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THE POWER OF WRITING HANDS:

LOGICAL MEMORY PERFORMANCE AFTER HANDWRITING AND TYPING TASKS WITH WECHSLER MEMORY SCALE REVISED EDITION

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Summary:

Information and communications technologies have generated a multilevel metamorphose not only of the educational field, but also of the usage of hands. The shift from handwriting to typing is bringing about a change in the ways people learn to recognize and recollect letters and words, read and write.

This study investigates how different writing methods affect memory retrieval. The aim is to understand how the memory performances compare after handwriting and typing tasks, and how the factor of time or age affects recollection. The Wechsler Memory Scale Revised Edition (WMS-R) was used with experimental within-subjects research design to measure memory functions of 31 University of Lapland students in 2016. Participants wrote down a dictated story with a pencil, computer keyboard, and a touch screen keyboard. Consequently, the degree of recollection of each writing task was measured and analysed with repeated measures analysis of variance.

Additionally, this thesis deliberates the embodied cognition theory, as learning and memorizing are not simply information processing in nothingness. Experiences, actions and senses all play part in learning, as well as in writing process with the harmonious co-operation of brain, mind and body.

The results of this study indicate that writing modalities have statistically significant effect on recollection, handwriting receiving the highest scores. These results are of interest due to the constant increase of digitalization of learning environments. Moreover, these results can be reflected upon when evaluating the impending changes in the Finnish curriculum, from which cursive handwriting is removed in autumn 2016.

Keywords: handwriting, typing, embodied cognition, recollection, memorising

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1 INTRODUCTION

Our hands are tools which we can do countless of things with, from opening a door to painting a portrait. However, we can additionally use our hands to learn new things. Repetition and practice will help us remember how to tie our shoelaces or write our name (Gazzaniga, Ivry & Mangun 2014, 404-405; Purves et al. 2014, 695). Teaching and learning practices worldwide have changed and progressed immensely in the last decades (Lieberman 2012, 3). Information and communications technologies have entered the classroom and consequently modified and diversified teaching and learning methods (Bransford, Brown & Cocking 2000, 206). However, new technologies are bringing about a change in the ways people learn to recognize and recollect letters and words, read and write, as typing is introduced to many children from the first grade of school. At the same time, the teaching of cursive handwriting is oftentimes reduced or completely removed. Concurrently, as handwriting is marginalized, the usage of hands in learning and memorizing is fundamentally altered. Furthermore, the considerable marginalization of children's practice of writing with pen and paper possibly compromises their hand motor skills.

Electrophysiological recordings have shown that learning promotes structural change to the brain. This means that by learning, the new information affects memory and the functional organization of the brain. Furthermore, structural change in the brain seems to make the nerve cells more powerful or efficient. (Bransford et al. 2000, 118, 121; Gazzaniga et al. 2014, 414; Purves et al. 2014, 184.) According to James and Engelhardt (2012, 32) letter perception is enhanced by handwriting and thus, influences reading acquisition in early childhood. Longcamp, Zerbato-Poudou and Velay, in their turn (2005, 74) support that handwriting practice enhances memory under particular circumstances. Typing is, nevertheless, becoming a necessity at schools due to the integration of information and communications technology in school curriculums. Simultaneously, writing on a conventional computer keyboard is getting more and more infrequent as tablet computers and touch screen mobile phones with Internet access have become increasingly popular due to their practical size and ease of use. Swiping and typing on a touch screen virtual keyboard are the actions of the present-day technology users. Still, whatever the writing method, we write more often than not, in order to remember.

This study examines and compares the logical memory performance of thirty-one University of Lapland students' after three writing modalities: handwriting, typing on a conventional keyboard, and typing on a touch screen virtual keyboard. The shift from handwriting to typing can have implications yet to be understood and it is important to establish what kind of differences can be perceived in the delayed memory retrieval after handwriting and typing assignments. Specifically, this study investigates how recollection after handwriting and typing on a conventional keyboard and virtual keyboard differentiate and compare, and to what extent time or age is a factor in forgetting and remembering. Therefore, this study was expanded by adding a 1-week delay recall to the standard 30-minute delay recall in order to investigate short-term, as well as long-term memory. The objective is to further the understanding of the relationships between writing methods and memorizing. This study, however, does not bring to light as to why any method is better from the other.

Recently in Finland the issue of typing and cursive handwriting has become current. This is due to the forthcoming renewal of the national core curriculum from which the cursive handwriting is removed in autumn 2016[1]. Consequently, this action gives room to typing which is considered to meet better the needs of the present-day's demands. Simultaneously, new educational technologies and the new curriculum have brought about a dissonant dualism between educators,

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[1] http://www.oph.fi/ops2016
http://bit.ly/1VDtzp3

as well as parents; some are utterly adamant by their potentials and others are filled with uncertainty and anxiety. The imminent amendment of the Finnish core curriculum has also inspired lively discussion for and against the impending typing practice, as well as for and against the dismissal of cursive handwriting, both in domestic media[2] and in international media[3]. However, Finland is not the first country to make the decision to change the core curriculum regarding cursive handwriting. Several American states have made this decision already, as the Common Core State Standards since 2013 do not require it to be taught. Yet, the public opinion is still divided weather this has been a wise decision or not, and if cursive handwriting should be made mandatory at schools again.[4] The issue of abandoning or keeping the cursive handwriting is thence globally a current topic in the international media.[5] The aforementioned researchers, James and Engelhardt, Longcamp, Zerbato-Poudou and Velay, among others have proved that handwriting develops the human brain, thus the anxiousness and mixed feelings to the forthcoming changes of many educators and parents alike are justified.

However, research comparing the recollection of dictated handwritten and typed logical texts is non-existent. Moreover, research on the subject of recalling handwritten and typed words is limited at present, to the best of the knowledge of the researcher, to only two studies that have been conducted in the last decade; Smoker et al. (2009) focused on remembering words after handwriting and typing practice, and Mangen, Anda, Oxborough and Brønnick (2015) likewise investigated the recollection of words, but this time after three writing modalities: handwriting, typing on a conventional keyboard, and on a touch screen keyboard. These studies have brought evidence that handwriting does

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[2] http://bit.ly/25DFnum
http://bit.ly/1PbIdNB
http://bit.ly/1Uormsq

[3] http://bit.ly/1KxDtyS
http://bit.ly/1r70rtH

[4] http://nyti.ms/1ksz0GN
http://bit.ly/1Dn5lIn

[5] http://bit.ly/1sxybBk

have some memory enhancing effect. The study by Mangen et al. (2015) also speculated the embodied cognition, indicating to the fact that the motor action of handwriting is connected to learning, together with emotions and perception. This new theory of embodied cognition illustrates that learning is the outcome of harmonious co-operation of body, mind and brain. This view calls for further investigation, since new media are already in use in many classrooms, but understanding their effects on memory and recollection of more than letters or words is missing. This information is greatly needed by educators that wish to know how to use information and communications technology in teaching and learning to its best potential and benefit of the learners. Therefore, in order to address the issue of recollection of stories written in different modalities, this multidisciplinary study was conducted, combining media education with cognitive neuroscience in the light of theory of embodied cognition. This is an attempt to study today’s issues with today’s methods and theory. Apart from being current issue for today’s educators worldwide, the results of this study will be of interest due to the rapid increase of information and communication technologies use in teaching and learning for the enhancement of media literacy. Moreover, it will elicit valuable information that is beneficial when evaluating the impending changes in the Finnish schools due to the new curriculum.

2 BACKGROUND

2.1 New media entering classrooms

New media[6], together with Information and Communications Technology (ICT)[7], have altered the way we communicate, read and write in the digital age. New or digital media has three distinct features that modify and define its inevitable cognitive implications. These features refer to interactivity, multimediality, and hypertextuality. (Mangen & Velay 2010, 389; Mangen & Velay 2014, 73.) Interactivity is one of the core concepts of the new media discourse offering to the user the possibility to modify and control the device at his/her own will. Multimediality, on the other hand, describes the new media's digital infrastructure that supports simultaneously any type of text or audiovisual material to be created, modified and displayed on a single portable device, creating a platform for multitasking. Lastly, hypertextuality refers to the fact that digital content often consist links to other texts making information consist of interconnected chunks. (Mangen & Velay 2014, 73–74.) All these factors of the new media are bound to have cognitive implications particularly in writing, yet, studies on this subject are still very sparse (Mangen & Velay 2014, 76). Nevertheless, writing has always needed a medium, and these mediums are developing constantly.

Education in a formal classroom setting has been around for centuries, first recorded Westerners being from the first century learning the Talmud. Multiple subjects have been taught to children since the 15th century and educational systems and approaches have since been evolving continuously. (Lieberman

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[6] http://bit.ly/1ZmipUN

[7] http://bit.ly/1hrA9cC

2012, 3; Panelius, Santti & Tuusvuori 2013, 627.) Pen and pencil have been the writing tools of choice for most of this time. A lot of time and effort is put to acquire the skill to produce legible text quickly. As the dexterity of the children learning this skill develops, the more it is used inside and outside of the classrooms (Dinehart 2015, 10). Yet, this time consuming practice seems to have multiple benefits; reading skills and their development are considerably supported by handwriting practice (James & Engelhard 2012, 39; Longcamp et al. 2005, 76; Panelius et al. 2013, 628). Moreover, handwriting has been associated with the prospect of later academic achievement (Dinehart 2015, 10). Carlson, Rowe and Curby (2013), for instance, confirmed that the association of academic achievement with motor skills can be credited to person's visual-spatial integration that first constructs a mental representation of the image to be recreated and then produces it using small controlled muscle movements (Carlson et al. 2013, 527, 515). This study confirmed the visual-spatial integration to be associated with written expression, as well as mathematics (Carlson et al. 2013, 527).

Computers and typing on computer keyboards have invaded homes, workplaces and schools alike in the last quarter of the previous century, being nowadays ubiquitous (Light & Littleton 1999, 1). However, neither typing, nor the keyboard for that matter, is a recent invention. Christopher Latham Scholes patented the English QWERTY keyboard in 1868, and the first book to be created with this newly invented typewriter was Tom Sawyer by Mark Twain in 1904. (Logan & Crump 2011, 6.) In present times, computers in education have been known to contribute to collaborative learning and peer facilitation as the devices are often shared due to resource constraints (Light & Littleton 1999, 2; Underwood & Underwood 1999, 11–12). This leads not only to learning more, but also to performing better at the given tasks (Light & Littleton 1999, 2). Naturally, with the introduction of computers in the classrooms, the need to learn typing has surfaced. The skill to touch-type is generally beneficial to all students, but specifically so to students with learning difficulties, and particularly in circumvention of their difficulties in handwriting (Weigelt Marom & Weintraub 2015, 208). Also many first-graders in a study conducted by Van Leeuwen and Gabriel (2007) voiced the facilitating factor of ready-made letters that you simply need to find (Van Leeuwen & Gabriel 2007, 423).

