Short-term memory takes part in processing information and generating ideas, while long-term memory is for retrieving and storing them. Both memory systems have forgetting issues and are easily affected by interference. Writing is an activity that heavily relies on memory but also contributes to it. By knowing how memory works, we can then realise the relationship between writing and memory. We can then find out what are the factors of great memory systems. Having the factors in mind, we can study if the writing methods can affect those factors. Since writing quality highly depends on memory, it is thought that greater memory can help authors produce better writing.

## **6. Memory in Writing**

Writing processes highly depend on our cognitive system and memory. The writing process involves prewriting, drafting, revising, editing and publishing. Prewriting is the stage when a writer makes a plan for the writing. According to Kellogg's (1996) componential model of working memory in writing, prewriting is processed with the visuospatial sketchpad and phonological loop components. During the planning, writers need to visualize the content and make plans. All this information is temporarily stored and generated in the visuospatial sketchpad. Nearly simultaneously, translation and



transcription processes are undergone in the phonological loop. To write an exposition, students need to plan the structure, then recall useful information from their long-term memory through the central executive component to support the structure, facts and translating of their writings. Vanderberg and Swanson (2007), assert that the executive functions that proceed in the central executive component are fundamental in writing because it involves and requires inhibition. Inhibition is one of the major functions of the executive skills on the central executive component in the working memory system. This function is used to keep a writer focused on his/her writing goal without other irrelevant interferences.

Interestingly, writing is an activity that consumes our memory while it can also serve our learning and enhance our long-term memory. The paper, *Writing to Learn Increases Long-term Memory Consolidation: A Mental-chronometry and Computational-modelling Study of “Epistemic Writing”* (Silva & Limongi, 2019), defines “writing to learn” as “the epistemic writing” which is a learning activity that assists in learning, allows self-reflection and helps build knowledge. This paper aimed to prove that writing can increase long-term memory consolidation. The experiment asked 25 participants to read a random passage from the database of eight texts. After that, they were asked to pronounce or write a summary of the passage they had read. After that, they needed to perform an episodic memory recognition task in which they needed to classify if the text was on the passage or not. All the data collected from this experiment were analysed using Bayesian statistics. The result proved that written production can decrease the reaction time of responses, either retrieval or motor response, and this is the evidence that writing plays a role in effective learning.

Our writing highly depends on our memory system. The previous paragraph has already answered the question of how we can improve our memory system by writing it because writing benefits long-term memory. However, would there be any way to strengthen or deepen the writing quality through the writing process itself? If we apply handwriting or keyboard typing to write, would there be any difference in the result on our writing quality? Before getting into the discussion, we need to find out the factors of producing great writing.

### **6.1 Greater Capacity, Greater Writing Quality**

According to McCutchen’s Capacity Theory of Writing (1996), a writer with a high working memory capacity can write better than writers who have weaker working memory. Here comes a question, can a person improve his/her working memory capacity to produce words with higher quality? The answer is yes and no. Short-term memory capacity has long been realised as a constant number that differs from person to person according to one’s intelligence, even though the number does not vary a lot with the amount four plus or minus one. As mentioned above, ageing is one factor in short-term

memory capacity. People believe if short-term memory capacity varies from age and is stable after 14, it must be changeable. Many studies were conducted to find out if memory can be trained or not. The first study was conducted in 1929 by Martin and Fernberger. They (Martin & Fernberger, 1929) trained two participants to recall digit serial spans for four months and the result was very convincing that the number of spans they could remember increased 40%. After that, a lot of studies of different serial tests, such as letter spans, spatial spans, colour spans, were conducted to prove that people can remember a larger number of spans after training. However, all these studies do not give evidence that these pieces of trainings enhance the short-term memory span because those improvements could be the consequences of using long-term memory instead. Also, some studies that did not apply for a long period could not improve the memory performance on the other memory tasks. Therefore, it is very hard to study short-term memory capacity. The latest paper, *Can Short-term Memory Be Trained* conducted by Norris, Hall and Gathercole in 2019 still cannot give a certain proof of that. If there is no evidence that short-term memory can be trained, there will not be evidence that handwriting or typing improves short-term memory. Therefore, memory capacity may be a constant and cannot be increased by implementing either handwriting or typewriting.