Touch-typing on a conventional keyboard, similarly to handwriting, requires time and effort to master. It is based on a different concept from handwriting all together, being bimanual and utilizing up to all 10 fingers. It relies on kinaesthetic feedback, rather than visual feedback, as in handwriting and typing on a touch screen virtual keyboard. Typing also requires, according to West and Sabban (1982, 370–371), three distinct stages to be acquired. In order to proceed from one stage, or from one level, to the other, students learn the position of the keys, fluent movement patterns, acquiring speed, gradually relying less on the visual feedback from the fingers, focusing their attention on the computer screen (Sormunen & Wickersham 1991, 463; Weigelt Marom & Weintraub 2015, 209). As Weigelt Marom and Weintraub (2015, 209) put it, the process becomes automated.

Nowadays, in addition to typing on a conventional keyboard, it is increasingly common to type or swipe type on a virtual keyboard of a touch screen phone or tablet computer, but typing on it differs from a traditional keyboard in multiple ways. Naturally, the fingers travel longer distances on a conventional keyboard and need more finger flexor and extensor muscle activity than on virtual keyboard. On a tablet computer the keys are activated by minimal tactile action, due to which users must keep their hands and fingers above the device to avoid accidental activation of the keys. Consequently, this can lead to muscle pain and discomfort. (Kim, Aulck, Bartha, Harper & Johnson 2014, 1406, 1410–1411.) Furthermore, typing speed and accuracy suffer on a virtual keyboard. In a study conducted by Kim et al. (2014) typing speed was sixty percent slower on a virtual keyboard compared to conventional keyboard. In addition, typing accuracy dropped from ninety-five percent in desktop keyboards to eighty-four percent in virtual keyboards. (Kim et al. 2014, 1409.) This is due to the fact that the size of the virtual touch screen keyboard is smaller and thus makes the use of all ten fingers rare when writing on a touch screen device. Subsequently, as one cannot differentiate between the keys, one’s attention is once again in the writing hands. (Taipale 2015, 767.)

The new haptic action that has emerged with touch screen devices is that of swiping. It is a navigating technique which can be used on a touch screen device interface to achieve multiple actions: change pages, scroll up or down, zooming in, or to go back or forward, just to name a few actions (Billinghurst & Vu 2015, 78). Concomitantly, haptics in virtual environments are developing and swipe typing, or swipe input method, is becoming increasingly popular. This refers to the method of writing on a touch screen device with swipe keyboard application by sliding a finger from key to key without lifting it, in order to form a word. The aim of this method of writing is to produce text more quickly than by tapping the separate keys to form the words. (Conway & Sangaline 2015,1.) As Spizer (2013, 95) puts it, “[…] swiping has now become a part of our culturally inherited ways of manual dexterity”. Nonetheless, in this study, the texts on the touch screen device were produced by tapping each key separately.

In typing, conventional type keyboard seems to have its advantages over touchscreen virtual keyboard. However, matters are not so black and white; touchscreen phone usage evokes more brain activity than the usage of an old mobile phone with pushbuttons. (Gindrat, Magali, Balerna, Rouiller & Ghosh 2015, 109). Therefore, the typing action of a touchscreen of any size might affect, assist and support learning in a different manner. Furthermore, tablet computers can advance classroom interaction and enhance new learning environments (Benlloch-Dualde & Buendia-Garcia 2013, 2583). In the figure 1, developed by Benlloch-Dualde and Buendia-Garcia (2013, 2585), the multiple advantages and uses of tablet PCs in teaching and learning are discernible. Tablet computers offer services which enable and facilitate interaction and communication, among plethora of other things. They can be used individually and in group work permitting active collaboration of all involved, in person or virtually. (Benlloch-Dualde & Buendia-Garcia 2013, 2585.)

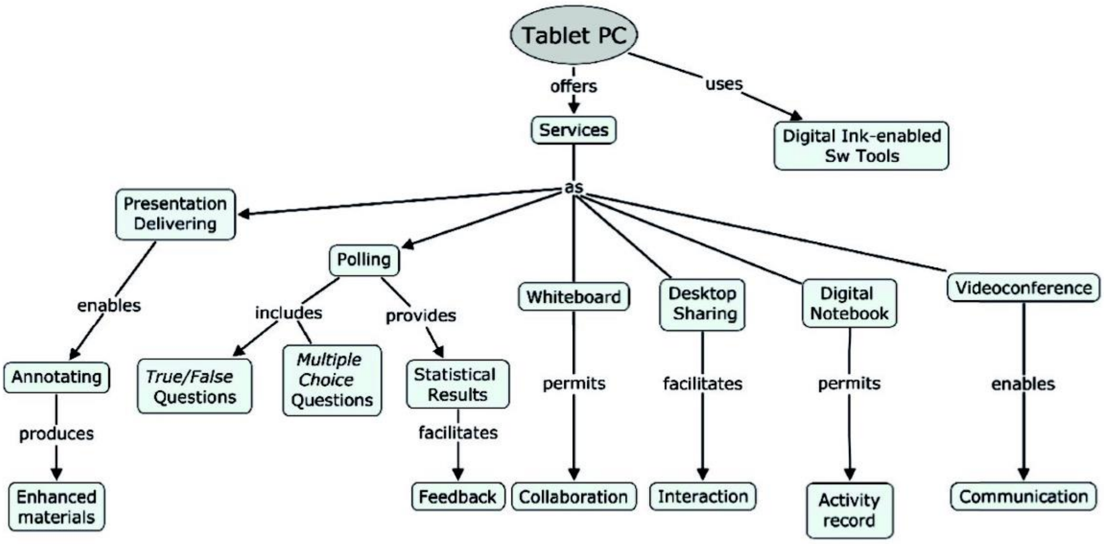

Figure 1. Tablet PC advantages (Benlloch-Dualde & Buendia-Garcia 2013, 2585).

Gartner, Inc., one of the world's leading information technology research and advisory companies, predicted in 2014 that tablet computer sales would surpass desktop computer sales by nearly 85 million units in 2015[8]. Furthermore, they anticipate more than half of consumers to choose tablet or mobile phone for all their online activities by 2018[9]. Considering the figure 1, the tablet PC's popularity is not surprising; the advantages of tablet computers are considerable. They can be used for notetaking, presenting, communication, just to name a few. Moreover, it is remarkable considering that iPad tablet computer

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[8] http://www.gartner.com/newsroom/id/2791017
[9] http://www.gartner.com/newsroom/id/2939217

was introduced only six years ago, in 2010 with the new technology touchscreens that are designed to be operated only with tactile interaction[10]. In education, the tablet computers have taken the role of supporting teaching and learning methods. Research has shown that in higher education students have greatly benefited from tablet computer use and subsequent individualized learning style. However, research on this subject at primary school level is needed. (Dunn, Beaudry & Klavas 2002, 88; Pruet et al. 2014, 3.)

Schools and universities alike have had to update their teaching methods in the globalizing world of education, as Information and Communications Technologies (ICTs) have become part of education providers' infrastructure at all levels of education (Wollscheid, Sjaastad, Tømte & Løver 2016, 70). Alongside the use of laptops, mobile devices are claiming their space rapidly in all educational fields due to their customizability (Pruet, Ang & Farzin 2014, 2). Mobile learning is an innovative way of taking advantage of information and communications technology. This means that various mobile devices, such as tablet computers and even mobile phones can be used as digital tools for learning anywhere, as they are hand-held, wireless and convenient. (Oberer & Erkollar 2013, 477–478.) Particularly in the Nordic countries, digital literacy is considered one of the core skills to be learned in compulsory education (Wollscheid Sjaastad, Tømte & Løver 2016, 70). Therefore, many educators have adopted various learning methods and opted for new learning environments. According to Van De Bogart (2012, 2) several studies support and emphasize the importance to prepare children in the digital age and develop their critical media literacy skills. However, at the same time there are concerns that the increase in media literacy has directly affected the decrease in the normal reading ability. This has been supported by research that has revealed fourth and fifth graders' severe reading difficulties to have increased in the last two decades by fifty percent. (Spitzer 2014, 81.) The message in this

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[10] http://apple.co/1jW50P4

might be that there is a need for further research on the subject of new media effects, in order to be able to use the new media devices efficiently in education.

2.2 The architecture of learning and memory process

The current study investigates short-term and long-term memory. Therefore, in the effort to facilitate the comprehension of the architecture behind these functions, memory and learning processes are explained. First these processes are described more generally, followed with a more detailed explanation of short-term memory and long-term memory.

Experience plays a key role in brain functions and memory. Different experiences have different effects on the brain, and learning experience adds synapses which means when information proceeds from one nerve cell to the other. Physical exercise, on the other hand, increases the density of blood vessels and hence the oxygen supply to the brain. Both of the above different mechanisms, oxygen supply and synapse formation, are essential forms of brain adaption. (Bransford et al. 2000, 118–120.) Bransford et al. (2000, 115) point out three main neural level aspects in the knowledge of learning development; the first is about structural changes to the brain caused by learning. The second aspect is that this structural change occurs due to the fact that learning simultaneously organizes the brain repeatedly. Finally, the third aspect is that the different sections of the brain of each individual might be ready to learn at different times. In other words, the brain is incessantly transforming through learning which takes place through synapses in the nerve cells. During learning experience synaptic connections are increased making them stronger, however, inactivity weakens the synaptic connections, a phenomenon known as Hebbian learning. Therefore, individual performances are defined by the synaptic activity and strength level. (Bransford et al. 2000, 115–116,119; Dubinsky, Roehrig & Varma 2013, 318; Gazzaniga et al. 2014, 381, 415–416; Howard-Jones 2010, 3; Korhonen 2006, 205.)

Correspondingly, studies of animals have shown greater blood supply to the brain in the animals that were raised in complex environments than the ones which were raised in cages. This is due to the bigger amount of capillaries, oxygen supplying blood vessels, per nerve cell. (Bransford et al. 2000, 118, 121.) Parasuraman and McKinley offer an example of jugglers, a study conducted by Draganski in 2004, where some individuals practiced juggling for three months and that were subsequently subjected to a Magnetic Resonance Imaging (MRI) scan. The jugglers showed "[…] increases in cortical grey matter in brain regions important in perpetual-motor coordination" (Parasuraman & McKinley 2014, 817). After the practicing period the participants were instructed to stop practicing for three months. A new MRI scan confirmed that the cortical regions had reverted to nearly their original size. (Parasuraman & McKinley 2014, 817.) This is a good example that establishes how skills need practice in order to be maintained.

Learning can be the outcome of many different actions and can therefore, occur in several regions of the brain. This means that there are different types of learning that are connected to different areas of the brain. For example, the cerebellum is involved in trial-and-error learning but in fear learning the amygdala plays a part. (Gazzaniga et al. 2014, 381–382; Purves et al. 2012, 703–706; Wikgren 2006, 329.) The medial temporal lobe memory system and the hippocampus are mainly involved with memory but other regions, such as the prefrontal cortex, together with the parietal cortex and subcortical structures can also participate in the storage of memories as well as their retrieval. (Gazzaniga et al. 2014, 381–382; Purves et al. 2012, 703–706.) Bransford et al. (2000, 122) further explain that the brain appears to have areas that are responsible for particular functions, such as processing audible, or visual message (speech and reading), producing an audible message (speaking), and thinking with language. However, further research is necessary to investigate the need to practice each component in an effort to promote each literacy and language skill (Bransford et al. 2000, 122).These above mentioned different language skills are obviously related, but at the same time more or less independent. Learners need to rehearse each of these skills in order to acquire the fluency of speaking, reading, and listening, and the ability to shift from one skill to the other effortlessly.

Learning and memorizing process of the information that is sustained has been divided into three stages: encoding, storage and retrieval. The first stage is where the information is encoded. Encoding creates memory traces which has two steps: acquisition and consolidation. In acquisition, the memories are stored in the short-term memory. In consolidation, on the other hand, a structural change in the brain reinforces the memory resulting in long-term memory. The second stage is storage, meaning that the outcome of acquisition and consolidation is recorded. Finally, the third stage is retrieval, implying to the ability to access, retrieve and use stored memories. (Eysenck & Keane 2010, 205; Gazzaniga et al. 2014, 381; Purves 2012, 698.) These memory traces are vulnerable and easily disrupted, and must therefore be well consolidated in order to prevent forgetting. Notably, when a memory or information is retrieved from the long-term memory, the same neural activity takes place again as during the initial registration of the occurrence. (Bauer 2015, 152.)

As mentioned before, memories are created by first encoding them, however, our brain processes and registers different things and aspects in different cortical areas (Bauer 2015, 152). The human brain has the ability to categorize long-term memories, which can last from a few seconds to one’s whole life, according to the type of the information stored. These two categories are referred to as declarative memory and non-declarative memory. Declarative memory consciously retrieves information that is explainable to others, whereas the non-declarative memory is called also procedural memory and refers to unconscious information, involving skills. (Eysenck & Keane 2010, 253; Gazzaniga et al. 2014, 381; Kellogg 2016, 142–143; Purves 2012, 695; Ward 2015, 203.)

Furthermore, memory has been traditionally divided into three basic storages according to the duration of the time that the memories are retained and other common features as follows: sensory memory, short-term memory or working memory, and long-term memory (Eysenck & Keane 2010, 205; Kellogg 2016, 106, 123; Purves et al. 2012, 696). The length with which we retain these memories can be anywhere from milliseconds to a lifetime. (Eysenck & Keane 2010, 205; Gazzaniga et al. 2014, 380; Purves et al. 2012, 696.) According to the traditional multi-store division, sensory memory may last only up to a few seconds, whereas short-term memory or working memory may last up to some minutes. Long-term memory, however, can last even a lifetime. (Eysenck & Keane 2010, 205; Gazzaniga et al. 2014, 380; Purves et al. 2012, 696.) However, this multi-store model has been criticized lately by some theorists, pointing out to the fact that memories are not stored simply in these clear-cut three different categories. They have defended a unitary-store model where the clear distinction between long-term and short-term memory is more flexible. (Eysenck & Keane 2010, 205.) The short-term memory and long-term memory are further explained in the following subchapters.

2.3 Short-term memory

Short-term memory holds information from milliseconds to some minutes. It includes three different forms; firstly, the echoic and iconic sensory store for the transient information we hear and see respectively, secondly, the short-term memory for the information about the surrounding world, and thirdly, the working memory for short-term limited-capacity temporary storage of information that can be manipulated. (Gazzaniga et al. 2014, 384–387; Kellogg 2016, 107–111; Koivisto 2006a, 195.) Even if short-term memory can be considered the limited capacity of information that is held “in mind” for the moment lasting less than half a second (Gage & Berliner 1998, 258; Ward 2015,196), it nevertheless, plays a vital part in learning and memory. According to Atkinson and Shiffrin (1968), if a piece of information from short-term storage is rehearsed, it can be relocated to long-term memory (Eysenck & Keane 2010, 206; Gazzaniga et al. 2014, 385; Kellogg 2016, 112; Ward 2015, 200). However, it is not certain if all information must be encoded in short-term memory prior to their retention in long-term memory (Eysenck & Keane 2010, 209; Gazzaniga et al. 2014, 385). Additionally, research has discovered that humans have the capacity to recode information into chunks; letters can be combined into words that are easier to recall. Therefore, the integrated units of information are as many as the letters of any given word, concurrently facilitating information retention. (Eysenck & Keane 2010, 207; Gazzaniga et al. 2014, 385; Koivisto 2006a, 196.)

Since the concept of short-term memory system was considered inflexible by some scientists, it was replaced by Baddeley and Hitch (1974) and Baddeley (1986) (Eysenck & Keane 2010, 211; Koivisto 2006a, 196). The new concept was that of working memory, which was not as clearly defined as short-term memory and encompassed four different components, giving it a wider meaning (Eysenck & Keane 2010, 211). The most essential of these components is the central executive. Even though with limited capacity, it deals with all cognitive tasks, resembling attention. The other components are the phonological loop, holding information in spoken form, the visuospatial sketchpad, coding visuospatial information, and lastly, the episodic buffer, where the information from the former two components are integrated with information from the long-term memory. The co-functioning of the phonological loop and visuospatial sketchpad with the central executive is essential to cognition. (Carlson 2006, 212–213; Gage & Berliner 1998, 259; Eysenck & Keane 2010, 211–212; Gazzaniga et al. 2014, 387–388; Kellogg 2016, 132–133; Koivisto 2006a, 196; Ward 2015, 255.) The central executive has been suggested to function also during dual-task situations (Eysenck & Keane 2010, 219). Furthermore, the capacity of the working memory differs between individuals. It has been suggested that this refers to the ability to retrieve and use previously acquired knowledge and skills. (Kaakinen 2006, 377–378.)

The functioning of working memory has been explained simply that it is used when we temporarily store and manipulate information in short-term memory (Ward 2015, 199). An example of this ability is the calculation of new prices in shops after a discount. Simultaneously, information is temporarily retrieved about mathematical equations from long-term memory, and used in an activated state in a cognitive task, as the new amount is calculated. (Carlson 2006, 212; Gazzaniga et al. 2014, 387; Kellogg 2016, 133.) This means that one is able to use earlier knowledge and experiences in processing new information (Kaakinen 2006, 379).

2.4 Long-term memory

Long-term memory (Fig. 2) can store unlimited amount of information that is consciously both retrievable and non-retrievable (Eysenck & Keane 2010, 253; Ward 2015, 196). As mentioned earlier, long-term memory includes two different forms: declarative and non-declarative. The knowledge that we are able to access at will is declarative memory. This entails facts and events from personal life, as well as generally from the world. This is sometimes described as "knowing what". Non-declarative memory, on the other hand, is knowledge that we cannot access at will, such as motor skills, habituation and cognitive skills. This is sometimes described as "knowing how", as these are skills that are learnt through rehearsal. (Bransford et al. 2000, 124; Eysenck & Keane 2010, 253; Gazzaniga et al. 2014, 389–393; Kellogg 2016, 142–144; Koivisto 2006a, 196; Parasuraman & McKinley 2014, 816; Purves et al. 2012, 695.)

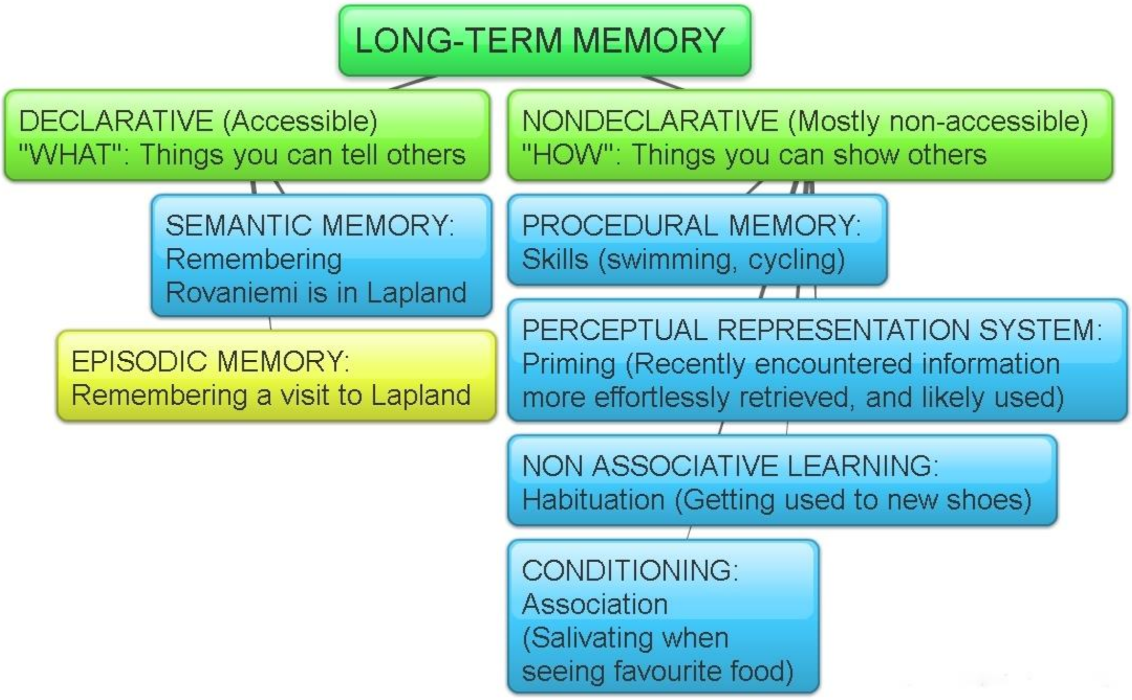

Figure 2. Long-term memory, modified from Gazzaniga et al. (2014, 381), Kellogg (2016, 143) and Purves et al. (2012, 696).