## 6.2 Limited Capacity, inefficient processing would take up some space

Following the above information, if every person has a certain amount of short-term memory capacity, the best way for them to maximise the use of short-term memory is to reduce interference. It illustrates that weak word processing skills can reduce writing efficiency, affecting the writing quality. Any automatized writing skill can release some capacity for a person to plan, translate and revise his or her words. According to the “*Working Memory in Writing*” paper (Thierry, 2011), beginning writers cannot process high-level writing processes simultaneously with handwriting. They can only share the capacity with strategy because they do not automatise their handwriting skills. The study “*Speaking, writing, and memory span in children: Output modality affects cognitive performance*” by Joachim Grabowski (2010) shows that unpractised writing modes cause a worse memory performance which Grabowski believed is because of a lack of graphomotor automation (Grabowski, 2010). This study conducted four sets of experiments and in the set C1 and C2 experiments, participants who applied typing as their writing modes could perform better memory spans than those who wrote by hand. If participants were familiar with both typing and handwriting, they should have had a similar performance on short-term memory capacity. According to the example in the non-declarative memory section of this paper, handwriting and typing are both motor memory, storing information for movements. If people manipulate their writing methods well and turn, or say automate, them into long-term memory, there should not be any differences as they are technically the same type of memory. However, this paper proved that participants with typewriting could perform better in the memory task. We can infer from this result that keyboard typing takes up

less space in our memory. Even more tricky is that there is not an enormous difference between unpractised typing skill and practised typing skill towards short-term memory. It is more likely to be the case that people can type words without practice, and it would not interfere with the memory capacity and writing quality at all. Handwriting seems to have no point to be used in this digital age according to the reasons above. However, Cunningham and Stanovich showed that people writing with their hands can access more correct spelling than keyboard typing. Brain activeness could be the reason that handwriting assists spelling more than typing.

### **6.3 A skilled writer can activate the brain better**

A skilled writer can activate his/her four components of working memory and have greater interaction within those four components during writing processes. Levy and Ransdell (1996) proved that skilled writing aligns with the features of interaction and recursion, which are the practice of embedding phrases inside one another to form sentences. Therefore, skilled writers can shift between calling knowledge from the episodic buffer and processing information. If skilled writers can activate their brain better, we might believe that any writing method that activates more brain areas can help people become skilled writers. Askvik, Van der Weel and Van der Meer (2020) conducted a study with a high-density electroencephalogram (HD EEG) to study the brain electrical activity when people were writing, typing and drawing. Twelve school-aged children and twelve young adults were recruited to take part in this study. The study shows that handwriting, having similar electrical activation patterns as drawing, can activate brain areas in the parietal and the central regions synchronously in lower frequencies. However, typing could only show event-related desynchronized activity in the parietal and central brain regions. The study stated that the brain activity in typing differed from handwriting and was event-related desynchronised, and the relation between typing and learning remains unclear. However, Silva and Limongi (2019) found that typing can assist learning. They applied keyboard typing as the writing method to study the hypothesis that writing can increase long-term memory. In the written condition section of the production task in their study, participants were asked to type the summary of the previous read article when a text box appeared. Even though the study applied typewriting as the writing method, this study could prove that writing assists learning. According to the EEG study, school-aged participants did not achieve the same intensity of the activity pattern. The study suggests that it would be because EEG is sensitive to children's irrelevant movement. However, why can handwriting synchronise with brain areas more than typing when both systems can help us learn? Is the EEG sensitivity a reason behind the different result?

### **6.4 Conclusion**

Memory is the most important role in cognition and it dominantly assists the writing process, while writing can give back to the memory system to help knowledge to be concrete. During the writing

processing, the visuospatial sketchpad and phonological loop components are functioning to make plans and drafts through translation while the central executive component generates those plans together with the support of calling information from the long-term memory. Memory capacity is a factor of quality writing. Once we can improve our memory capacity, we can improve our writing quality. However, since memory capacity is a constant number that varies from person to person, and it might not be changeable through training. It is impossible that handwriting or typewriting can improve it in any way. Because of the limited capacity, the best way we can increase our memory efficiency is to reduce inefficient processing. Theoretically, if we trained our writing methods into automatic skills, we can perform evenly and fairly with both handwriting and typewriting methods. However, some research proved that people perform better with fewer spelling mistakes if they write by hand. However, there is no difference in writing quality when applying unfamiliar typewriting or automated typewriting. As skilled writers can activate their brain better, writing methods that can activate more brain areas might influence writing quality. Handwriting is proved that it can activate our brain better but both writing methods can help us write. However, why can handwriting activate more brain area when it is also a skill of procedural memory just as typewriting? Here come two hypotheses, (1) the method of writing that is first learned is the most useful one for the author and (2) repeated rehearsal occurs during the response of movements.