The non-declarative memory has further subdomains from which the procedural memory relates to skills such as swimming that is non-consciously retrieved. Perceptual representation system is another subdomain of the non-declarative memory, however, this system uses perceptual priming, taking advantage of the fact that information is more effortlessly retrieved if it has been recently encountered. Other subdomains of non-declarative memory are the non-associative learning that involves habituation and sensitization. Simply put, we get used to new shoes or eyeglasses. Conditioning involves also associations, such as salivation is a result from seeing favourite food. (Eysenck & Keane 2010, 256, 272–278; Gazzaniga et al. 2014, 390–393; Kellogg 2016, 143; Purves et al. 2012, 695–696; Ward 2015, 203.) Parasuraman and Mckinley (2014, 816) explain that to acquire certain skills, both declarative and procedural components of learning and memory are involved. Hence, learning is increased by practice and repetition, through which the brain's memory functions will store information that is then retrievable later on. (Bransford et al. 2000, 124–125.)

The declarative memory has two distinctive subdomains proposed by Tulvig (1972, 384), those of semantic and episodic memory (Koivisto 2006a, 197; Laatu, Revonsuo & Luokkakallio 2006, 227; Ward 2015, 203). The semantic memory is knowledge about facts and concepts, such as people, world, objects and language, whereas the episodic memory is knowledge about events and personal experiences, as well as meaningful occurrences in particular context. (Alhola & Portin 2006, 218; Eysenck & Keane 2010, 256–257; Gazzaniga et al. 2014, 421; Kellogg 2016, 142–143, 146; Laatu et al. 2006, 227; Tramoni et al. 2011, 817; Tulvig 2002, 1, 3; Ward 2015, 203.) For example semantic memory means knowing that Rovaniemi is the capital of Lapland. Remembering a visit there, however, requires episodic memory. Hence, these two memory systems are often combined in their functioning. (Eysenck & Keane 2010, 259.) One theory is that episodic memory evolved from semantic memory (Tulvig 2002, 6). However, these are two separate memory systems as semantic memory retrieval occurs mainly on the left hemisphere, whereas also the right frontal hemisphere is associated with memory retrieval from the episodic memory. (Tulvig 2002, 18.)

The process of slow long-term memory consolidation is still unclear; nevertheless, there are two main theories: the standard consolidation theory, and the multiple trace theory. The former was presented by Larry Squire and colleagues in 1984, presenting neocortex's essentiality in storing thoroughly consolidated long-term memories, with the hippocampus in only minor temporary part. On the contrary, the latter theory proposed by Nadel and Moscovitch in 1997, considers hippocampus to play an important role in episodic memory retrieval, consolidated or not. Neocortex in this case is used for the storage of long-term semantic information. (Gazzaniga et al. 2014, 414–415.) As mentioned, more research is still needed in order to clarify memory processes.

Experiences, events and stories that are contextually-bound, and flow in time and place, form consequently a narrative that can be retrieved from the episodic memory (Kiefer & Trumpp 2012, 16; Tramoni 2011, 820). Logical memory that is investigated in this study, belongs to the episodic memory (Fig. 2, in yellow), and is also referred to as story or paragraph memory, as one remembers occurrences of stories in logical or chronological order (Cunje, Molloy, Standish & Lewis 2007, 65; De Anna et al. 2008, 305). Time cannot be turned back; however, we can mentally travel back in time and remember past events, retrieving the memories from episodic memory. This past-oriented memory system is exceptional and unique for humans, with some reservation. It develops late and deteriorates often early (Tulvig 2002, 2, 5) however; it gives us the possibility to relive past experiences at will (Gage & Berliner 1998, 263; Tulvig 2002, 6).

2.5 Forgetting

The mnemonic powers of the human brain are incredible, however, the human brain has the ability to retain rather limited amount of meaningless information. Memories fade over time, particularly if things are not used or rehearsed, or if they are not perceived important. (Gage & Berliner 1998, 260; Purves et al. 2012, 702.) Simply put, this means that people are good at forgetting (Bauer 2015, 147; Purves et al. 2012, 702). The forgetting mechanisms of short-term memory and long-term memory seem to differ (Fig. 3).

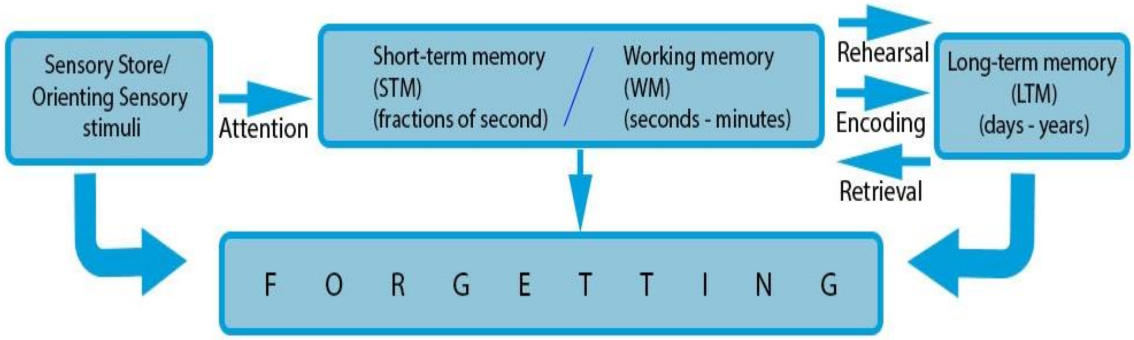

Figure 3. Information processing in different categories of memory, modified from Gage and Berliner (1998, 258) and Purves et al. (2012, 696).

From the sensory store, where we momentarily hold iconic and echoic stimuli for further processing, information is lost due to decay. If attention is given to the stimuli, it will be stored in the short-term memory from which the information is, in turn, displaced. On the other hand, rehearsal and encoding of the information promote their long-term memory retention. Yet again, information is lost from long-term memory, but this time due to interference. (Eysenck & Keane 2010, 206–209). It is notable that autobiographical and episodic memory improves with age. Young children do not have the same capacity to remember past events as adults do, and similarly, adults do not remember much of their toddlerhood. This is explained simply through the fact that young children do not have a past or memories to forget yet. (Bauer 2015, 147–148, 154.)

Nevertheless, information is lost constantly, either by decay over time or by interference of new information that displaces the old, or by a combination of these two (Gazzaniga et al. 2014, 385). Forgetting may also be essential part of efficient use of the brain’s potential (Ward 2015, 220). Currently vital information, such as the location of the eyeglasses, is retrieved with ease, compared to the same information about the location of the eyeglasses last week. Additionally, information may not be retrievable if it is not processed adequately at encoding, and consequently failed to get consolidated (Kellogg 2016, 154; Ward 2015, 220, 228). Nonetheless, it is very hard to ascertain whether something has been forgotten, or merely hard to retrieve (Kellogg 2016, 106, 126, 161; Ward 2015, 220).

2.6 Remembering

If properly rehearsed, encoded and consolidated, our brain can store an immense amount of information. Some of the information we purposefully memorize, however, a lot of information is stored without any particular conscious effort. Hence, acquiring new information occurs through learning which may be achieved from no effort at all, or from many repeated efforts. Moreover, significant individual differences do apply. Some people may learn any given material from only one attempt, whereas someone else might need several repetitions of the same material in order to learn and remember it. The outcome of this learning process is memory. (Kaakinen 2006, 374, 376–377.) Another important factor in learning and remembering is the attention one pays to any given audible, visual or other stimulus. Sometimes people’s attention is directed involuntarily from one target to another, however, people have the ability to voluntarily pay attention to something in order to remember it better. (Alho, Salmi, Degerman & Rinne 2006, 242–247.) Simple awareness or consciousness of matters does not have this outcome (Koivisto 2006b, 286–287).

However, the brain does not have a tendency to keep pointless information (Koivisto 2006a, 196; Purves et al. 2012, 698). Meaningless digits are hard to remember, but lists of single words, familiar dates, or otherwise meaningful chunks of information are more easily remembered. Moreover, the retention of information depends on how it is associated with past experiences, in which context it appears now, and how much the person values this information. (Purves et al. 2012, 699–701.) According to Miller (1956, 81) only approximately seven items can be remembered by humans from a list. Purves et al. (2012) agree to this and also point out that it is possible to remember fourteen to fifteen items from shortly presented 5x5 matrix (Purves et al. 2012, 698). This is also a skill that can be improved with practice.

On the other hand, it has been verified that the capacity to retain information is considerably reduced when polysyllabic words are used (Baddeley et al. 1975) or when the words are phonologically similar (Baddeley 1966, 334). However, rehearsal plays an important role in remembering (Kellogg 2016, 112; Ward 2015, 197). In fact, memory span can be exercised and hence, increased. One method is to associate the digits with something and give them a meaning. (Purves et al. 2012, 699.) The intention to remember something and repeating it mechanically in the phonological loop of the working memory does not guarantee that the issue will be stored in the long-term memory. A more productive way to remember would be associating the issue with some earlier information to give it a meaning. (Koivisto 2006a, 196.)

There are sometimes occurrences or events that we would like to forget, and other occasions that we would like to remember. Memory, however, works its own ways for all of us. There are no two identical memories of events, as we perceive things differently, each from our own individual perspective, which is affected by our surroundings, mental state, past experiences and emotions. In the following chapter, the concept of embodied cognition is discussed. This means that learning and remembering are influenced by not only by the pure information that is processed in the brain, but the external and internal simulations, as well as experiences, taking into account a holistic perception of the learning situation.

3 THEORETICAL FRAMEWORK

3.1 The embodiment of cognition

The brain has two hemispheres, left and right. These two hemispheres are then further divided into four lobes: the frontal, parietal, occipital and temporal lobes. Each lobe of the cerebral cortex has different cognitive functions which have been studied by different neuroimaging techniques. The frontal lobe is involved with problem solving, reasoning, concentrating, thinking, behaviour and movement. The frontal lobe has two subdivisions, those of prefrontal cortex and the motor cortex. The temporal lobe is responsible for memory, as well as auditory and language skills. The parietal lobes are associated with perception and integrating different somatosensory information and memories, as well as some mathematical skills. The occipital lobes are involved in visual processing and perception. (Gazzaniga et al. 2014, 222; Purves et al. 2014, 53–57.) However, is learning purely information processing and different areas of the brain?

Mangen et al. (2015, 302) and Kiefer and Trumpp (2012, 16) explain that theories of embodiment are receiving all the more increasing empirical support for proposing synchronized function of sensory and motor brain functions. They further justify their view with behavioural and neuroscientific studies, that cognitive processes do not occur in vacuum. This connection and reciprocity of motor actions and perception is referred to as embodied cognition. It has its roots in disciplines such as, cognitive psychology, neuroscience, philosophy of the mind, anthropology, robotics and phenomenology. (Jirak, Menz, Buccino, Borghi & Binkofski 2010, 711; Mangen et al. 2015, 302; Mangen & Velay 2010, 385.) The theory of embodied cognition is fundamentally based on the concept of harmonious cooperation of the brain, mind and body, a theory founded in the 1990’s by Damasio, LeDoux and Edelman (Paloma, D’anna, Rio & Pastena 2013, 1054). Cognitive processes are the result of perceiving external simulation together with bodily affects and internal understanding of the emotions, sensations and state that produce reminiscences of previous experiences, simultaneously prevailing the dualism of mind and body (Ionescu & Vasc 2014, 276; Kiefer & Trumpp 2012, 16; Paloma et al. 2013, 1054, 1056; Zwaan & Pecher 2012, 1.) Cognition and motor action, together with visual, tactile and audio perception are thereby interconnected in learning processes (Mangen et al. 2015, 302). Consequently, the theory of embodied cognition presumes sensory and motor brain systems to be the key factors of embodiment together with body’s own morphology and mind’s state (Ionescu & Vasc 2014, 275; Kiefer & Trumpp 2012, 16) linking single sensorimotor experiences with more complex cognitive functions, such as language processing (Jirak et al. 2010, 711). Simply put, affective neuroscience is revealing that the mind is influenced by an interdependency of the body and brain; both the body and brain are indeed involved in learning (Immordino-Yang & Damasio, 2007).

The theory of embodied cognition supports the view that perception and action of same concepts are represented in the brain within the same sensory-motor circuitry (Aziz-Zadeh & Damasio 2008, 35). This theory has received further biological verification with the finding of mirror neurons first in monkeys, and sequentially in humans in 2010 by Mukamel, Ekstrom, Kaplan, Iacoboni and Fried (2010, 750) while observing single neuron responses. Furthermore, the same year Keysers and Gazzola (2010, R353) confirmed the existence of mirror neurons in several more brain regions than had been assumed previously. These findings confirmed that mirror neurons are active during execution of action, as well as when merely observing it. (Aziz-Zadeh & Damasio 2008, 36; Jirak et al. 2010, 713; Keysers & Gazzola 2010, R353; Mangen et al. 2015, 303; Mukamel et al. 2010, 750.) This means that a person observing others performing an action causes the observer’s brain to be stimulated as if he/she was actually performing the action in question him/herself. (Aziz-Zadeh, Wilson, Rizzolatti & Iacoboni 2006, 1818, 1821; Mukamel et al. 2010, 750.) Moreover, observing someone’s emotions from facial expressions also simulate the same brain regions in the observer (Mukamel et al. 2010, 750; Paloma et al. 2013, 1056). Furthermore, there is neurophysiological evidence that when we recall actions that we have performed ourselves, the brains’ motor areas are activated (Senkfor, Van Petten & Kutas 2002, 402) and when we recall visual or acoustic information, the visual (Ranganath, Cohen, Dam & D’Esposito 2004, 3917) and auditory (Wheeler, Petersen & Buckner 2000, 11125) brain areas are activated respectively.

Reading and writing have also an effect on brain’s motor area activation. Merely reading written text symbols causes the same motor areas of the brain to active that are activated when one is actually handwriting those same symbols (Heimann, Umilta & Gallese 2013, 2833). Similarly, action verbs seem to activate the brain’s motor areas whereas abstract verbs do not have this effect (García & Ibáñez 2016, 56; Jirak et al. 2010, 714). Additionally, performing the action together with the corresponding verb facilitates remembering it, rather than just reading the verb (Engelkamp, Seiler & Zimmer 2004, 1). From this, we can deduce that human cognition is a so called “action-perception loop” where the mind receives perceived input from the outside environment resulting in action output to the outside environment (Mangen et al. 2015, 303; Mangen & Velay 2010, 394). Thus, the importance of embodiment of cognitive processes cannot be overlooked, as cognition is not solely information processing in the brain. The brain works in congruence with the mind and body, perceiving simultaneously multiple types of stimulations resulting in embodied cognition.

3.1.1 Embodiment of cognition and writing

Hand gestures can facilitate the cognitive load of explaining (Goldin-Meadow & Wagner 2005, 238–239). If simple hand gestures produce such an effect, one can only speculate how much hand movements facilitate other cognitive functions and in memorizing these functions. Hands are the crucial element of writing, in all writing methods. Learning to write in all methods require effort and repetition, as well as different brain activities. Reading is often considered directly connected to writing, even if it is perceptual, whereas writing requires manual sensory-motor skills and visual perception, hence separating haptics and visual component of writing. Moreover, the haptic affordances of different writing modalities, such as handwriting and typing are distinctly different. Haptics imply to the active execution of movement together with the tactile perception that is associated with it. (Mangen & Velay 2010, 385, 389.)

Nevertheless, handwriting has been confirmed to enhance letter recognition and subsequent reading acquisition that simple pressing of keys does not. (Kiefer & Trumpp 2012, 16.) Furthermore, a magnetoencephalography (MEG) study by Longcamp, Tanskanen and Hari (2006) revealed stronger excitation of primary motor cortex when the participants were presented with handwritten letters than with printed letters. This, in turn, can be deduced to support the embodied element of interpreting and perceiving handwritten characters. (Longcamp, Tanskanen & Hari 2006, 687.) Thence, reading is affected by writing techniques, since reading activates sensory-motor programs of writing in people who use handwriting. Subsequently, they also have superior letter recognition skills in reading tests to those who type, supporting stronger consolidation and sensory-motor memory traces of meaningful actions. (Kiefer & Trumpp 2012, 16.) Therefore, the theory of embodiment offers a compelling argument opposing the view that reading and writing are separate entities, calling for recognising writing and writing technique’s influence to reading acquisition and performance. This relation is becoming increasingly complex as diverse digital devices are inundating the classrooms at all levels of education, marginalising handwriting.

3.1.2 Embodiment of cognition and episodic memory

The current research seeks to investigate the episodic memory which one needs in order to comprehend and interpret entire sentences and consequences (Berkum 2008, 378). The skill to competently process and comprehend complex sentences develops across childhood, requiring brain maturity together with verbal working memory (vWM) (Fengler, Meyer & Friederici 2016, 268, 277). Sentences are processed one word at a time, building on the cumulating knowledge of it in two phases: analysis and evaluation. First, the human mind analyses the words' syntax. In the second part the meaning from the first analysis is evaluated using grammatical, as well as, semantic, visual and experiential information in order to interpret first the words and then sentences.

How people process sentences has been divided into two distinct parsing categories or strategies; the first category is that of serial parsing where one assumes only one possible interpretation for the sentence from the beginning of it. Yet, when it is realized that the interpretation is not correct, another interpretation is considered. In the second so called parallel parsing one considers several possible interpretations from the beginning of the sentence, refining the analysis with each new word. (Järvikivi & Pyykkönen 2010, 117.) This means that during processing the sentence it is constantly interpreted and reanalysed. Consequently, the following sentence will be understood in the context of the previous one, as the story unfolds. (Berkum 2008, 376; Järvikivi &

Pyykkönen 2010, 117–118.) This, in turn, will result in a sort of discourse analysis (Berkum 2008, 377) of logical stories, such as the ones stored and retrieved from the episodic memory. Furthermore, the process of interpreting sentences containing actions, simulate potentials in the same sensorimotor and emotional circuits of the brain as if the person was actually executing these actions. This gives rise to the thought that action, perception and cognition are intertwined and thus, embodied, and not arbitrary. (Chersi, Thill, Ziemke & Borghi 2010, 1; Scorolli & Borghi 2007, 119, 121.)

3.2 Previous studies on handwriting and typing

The essence of learning lies in the process of learning and cognition, in the brain and mind. Neuroimaging and brain technology has gone forwards in the last decades immensely, simultaneously offering a new opportunity to explore the neural mechanisms behind learning and cognition. This has given new insights into the functioning of the human brain during learning, and has led to the insinuation of cognitive neuroscience and cognitive psychology into education.

Writing always requires a tool or a physical device, may it be a quill, pen, keyboard, touch screen or simply a finger applied on a surface or a pad (Mangen & Velay 2010, 387). The end result using any of the different tools is however, written text. The writing modalities with different tools can be differentiated mainly according to their involvement with hands, as well as eyes, as the haptics of writing differ greatly from one writing modality to the other. Handwriting's unimanuality and relative slowness compared to typing's bimanuality and speed are merely the primary visually perceived differences (Mangen & Velay 2010, 385). The sensorimotor processes of handwriting and typing are hugely different (Alonso 2015, 263). In handwriting, as only one hand is used to form each letter at a time, the attention is on the tip of the tool, simultaneously seeing and observing the written result. Typing, on the other hand, mostly being bimanual, can utilize all 10 fingers. An experienced typist can type without looking at his/her fingers, locating and pressing the readymade letter keys, whilst eyeing the text appearing on the screen. Less experienced typist will need to struggle eyeing fingers on the keyboard and text on the screen at the same time. What is more, graphomotor processing is not involved in mere pressing of keys, as it is in handwriting. (Alamargot & Morin 2015, 32; Alonso 2015, 265; Mangen et al. 2015, 301; Mangen & Velay 2010, 385–386, 389.) Interestingly, Farinosi, Lim and Roll (2016) point out the new habit of many to choose writing modality according to the length of the text to be written. In total 206 students from Germany, Italy and United Kingdom participated in a study which found that the students preferred traditional pen and paper for short text and creative tasks, whereas keyboard was preferred for longer texts (Farinosi et al. 2016, 411, 414).

Handwriting, typing on conventional keyboard and typing on touch screen devices have been compared in various studies. For the sake of this research relevant studies have been analysed and divided into two categories according to their research approach: cognitive neuroscientific, and multidisciplinary research approach that includes behavioural and cognitive psychological perspective. However, studies with social or cultural perspective have been excluded, as in this study the essence is the recollection of written text.