## **7. The hypotheses**

### **7.1 The method of writing that is first learned is the most useful one**

The first writing method can have a better brain connection. Handwriting or typing is a method for us to write our thinking. Here, they are both procedural memories that involve actions and movements. Handwriting and typing are the same because they are motor skills involving a lot of implicit learning that we need to manipulate. Take doing a paper as an example. To finish an exposition, students consider the idea first and then write the information by handwriting or typing. After prewriting and drafting, they revise their words and edit them for publication. How they produce a paper is the same, except for the writing method. Consequentially, both writing methods should have no difference because they both produce the same outcome, which is an exposition. Chinese people use chopsticks for food at their sensorimotor stage while western people use forks and spoons to master self-feeding. Both tableware requires practice, and they are tools for people to eat. We would not say people using chopsticks can have better control of eating than people with forks and spoons because tableware is just a tool that allows us to fulfil our eating. Some people may say using chopsticks is a fine motor that can help us develop precise hand-eye coordination and movement. However, there is no proof that Asian people using chopsticks perform better in those conditions than Western people. You may want to argue that Asian children can perform better at school and that would be the result of using

chopsticks, which is a precise motor movement that can train our brain better. However, there is no evidence of that argument. According to the paper, “*Why Do Asians Do Well At School?*” by Otsuka (1996), cultural differences and genetic intelligence are the reasons for the differences in better academic achievement. Therefore, there is no proof that the precision of hand movement can enhance people’s learning, especially when it is about national differences. Similarly, the methods of writing might not refer to better cognitive development, learning or memory because there must be other factors that truly affect our learning. However, why is keyboard activity less demanding? Longcamp et al. (2006) believed it is because typing requires much less kinaesthetic information when it compares to writing with hand movements. Typing is indeed kinaesthetically less demanding, however, there is no proof that typing activates less brain area because of that. As both writing methods are a type of non-declarative memory, there can be the existence of priming. Priming is non-declarative memory, and it helps us to process things efficiently by comparing similar conditions without enormous efforts. Mostly, we learn letters and words in kindergarten and we practice those teachings by handwriting. We learn the alphabet of letters from A to Z with the letter tracing method to write the letter. When we are being exposed to typing, we already know every letter of the alphabet, therefore, it would be so much easier for us to learn to type in a short time. Here comes a hypothesis that if people learn to type before handwriting, the existence of priming can reduce the demand for brain activeness caused by handwriting. Askvik, Van der Weel and Van der Meer (2020) found out that when people are practising typewriting, they have a higher frequency in the parietal and central areas. According to the paper, *Decrease and increase in brain activity during perceptual priming: an fMRI study on similar but perceptually different complex visual scenes* (Blondin & Lepage, 2005), visual priming can increase the brain activities in frontal and parietal regions, while the brain activities in late-stage visual processing areas are reduced. Therefore, the fact that typewriting can activate fewer brain areas could be because handwriting takes up the role of the “first” writing presentation, therefore leaving a priming effect on the second writing presentation. This hypothesis can also explain that there is a higher frequency in our frontal and parietal regions when we type because we retrieve information from our memory rather than encoding new knowledge of a writing method. That could also be the reason we can manipulate typewriting in a short time. So, what is the best way to improve our writing quality along with the use of writing methods? It would be that we learn how to write with typewriting because it is less kinaesthetically consuming. Children can know how to write at their early age, however, they might not have coordinated motor movement to write, so they write slowly and practise their knowledge passively. If they can be exposed to writing with the typewriting method, they can begin writing with more ease at an early age.