3.2.1 Studies with cognitive neuroscientific approach

The following studies have used a cognitive neuroscientific approach with different brain imaging methods, naturally including educational insights in their research in order to study writing from different perspectives. Neuroscientific evidence supports that three brain regions activate during handwriting: left superior frontal sulcus (SFS) / middle frontal gyrus (MFG) area, left intraparietal sulcus (IPS) / superior parietal area, and anterior cerebellum (CB) (Planton, Jucla, Roux & Démonet 2013, 2778), indicating the importance of the left frontal and superior parietal regions relation with handwriting (Planton et al. 2013, 2772). The acquisition of handwriting requires first the memorizing of each letter's visual representation, as well as memorizing the motor representation for each letter in order to be able to use them in their reproduction (Bara & Gentaz 2011, 745). Reading, even if related to writing, requires several cognitive functions, such as letter and word recognition, grammatical processing, text modelling and analysis, and metacognitive monitoring (Bruer 1997, 10; Heimann et al. 2013, 2833). On the other hand, typing and other similar learned motor actions, such as playing the piano, requires co-operation of several brain regions; motor cortical regions, cerebellum and the striatum being essential both in acquisition of the skill, as well as maintaining it. (Underleider, Doyon & Karni 2002, 554.)

Marieke Longcamp has studied different writing methods and their effects on retention and recall of single letters with numerous methods and with multiple research teams over the years. In their study, Longcamp, Zerbato-Poudou and Velay (2005, 67), aimed to confirm differences and motor changes in single letter recognition after handwriting and typing practices in 76 preschool children aged three to five years old. Earlier functional Magnetic Resonance Imaging (fMRI) study by Longcamp, Anton, Roth and Velay (2003, 1492) had confirmed activation of premotor zone in the left hemisphere when right-handed subjects were presented visual stimulation. The occurrence of the opposite in left-handed subjects was confirmed in a similar fMRI study by Longcamp, Anton, Roth and Velay (2005, 1801). All these studies confirmed that letter recognition is not purely visual but a complex network of neurological components. (Longcamp, Zerbato-Poudou & Velay 2005, 69.) Furthermore, Longcamp, Zerbato-Poudou and Velay (2005, 76) found that the older children's character recognition was considerably improved after handwriting exercises. This corresponds with a study by van Galen (1980) which confirmed motor development as a central factor in handwriting. However, Longcamp, Zerbato-Poudou and Velay (2005, 76) emphasize that the maturity of a child plays a significant role in his/her sensorimotor skills and hence in the correct representation of characters. (Longcamp, Zerbato-Poudou & Velay 2005, 77.) Generally, the children that wrote the letters by hand got more correct replies than the children who had typed them, but the difference between these two results reached only marginally the significance level ($F(1,70)=3.86$, $p < 0.06$). Interestingly, the older children that had used handwriting to learn the characters, produced more correct replies compared to the children of same age that had used typing to learn the characters ($F(1,23)=7.35$, $p < 0.02$). (Longcamp, Zerbato-Poudou & Velay 2005, 74.) One cannot, consequently, draw a conclusion that these results are applicable as such to reading or writing that involves words, and not isolated letters. Similarly these results are not generalizable to adults or literate persons, however, assumptions can be drawn that handwriting practice supports memory under certain circumstances. The following year, Longcamp, Boucard, Gilhodes and Velay (2006) conducted a similar study on twelve adults with similar outcome; letters learned through typing were not recognised as accurately as the letters that had been learned through handwriting (Longcamp, Boucard, Gilhodes & Velay 2006, 646).

The two above mentioned studies on adults (2006) and preliterate children (2005) formed the basis of the fMRI study conducted by Longcamp et al. (2008) where twelve adults were given the task to learn new unfamiliar letters by handwriting and typing. Again, the group that was given the handwriting task performed better, recalling and recognizing the letters longer than the control group that had been typing these characters. (Longcamp et al. 2008, 802.) This suggests that long-term consolidation happened during writing practice, and that there is a deep neural interconnection between the practice of handwriting, letter recognition and reading.

James and Engelhardt (2012), on the other hand, conducted a study in which fifteen preliterate five-year old children were given the opportunity to learn single letters through tracing, drawing and typing. As these learning methods use different types of motor experiences the children's letter perception in different brain regions could be measured with fMRI. (James & Engelhardt 2012, 32.) As a result, James and Engelhardt (2012, 39) argue, that handwriting practice promotes the development of brain areas known to activate during reading and letter processing. These areas are the left Inferior Frontal Gyrus (IFG), the left Anterior Cingulate Cortex (ACC), and particularly the left fuciform gyrus. However, typing practice together with letter perception does not produce more brain activity than other sensori-motor actions. Additionally, contrary to earlier findings of Katanoda, Yoshikawa and Sugishita (2001, 34) and Richards et al. (2011, 493), this study found bilateral activation of the precentral gyrus. The earlier studies had found unilateral activation, however, this can be explained with the participants´ mature age and reading abilities. The study of James and Engelhardt (2012, 41) supports the hypothesis together with earlier studies that printing practice develops the fuciform gyrus and hence alters the visual processing of letters. At the same time it enhances letter recognition. Merely viewing the letters does not result in this kind of neural activity.

As the present study investigates also writing on a touch screen device, it is necessary to take into consideration the various different sizes of these devices, and the consequent different typing method. For example, due to the touchscreen phone devices' limited size, the most used fingers to interact with a smaller device are the index finger, thumb and the middle finger (Gindrat et al. 2015, 109). Therefore, in the study by Gindrat et al. (2015), the above mentioned right hand fingers have been subjected to research which aimed to confirm whether there is any difference in the somatosensory cortical electrical activity between the old-technology phone users and the touchscreen phone users after simulation of their fingertips. This is particularly interesting approach since fingertips are used on all sizes of touch screen devices. The measurements were taken with electroencephalography (EEG) using sixty-two electrodes on the thirty-seven right-handed subjects' scalp that were all university students between 19 and 34 years old. Event-related potential technique (ERPs) was used to measure brain response to the 1250 tactile stimulations on each of the three fingertips chosen for this study. Each stimulus lasted 2ms. (Gindrat et al. 2015, 109.) The ERP is a technique which is used to pinpoint where specific cognitive processes occur during planned or simulated tasks (Luck 2005, 4).

The results of the touchscreen phone study were thought-provoking: For the touchscreen phone users, the right hand thumb, index and middle fingertips all produced larger magnitude of the positive ERP than the old-technology phone users. Moreover, when the results were put on a statistical map of the skull, differences for all the measured fingertips were clustered in the same region of the contralateral parietal scalp. (Gindrat et al. 2015, 109.) From the three fingers the thumb was noticed to be mainly involved with the touchscreen. Additionally, the touchscreen users' potentials from the three fingers were increased with comparison to the old-technology users. The higher level of cortical activity within the group of touchscreen phone owners was considered possibly to be the result of the elevated usage of the right hand thumb compared to the old-technology phone users (Gindrat et al. 2015, 109). The possibility of particular skills related to touchscreen usage was considered to be the reason for the elevated level of cortical activity. (Gindrat et al. 2015, 110.)

The age of inception did not seem to be connected with the amount of phone usage per hour (Gindrat et al. 2015, 111). However, there seemed to be a connection between the hourly usage of the phone and the conducted ERP. The ERPs triggered larger positive signals the more the touchscreen phone had been used during the 10 days prior to the EEG recordings. (Gindrat et al. 2015, 111.) “The cortical activity evoked by touch to the thumb tip was directly proportional to the amount of phone use over the past 10 days and inversely proportional to the time elapsed from a period of intense use” (Gindrat et al. 2015, 111). In the light of these results, the possibility of the cortical sensory processing being reshaped without cessation according to the usage of a touchscreen is considered. (Gindrat et al. 2015, 109.) Moreover, 80 percent of the owners of touchscreen phones used their devices actively to send and receive e-mails and text messages, which is consistent with a Pew Research Center’s survey findings from 2013[11]. Furthermore, the old-technology phone users spent considerably less time with their devices compared to the touchscreen phone owners. (Gindrat et al. 2015, 109.)

Writing from dictation is known to involve particular areas of the temporal-parietal cortex of the left hemisphere (Roux et al. 2014, 70). The earlier mentioned research by James and Engelhardt (2012) corresponds to previous studies regarding the role of the left fuciform gyrus that was confirmed to develop as a consequence to motor experience which in this context implies handwriting. Longcamp, Zerbato-Poudou and Velay (2005, 75) together with Longcamp et al. (2008, 802) support this view as well, believing that handwriting practice of single letters facilitates their memorizing and recognizing. The most compelling argument is that handwriting modulates visual processing. This, in turn, enhances the child’s ability to differentiate between letters. (James & Engelhardt 2012, 41.) These studies have confirmed the positive effect of handwriting to sensorimotor skills and the influence that the practice of this skill has subsequently to the recollection and recognition of

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[11] http://pewrsr.ch/OotDJE

single letters. However, these results are not generalizable, as the results are confirmed under certain circumstances, concerning only particular age group or a group of certain level of literacy. Moreover, the sample sizes have been rather small in all of these studies concerning letter recognition or recall with the only exception of the study conducted on seventy-six children by Longcamp, Zerbato-Poudou and Velay in 2005.

3.2.2 Studies with multidisciplinary approaches

The following studies have used multidisciplinary approaches in their effort to research writing methods and recollection from multiple perspectives. Smoker, Murphy and Rockwell (2009, 1744) conducted a between-subjects study on sixty-one undergraduate students from 18 to 24 years old to investigate the recollection and recognition of certain entire words after handwriting and typing practice. This is the first study about the potential connection of writing modality and memory on a word level. The study wanted to confirm a connection between psychomotor action and memory and consequently the handwriting practice's enhancing effect on memory. (Smoker et al. 2009, 1744.) A one-way ANOVA variance analysis was used to see if memory works better after handwriting the stimuli words rather than typing them. The recollection test produced borderline statistically significant results for handwritten words (F(1,59)=3.34, p= .065) and interestingly for typing, the number of errors were statistically significantly higher in this test (F(1,59)=4.803, p= .032). At the same time, the recognition test brought statistically significant results (F(1,59)=4.63, p= .036) for handwritten words. (Smoker et al. 2009, 1746.) Even though the results of the recall test of handwritten words are not statistically significant, according to Smoker et al. (2009) the results do support the hypothesis that a connection between psychomotor action and memory exists. Words can be more easily remembered after printing practice than after typing, supporting the view that the repeated kinaesthetic information from handwriting practice results in a more complex and durable memory trace than typing practice does. (Smoker et al. 2009, 1746.)