## 7.2 The more time involved in a movement, the more repeated rehearsal circles occur.

Cunningham and Stanovich have proved that we can spell words and recall them better in handwriting than typing. If handwriting and typing are undergoing a similar process in our brain with similar processes, there should not be any difference between them. So, why can we spell words better with handwriting? There are many studies about handedness conveying to us that left-handedness is highly associated with intelligence and those who are left-handed are mostly considered smarter than those who are right-handed. For example, Oxford University found that left-handers may have better verbal skills than the majority of those who are right-handed. Even though scientists from the University of Oxford have proved that handedness is 25% related to genes, there is still a possibility that 75% of handedness depends on the environment (Wiberg et al., 2019). If people trained to be left-handed can be in a way smarter, why does typing with both hands seem to be weaker when it compares to handwriting? If the previous hypothesis is true, that both writing methods are processed in similar mechanics, people might perform better with handwriting because it involves more time in the process that can allow for a couple of repetitions of rehearsals. Our brain activities could be processed in the same way when we type and write. However, because it takes time for us to respond to commands from the brain, the brain would have waited for our body movements to be completed during the whole writing movements. This means that the reaction time for us to perceive commands from the brain and respond to action would trigger the repetition of processing that allows us to understand and react to the information. Moscoso del Prado (2009), studied human reaction time and he brought up the rate of 60 bits per second as the maximum speed of our reaction time. Our body seems to respond to the command from our brain instantly. However, according to the information from the cognition section and the memory section, our brain needs to generate all the stimuli and information first, then respond to an output. Therefore, our brain and body are not working simultaneously. However, just because the entire process happens in a quick time, we think they function synchronously. As mentioned before, the central executive component of our working memory has a function to help us stay focused on the task that we are doing. As a result of this function, our brain may keep encoding and processing the same chunk of data, again and again, to wait for our body to be ready for the next movement, while keeping us focused on the task. It is because handwriting is much more kinetic movement consuming, it might limit the speed of processing so the brain might recall the same information from the long-term memory repeatedly. Repeated rehearsal strengthens our memory, therefore we seem to have better recall performance on information and can spell words more accurately. In comparison, the time consumption of typing is three times less than handwriting. Therefore, there might not be any repeated recall going on in one's brain when he or she is typing to write an exposition, or the number of repeated recalls is less than handwriting. Therefore, there may be weaker performances on recall and spelling. This hypothesis could therefore explain, apart from priming, why handwriting can activate more brain areas and also

reduce spelling mistakes. To prove that time is the main condition, we can conduct an experiment having two groups of people type at different speeds and observe the brain activities of two groups with an electroencephalogram. According to Ratatype (n.d.), the average typing speed is 41.4 words in one minute. The experiment should have a group of people completing the experiment at a normal typing speed while the other group is typing at the handwriting speed, which is 13 words per minute. If there is a difference in brain activeness between the two groups, we can realise that time consumption is a factor of brain activeness. Then, we can compare handwriting and typing examined at the same speed to see if they have the same pattern of brain activeness, however, the condition is there is no priming effect in the experiment. If the hypothesis can be proved with evidence, we should then study how much time we need to spend to remedy the lack of rehearsal during writing. Returning to the word processor, if typewriting and handwriting are the same, there must be help that the word processor itself can provide. The study, *The Effect of Computers on Student Writing: A Meta-Analysis of Studies from 1992 to 2002* (D. Owston et al., 1992), implemented meta-analyses to study the differences in writing quality and quantity between K-12 students writing with word processors versus handwriting. The analysis found out that students who write with word processors can produce longer passages than those who write by hand, especially when children are above the age of twelve. Also, word processing has a positive impact on student writing for the students who develop their writing skills with word processors. They are 0.4 standard deviations higher in quality than those students using handwriting. Word processors can help students become familiar with the writing process while using technology, such as the word algorithm and card system that Trello provides. As mentioned in section 2.vi, secondary school students find that the main difficulties for them to write an exposition are translation and generating ideas. To combat these difficulties, they need to apply the word processors that have an algorithm in them to predict their thoughts or even accommodate them with functions of generating ideas. If we can prove that typewriting with a slow writing speed can assist our learning better, we need to think about how to implement the word processor wisely with the balance of effectiveness and efficiency and how to improve the performance of word processors.

## **8. The Summary**

At the beginning of this paper, we asked the question of which is the better writing method for children when doing academic writing, or are they both the same? In analysing this question, we have considered how memory influences the quality of academic writing in section 6, and how modes of writing, particularly handwriting and typing, interact with the long- and short-term memory, improving our writing quality.

First, we need a framework to think about the question precisely, therefore sections 1-4 explain the relationship between academic writing, writing methods, cognition and memory. Then section 5 introduces us to how our memory systems function when we are writing.