Mangen et al. (2015, 306–307) conducted the second, and so far the last, research investigating the associations between writing methods and memory at single word level. This time thirty-six female Norwegian university students and staff participated in an experimental within-subjects research. The participants were given the task to write word lists using pen and paper, touch screen device, and computer keyboard in order to test episodic verbal memory. As the writing methods were three, the participants were to listen to three different words lists and write them down each list with different method. (Mangen et al. 2015, 308.) The results indicated statistically significant for free recall in the handwriting condition (p< .049). Additionally, positive correlation was found between the years of experience with touch screen devices and the touch screen recall lists (rho= .329, p= .050), meanwhile this type of correlation between keyboard and recall lists did not appear. The recall lists for keyboard and touch screen device did not have any difference. (Mangen et al. 2015, 310–311.) The results of positive correlation between touch screen device experience and the recall lists give rise to the thought that the findings of the research by Gindrat et al. (2015) on the touch screen phone use are applicable here as well. Their results indicated increased cortical activity from the fingers involved with the touch screen by touch screen phone users compared to the old technology phone users (Gindrat et al. 2015, 109).

Some other studies that investigated writing and typing but not the ability to recollect the written text have had various outcomes, however, are worth mentioning. Berninger, Abbott, Augsburger and García (2009) conducted a study analysing a total of 241 children’s handwriting and typing in the second, fourth and sixth grades as they wrote the alphabet, sentences and essays.

Berninger et al. (2009, 123) believe that handwriting does support learning outcomes. However, in their study, keyboard produced faster results in writing the alphabet. On the other hand, essays were more quickly executed by hand and the handwritten sentences were more complete for fourth and sixth graders. Children with disabilities had also better results when using pen. (Berninger et al. 2009, 123.)

Ouellette and Tims (2014), on the other hand, compared the difference in orthography after learning non-words by practicing their spelling by handwriting in one group and by typing in another. They got null findings from their quantitative study on forty second-graders. The participants were tested one, and seven days later, however, the practice modality did not exhibit any difference in the outcome. (Ouellette & Tims 2014, 1, 7.) Mueller and Oppenheimer (2014), in their turn, compared university students' subject comprehension after taking notes with laptops and by handwriting. Their findings indicated typing to be detrimental to learning, suggesting shallower information processing than handwriting. Handwritten notes were written more in the students' own words, hence promoting deeper understanding of the subject. (Mueller & Oppenheimer 2014, 1159–1166.)

Furthermore, Alamargot and Morin (2015) conducted an exploratory study comparing graphomotor execution of ballpoint pen and paper with plastic-tipped pen on a tablet screen with twenty-eight second, and ninth graders. All participants were asked to write the alphabet and their names and surnames with both writing methods while the kinematics was recorded. The letter legibility decreased for both groups in the tablet screen test. Simultaneously, the ninth graders increased letter size, as well as their writing speed and the strength with which they pressed the pen down on the tablet surface. These results suggest new technology writing devices instigating disturbance in graphomotor execution and muscle control during handwriting. (Alamargot & Morin 2015, 38–39.)

To end with, the research conducted by Kiefer et al. (2015) on twenty-three preliterate children investigated reading and writing performance after introducing eight letters to half of the children by typing and other half by handwriting during sixteen sessions. From the letters also four letter words were formed and taught. The hypothesis was that the sensory-motor memory trace of handwriting would be a facilitating factor for literacy acquisition compared to the relative easiness of typing. Indeed, the pre-schoolers showed some increased accuracy of reading and writing of four letter words they had learned by handwriting, supporting the assumption of meaningful connection between action and perception. However, on single letter level no difference was perceived between writing modalities. (Kiefer et al. 2015, 136–144.)

Writing and remembering what one has written are essential in studying, hence difficulties in writing can cause multiple problems. If writing is laborious, it often results in short notes and exam replies, lacking in substance. (Ahonen 2008, 80). Moreover, the same difficulties that one has with handwriting can occur in typing as well. Typing requires considerable practice in order to facilitate text production. However, typing has the considerable advantage of producing more legible text. (Ahonen 2008, 82.) The results of the studies concerning typing and handwriting generally indicate positive outcomes for all writing practices, depending on the research perspective. The same inconsistency has been found in a research review conducted by Wollscheid Sjaastad and Tømte (2016, 29). The cognitive neuroscientific studies support the handwritings' significant positive effects, whereas other disciplines found advantages also in digital tools considering writing. Typing is associated with speed, ease and legibility. Additionally, it has been reported to promote collaborative learning. (Light & Littleton 1999, 2; Underwood & Underwood 1999, 11,12; Van Leeuwen

& Gabriel 2007, 423; Weigelt Marom & Weintraub 2015, 208.) Therefore, any definite favourable conclusion towards any writing method is impossible based on these studies.

However, studies concerning memory and recollection of written letters or words lean towards the mnemonic power enhancing effect of handwriting. Children’s printing practice seems to result in enhanced memorizing, more brain activity, and development in brain areas used for reading and writing than other learning practices, thus confirming handwriting’s importance in letter perception. (James & Engelhardt 2012, 41; Longcamp, Zerbato-Poudou & Velay 2005, 75.) The same has been confirmed on adults (Longcamp, Boucard, Gilhodes & Velay 2006, 646; Longcamp et al. 2008, 802; Mangen et al. 2015, 310–311; Smoker et al. 2009, 1746). This is consistent with the research review conducted by Wollscheid Sjaastad and Tømte (2016, 29) even if their review regarded only five articles relevant to this study from a slightly different angle.

The aforementioned studies on letter and word memorizing and recollection have confirmed handwriting having some enhancing effects compared to typing practice. Yet, the results of only one study by Mangen et al. (2015) had statistically significant results. Thence, general conclusions cannot be drawn from these results concerning longer texts, only assumptions can be made that handwriting might have some memory enhancing effect compared to typing. Both typing and handwriting practices, nonetheless, are needed to maintain motoric skills and mitigate memory loss. Handwriting and typing are completely different projects, even if the produced results are the same: written text. Thus, the marginalizing of handwriting by the replacement of cursive handwriting with typing during learning to write can lead to implications on sensory motoric level, as the cerebral representations of letters are changing together with their memorizing process (Mangen & Velay 2010, 397). Therefore, the lack of research is evident, and more research is needed on all age groups.

Neuroscientific research is needed to define the brain functions of writing longer texts with different modalities in order to comprehend the memory functions behind these practices. Furthermore, the complete lack of research on recollection of handwritten and typed text, particularly by the children that have learned typing instead of cursive handwriting, calls for immediate empirical multidisciplinary investigations. Research on this subject is urgently needed in order to assist the teaching and learning of the new generation in the best possible manner and to understand if and how generational differences apply. The current study is an attempt to narrow the gap in this multidisciplinary field of research.

4 METHODS

This study investigates and compares the immediate and delayed logical memory performance, also referred to as story memory or paragraph memory performance after tasks in handwriting, typing on a conventional computer keyboard, and typing on a touch screen virtual keyboard. Thirty-one Finnish University of Lapland students participated in this study. The Wechsler Memory Scale Revised Edition (WMS-R) Logical Memory (LM) subtest was used with experimental within subjects' research-design. With each method the participants wrote down a dictated short story. The retention of these stories was measured after a 30-minute delay, and additionally after a 1-week delay in order to assess short-term and long-term memory.

4.1 Objectives and research questions

The objective of this study is to provide additional insights into the connection between writing method and memorizing. Moreover, this study aims to investigate the differences perceived in the memory retrieval after writing tasks with different writing modalities, and to examine the effect of time, and writing speed in recollecting the written tasks. This study, however, does not aim to bring to light as to why any method is better from the other. The following research questions emerged in the effort to find answers to the objectives of this research. It should be noted that in the research questions the word typing refers to both, typing on a conventional keyboard, and typing on a touch screen keyboard.

Research Question 1: How is the logical memory performance affected by a 30-minute and 1-week delay after handwriting and typing tasks?

Research Question 2: How is the logical memory performance affected by delay after handwriting and typing tasks if the factor of time spent for the task completion is considered?

Research Question 3: How is the logical memory performance affected by age after handwriting and typing tasks?

Research Question 4: How do the recall results of handwriting and typing tasks compare among each other?

Research Question 5: How does the logical memory performance differ after handwriting and typing tasks?

4.2 Participants and ethics

Thirty-one Finnish University of Lapland students volunteered for the measurements of their degree of recollection of stories after using three different writing modalities. The volunteers were recruited from six different methodological and language courses that are common for all students by distributing an appointment list among students while explaining the purpose of this study and asking for volunteering participants. From the participants thirty were right handed and one was left handed. All participants had Finnish as their native language. This confirmed that all participants had as similar level of the language as possible, since the native language's phonetic and intonation processing abilities are acquired in the first year of childhood, whilst more complex syntax and grammar is learned from before the age of three until seven (Fengler et al. 2016, 268). Three participants reported mild dyslexia. None of the participants had physical issues with their hands. The mean age these participants had started typing was ten years, which is coherent with the study conducted by Logan and Crump (2011, 6) on 246 typists. The participants were also required to be available in person or by phone for a follow up measurement after one week. In table 1, there are descriptive statistics for gender and faculty of the participants.

Table 1. Demographics of participants.

	Frequency	Percent
Gender		
Male	10	32.3
Female	21	67.7
Faculty		
Faculty of Education	16	51.6
Faculty of Law	2	6.5
Faculty of Social Sciences	13	41.9

Additionally, in table 2, there are descriptive statistics of the participants' age to start typing, years of experience with conventional and touch screen keyboards, and number of fingers used in typing.

Table 2. Participants' age and typing experience.

	Mean	SD	Min	Max
Age	29.5	8.6	21	51
Age to start typing	10.2	3.5	4	20
Years of experience with conventional keyboard	16.7	4.7	10	26
Number of fingers used in typing	8.2	2.2	2	10
Years of experience with touch screen keyboard	4.8	1.7	1	9

The participants mostly used writing method (Fig. 4) was typing on a conventional keyboard by 67.7 percent. Only 9.7 percent of the participants reported handwriting to be their writing method of choice, and 16.1 percent chose touch screen devices to write. Mere 6.5 percent reported not to prefer any method more than another.