Having examined these we can see the possibility that not either mode of writing is necessarily superior for constructing academic arguments. However, instead, there would be a possibility that the mode of writing that is first learned is the most useful for the author. It is because we can see that there is no firm support for saying one mode of writing is superior, at least for the construction of an academic argument.

However, there is suggestive evidence in the first part of section 7 that it is the mode of writing that is first learned that is the most useful for the author. Also, the second part in section 7 suggests that it is possible that a time-consuming movement can allow us to retrieve information repeatedly, therefore it can then improve our writing skill, meaning that this is nothing to do with either writing method.

Exploring these two hypotheses further would require experimental work. For example, exploring how students from similar educational backgrounds who learn different writing systems first, find those writing modes affect their memory with academic writing. While clearly beyond the scope of a research paper such as this, as early use of keyboards in schools becomes more common, evidence for or against this proposition is likely to come.

This paper has tried to ask an interesting question about how different modes of writing affect memory, and therefore thought; has tried to present a framework for thinking about how to explore that question; give some provisional answers to the question and propose future work to investigate the questions further.



Reference:

1. Allen, R. J., Hitch, G. J., Mate, J., & Baddeley, A. D. (2012). Feature binding and attention in working memory: A resolution of previous contradictory findings. *Quarterly Journal of Experimental Psychology*, 65(12), 2369–2383.  
<https://doi.org/10.1080/17470218.2012.687384>
2. Atkinson, R. C., & Shiffrin, R. M. (1968). Human Memory: A Proposed System and its Control Processes. *Psychology of Learning and Motivation - Advances in Research and Theory*, 2(C), 89–195. [https://doi.org/10.1016/S0079-7421\(08\)60422-3](https://doi.org/10.1016/S0079-7421(08)60422-3)
3. Baddeley, A. D., & Hitch, G. (1974). Working memory. *Psychology of Learning and Motivation - Advances in Research and Theory*, 8(C), 47–89. [https://doi.org/10.1016/S0079-7421\(08\)60452-1](https://doi.org/10.1016/S0079-7421(08)60452-1)
4. Blondin, F., & Lepage, M. (2005). Decrease and increase in brain activity during visual perceptual priming: An fMRI study on similar but perceptually different complex visual scenes. *Neuropsychologia*, 43(13), 1887–1900.  
<https://doi.org/10.1016/j.neuropsychologia.2005.03.021>
5. Chekaf, M., Gauvrit, N., Guida, A., & Mathy, F. (2018). Compression in Working Memory and Its Relationship With Fluid Intelligence. *Cognitive Science*, 42, 904–922.  
<https://doi.org/10.1111/cogs.12601>
6. Chen, L., Zechner, K., & Xi, X. (2009). *Improved Pronunciation Features for Construct-driven Assessment of Non-native Spontaneous Speech*.
7. Course Hero. (2019, March 15). *Retrieving Memories | Psychology - YouTube*. YouTube.  
<https://www.youtube.com/watch?v=oCBe2ynPPHI>
8. Cowan, N. (2010). The magical mystery four: How is working memory capacity limited, and why? *Current Directions in Psychological Science*, 19(1), 51–57.  
<https://doi.org/10.1177/0963721409359277>
9. D. Owston, R., Murphy, S., & H. Wideman, H. (1992). The effects of word processing on students' writing quality and revision strategies. *Research in the Teaching of English*, 26(3), 249–276.
10. Eysenck, M. W., & Brysbaert, M. (2018). *Fundamentals of Cognition* (3rd ed.).  
<http://web.b.ebscohost.com/ehost/detail/detail?vid=7&sid=3170d61e-d049-445c-aa13-67e3885f5f13%40sessionmgr101&bdata=JnNpdGU9ZWwhvc3QtbGl2ZQ%3D%3D#AN=1699310&db=nlebk>
11. Gathercole, S. E., Service, E., Hitch, G. J., Adams, A.-M., & Martin, A. J. (1999). Phonological Short-term Memory and Vocabulary Development: Further Evidence on the Nature of the Relationship. In *Appl. Cognit. Psychol* (Vol. 13).  
[https://doi.org/10.1002/\(SICI\)1099-0720\(199902\)13:1](https://doi.org/10.1002/(SICI)1099-0720(199902)13:1)
12. Grabowski, J. (2010). Speaking, writing, and memory span in children: Output modality

- affects cognitive performance. *International Journal of Psychology*, 45(1), 28–39.  
<https://doi.org/10.1080/00207590902914051>
13. Hayes, J. R. (2011). Kinds of knowledge-telling: Modeling early writing development. *Journal of Writing Research*, 3(2), 73–92. <https://doi.org/10.17239/jowr-2011.03.02.1>
  14. Hirschler Lichtsteiner, S., Wicki, W., & Falman, P. (2018). Impact of handwriting training on fluency, spelling and text quality among third graders. *Reading and Writing*, 31(6), 1295–1318. <https://doi.org/10.1007/s11145-018-9825-x>
  15. Ian, & Bruce. (2010). *Academic Writing and Genra: A Systematic Analysis*. Continuum; Reprint edition.
  16. Jonides, J., Lewis, R. L., Nee, D. E., Lustig, C. A., Berman, M. G., & Moore, K. S. (2008). The mind and brain of short-term memory. *Annual Review of Psychology*, 59, 193–224. <https://doi.org/10.1146/annurev.psych.59.103006.093615>
  17. Kellogg, R. T. (1996). *A model of working memory in writing*. <https://psycnet.apa.org/record/1996-98203-003>
  18. Kunde, B. (1986). A Brief History of Word Processing. *Foothill College*. <https://web.stanford.edu/~bkunde/fb-press/articles/wdprhist.html>
  19. Larsen, J. D., Baddeley, A., & Andrade, J. (2000). Phonological similarity and the irrelevant speech effect: Implication for models of short-term verbal memory. *Memory*, 8(3), 145–157. <https://doi.org/10.1080/096582100387579>
  20. Levy, C. M., & Ransdell, S. (1996). *The Science of Writing: Theories, Methods, Individual Differences and*. Routledge.
  21. Li, B. (2018, October 18). *The Evolution of Graphic Tablet. Graphic tablet is an important tool for...* | by Brandon Li | Medium. <https://medium.com/@bleeskyar/graphic-tablet-ae9752ddad7a>
  22. Lincoln Learning Solutions. (2020, April 3). *The Writing Process - YouTube*. YouTube. <https://www.youtube.com/watch?v=fsffR-cu00k>
  23. Llosa, L., Beck, S. W., & Zhao, C. G. (2011). An investigation of academic writing in secondary schools to inform the development of diagnostic classroom assessments. *Assessing Writing*, 16(4), 256–273. <https://doi.org/10.1016/j.asw.2011.07.001>
  24. Logie, R. H., Della Sala, S., Wynn, V., & Baddeley, A. D. (2000). Visual similarity effects in immediate verbal serial recall. *Quarterly Journal of Experimental Psychology Section A: Human Experimental Psychology*, 53(3), 626–646. <https://doi.org/10.1080/713755916>
  25. Longcamp, M., Boucard, C., Gilhodes, J. C., & Velay, J. L. (2006). Remembering the orientation of newly learned characters depends on the associated writing knowledge: A comparison between handwriting and typing. *Human Movement Science*, 25(4–5), 646–656. <https://doi.org/10.1016/j.humov.2006.07.007>
  26. Martin, P. R., & Fernberger, S. W. (1929). Improvement in Memory Span. *The American*

- Journal of Psychology*, 41(1), 91. <https://doi.org/10.2307/1415112>
27. McCutchen, D. (1996). *A Capacity Theory of Writing: Working Memory in Composition on JSTOR*. 8(3). <https://www.jstor.org/stable/23359419?seq=1>
28. Miller, G. A. (1956). The magical number seven, plus or minus two: some limits on our capacity for processing information. *Psychological Review*, 63(2), 81–97. <https://doi.org/10.1037/h0043158>
29. Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The Unity and Diversity of Executive Functions and Their Contributions to Complex “Frontal Lobe” Tasks: A Latent Variable Analysis. *Cognitive Psychology*, 41(1), 49–100. <https://doi.org/10.1006/cogp.1999.0734>
30. Montague, M. (1990). *Computers, Cognition, and Writing Instruction*. New York Press. <https://ebookcentral-proquest-com.ezproxy.hkpl.gov.hk/lib/hkpl-ebooks/detail.action?docID=3406995>
31. Moscoso del Prado, M. F. (2009). *The thermodynamics of human reaction times*. <http://arxiv.org/abs/0908.3170>
32. Nairne, J. S., Whiteman, H. L., & Kelley, M. R. (1999). *Short-Term Forgetting of Order Under Conditions of Reduced Interference*.
33. NDLab. (2014, June 19). *Brain Rhythms: Functional Brain Networks Mediated by Oscillatory Neural Coupling - YouTube*. YouTube. [https://www.youtube.com/watch?v=OCpYdSN\\_kts&t=714s](https://www.youtube.com/watch?v=OCpYdSN_kts&t=714s)
34. Nisbet, P., Spooner, R. W. ., Arthur, E., & Whittaker, P. (1999). *Supportive Writing Technology*. CALL Centre, University of Edinburgh.
35. Otsuka, S. (1996). “WHY DO ASIANS DO WELL AT SCHOOL?” by Setsuo Otsuka. *Deep South*, 2(1). <https://www.otago.ac.nz/deepsouth/vol2no1/setsuo.html>
36. Peterson, L., & Peterson, M. J. (1959). Short-term retention of individual verbal items. *Journal of Experimental Psychology*, 58(3), 193–198. <https://doi.org/10.1037/h0049234>
37. Piaget, J. (1976). Piaget’s Theory. In *Piaget and His School* (pp. 11–23). Springer Berlin Heidelberg. [https://doi.org/10.1007/978-3-642-46323-5\\_2](https://doi.org/10.1007/978-3-642-46323-5_2)
38. Ratatype. (n.d.). *Average typing speed infographic — Ratatype*. 2021 Ratatype. Retrieved May 31, 2021, from <https://www.ratatype.com/learn/average-typing-speed/>
39. Sassoon, R. (1999). *Handwriting of the Twentieth Century*. Routledge; 1st edition (July 29, 1999). <https://www.amazon.com/Handwriting-Twentieth-Century-Rosemary-Sassoon/dp/0415178827>
40. Schleppegrell, M. J. (2008). *The Language of Schooling*. Lawrence Erlbaum Associates, Publishers.
41. Silva, A. M., & Limongi, R. (2019). *Writing to Learn Increases Long-term Memory Consolidation : A Mental-chronometry and Computational-modeling Study of “Epistemic*

*Writing*” (Issue April).

42. Simon, H. A. (1974). How big is a chunk? *Science*, *183*(4124), 482–488.  
<https://doi.org/10.1126/science.183.4124.482>
43. Snyder, K. M., Ashitaka, Y., Shimada, H., Ulrich, J. E., & Logan, G. D. (2013). *What skilled typists don't know about the QWERTY keyboard*. <https://doi.org/10.3758/s13414-013-0548-4>
44. Thierry, O. (2011). Working Memory in Writing. In P. Press (Ed.), *Past, Present, and Future Contributions of cognitive writing* (pp. 485–503). Psychology Press.  
[https://www.researchgate.net/publication/258861424\\_Working\\_memory\\_in\\_writing](https://www.researchgate.net/publication/258861424_Working_memory_in_writing)
45. University of Leeds. (n.d.). *What is academic writing?* | *Academic writing* | *Library* | *University of Leeds*. University of Leeds Library. Retrieved May 31, 2021, from [https://library.leeds.ac.uk/info/14011/writing/106/academic\\_writing](https://library.leeds.ac.uk/info/14011/writing/106/academic_writing)
46. van der Meer, A., Ose Askvik, E., & F.R, van der W. (2020). *The importance of cursive Handwriting Over Typewriting for Learning in the Classroom: A High-Density EEG Study of 12-year-old Children and Young Adults*.
47. Vanderberg, R., & Lee Swanson, H. (2007). Which components of working memory are important in the writing process? *Reading and Writing*, *20*(7), 721–752.  
<https://doi.org/10.1007/s11145-006-9046-6>
48. Wiberg, A., Ng, M., Omran, Y. Al, Alfaro-Almagro, F., McCarthy, P., Marchini, J., Bennett, D. L., Smith, S., Douaud, G., & Furniss, D. (2019). Handedness, language areas and neuropsychiatric diseases: Insights from brain imaging and genetics. *Brain*, *142*(10), 2938–2947. <https://doi.org/10.1093/brain/awz257>
49. Wixted, J. T. (2004). THE PSYCHOLOGY AND NEUROSCIENCE OF FORGETTING. *Annu. Rev. Psychol*, *55*, 235–269. <https://doi.org/10.1146/annurev.psych.55.090902.141555>