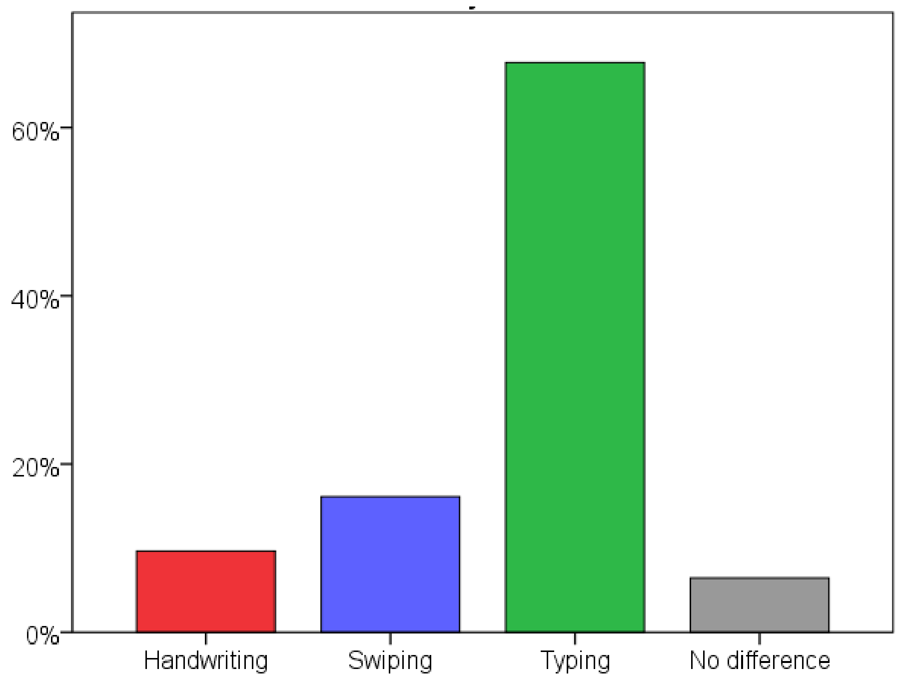

Figure 4. Method mostly used by the participants (N=31).

The University of Lapland is committed to the guidelines of the Finnish Advisory Board on Research Integrity (TENK)[12] for promoting responsible conduct of research, and monitoring research integrity. Research conducted, should be ethically acceptable, reliable and it should produce credible results. Furthermore, responsible research follows the principles of integrity, meticulous conduct of research and data recording, as well as accurate presentation and evaluation of the research results. (TENK 2012, 30.) In the realization of the current study, all possible measures were taken in order to conduct the research according to the above principles. Prior to data acquisition, all participants signed a consent form (Appendix A). In the consent form details of the study and its purpose was written according to the guidelines of National Advisory Board on Research Ethics 2009. These guidelines have also been described by Cohen, Manion and Morrison (2000, 51).

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[12] http://www.tenk.fi/fi/htk-ohje/sitoutuneet-organisaatiot

Before the data collection, the subjects were informed about the aims of the study, what this study is about, its topic, how the data was going to be collected, what the data would be used for, and how much time the data collection would approximately take. Besides, they were given contact information in case they needed any additional information later on. (National Advisory Board on Research Ethics 2009, 7.) Furthermore, the subjects' participation in the data collection was confidential and any information retrieved during the data collection is treated as such. Subjects were promised complete anonymity (Cohen, Manion & Morrison 2000, 61–62; National Advisory Board on Research Ethics 2009, 10–11, 13) and that when presenting the results of this research, the identities of the subjects will in no way be compromised. The research data is confidential and does not contain any direct or indirect identifiers in order to protect the privacy of the subjects. Access to any research data is limited only to the researcher, and the data are securely archived by the researcher as advised by the Finnish Advisory Board on Research Integrity (TENK)[13].

4.3 Research design

An experimental within-subjects research design was used in this study. Experimental research is rarely used in educational field; however, this method can provide further understanding of causal relationships also applicable in education. It aims to discover something by varying certain conditions, and consequently observing or measuring the effect. (Cohen, Manion & Morrison 2000, 126; Mertens 2010, 143; Schumacher & McMillan 1993, 295.) Simultaneously, maximum control is exercised on any probable impertinent or extraneous variables (Krauth 2000, 21; Mertens 2010, 143; Schumacher & McMillan 1993, 295), and randomizing assignments, tasks and subjects are commonly used to enhance statistical conformity (Schumacher & McMillan

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[13] http://bit.ly/1TPOZuB

1993, 296). Furthermore, in a within-subjects experimental research, such as this study, a single group of participants is exposed to two or more conditions, followed with measurements and comparisons of the effect (Schumacher & McMillan 1993, 296). In this study the conditions were handwriting, typing on a conventional keyboard and typing on a touch screen keyboard. The conditions imply to the independent variable that is essential in experimental design. The independent variable needs to be manipulated, in order for the effect of the manipulation to be measured. (Hoy 2010, 16; Schumacher & McMillan 1993, 296.) This independent value is the predecessor causing an effect on the consequent dependent variable (Hoy 2010, 32) that needs to be measurable in magnitude or quantity (Hoy 2010, 30; Schumacher & McMillan 1993, 297). Variables are thus either measured or manipulated; the measured variable needing a scale of measurement while the manipulated variable is controlled by the researcher. (Hoy 2010, 33.)

In this study, there was a single group of random students from the University of Lapland. The aim was to measure the effect of writing modality on memory retrieval. The measured variable is the recollection of the students, meaning that the dependent variable (DV) of this study is memory that is assumed to be affected by the manipulated independent variable (IV) that is the writing modality. Moreover, memory, the dependent variable (DV), is operationally defined by the Wechsler Memory Scale making the measurements as constant as possible, and hence also reproducible. The group of participants was subjected to three different writing conditions: handwriting, typing on a conventional keyboard, and typing on a touch screen virtual keyboard.

4.4 Research method

At the beginning of the data collection, all participants signed a consent form (Appendix A) and filled in a questionnaire (Appendix B) about their basic details prior to the measurements. The flow of the research is shown in figure 5. In the questionnaire the participants revealed their gender, age, and handedness, faculty of studies, preferred writing methods and details of them.

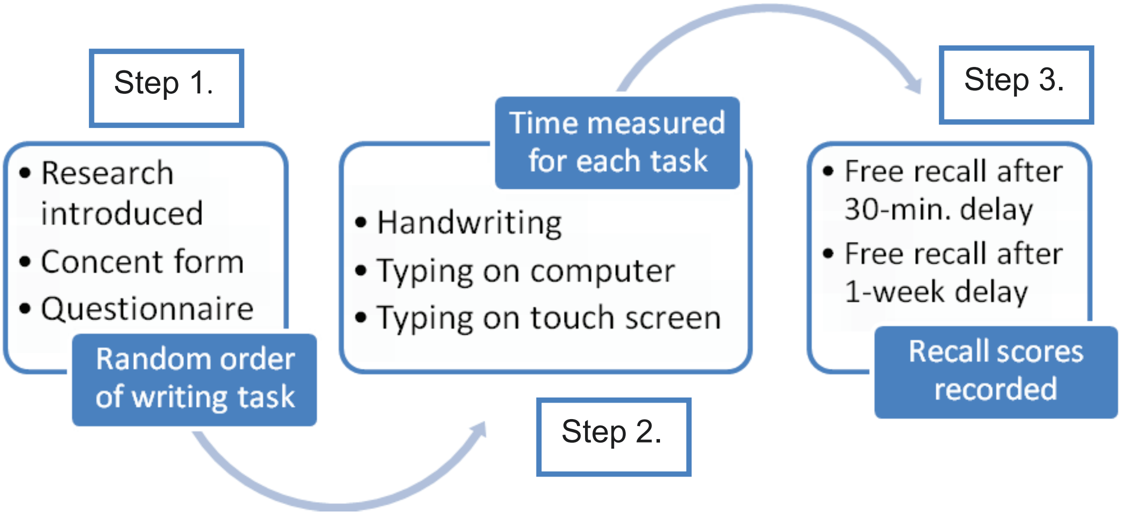

Figure 5. Flow of research.

For this study, the Finnish-abridged version of Wechsler Memory Scale (WMS) Revised Edition Logical Memory (LM) subtest was used as it is internationally recognized memory test used by psychologists around the world (Kuuskorpi 2012, 84).[14] Additionally, it is the most common memory test used by Finnish psychologists (Kuuskorpi & Keskinen 2008, 7). Logical Memory subtest is one of the primary subtests of the battery of tests included in WMS-R. Although

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[14] www.psych.ufl.edu/~fischler/Hm/wmspres.ppt

previous studies have examined different writing methods and learning, previous studies have concentrated mainly on single letters or words. In order to investigate memorizing of longer texts, short stories were needed which this particular subtest provides. Furthermore, plain observation or alternatively interview or questionnaire alone could not possibly give precise enough conclusion as to how much one retains of text that one has written with one or another method. Therefore, Wechsler Memory Scale (WMS) Revised Edition Logical Memory (LM) subtest was used to extract segments valuable to this research. The test was conducted in Finnish which is the first language of all participants.

The two texts of the logical memory subtest (Wechsler 1987, 54–55) are logical and contextually-bound in order to investigate the episodic memory within the declarative memory. Standard delays of free recall without cues are measured immediately after auditory presentation and again after approximately 30 minutes by asking the participants to recount the stories they were subjected to. The stories incorporate 25 details, each of which the participant must recall in order to obtain points. The scores are calculated from the sum of points remembered by the participant. As these stories are part of a battery of tests used by psychologists around the world, the stories cannot be enclosed in this study.

Some necessary alternations and an addition were made to the above mentioned logical memory subtest. This subtest having two different stories, and the writing methods investigated in this study being three, an additional similarly challenging story was created. This story was tested with the students of a psychological measurements course in University of Jyväskylä to see that the students recalled as many details as they normally would in the logical memory test. Additionally, this logical memory subtest is normally used to recall only orally heard stories, however, for this study the stories were dictated once and simultaneously written down (see figure 5 for flow of research). The subjects were allowed to shortly view their text after finishing each of them. The writing speed of the subjects' was measured and quantified by recording the time needed for each task completion facilitating the comparisons between the different writing methods. The retention of the three stories was measured with a free recall test after a standard 30-minute, and after an additional extended 1-week delay to see the longer term retention of the written stories. No cues were given to the participants about the stories before recounting them.

4.5 Data collection

Data collection was conducted in an office provided for this purpose at the Centre for Media Pedagogy, Faculty of Education in the University of Lapland in February and March 2016. As this was an experimental study, a randomizer[15] was used to make sure that both the writing methods and the texts to be written were assigned randomly for each participant. With each writing method, handwriting, typing on a conventional keyboard and typing on a touch screen virtual keyboard, the participants wrote down a different dictated short story seated comfortably on an office chair by an office table. The participants were told to write down verbatim each dictated story. They were also told that they would need to recall as many details of the stories as possible. The time required to write each story was recorded. The participants were given unlimited time to freely recall the written stories after thirty minutes and again after one week delay. The test took approximately 1,5 hours to take on the first day together with the explanation of the procedure, the filling of the consent form and the questionnaire, and fifteen minutes the following week for each participant.

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[15] https://www.randomizer.org/

A Dell Optiplex 990 desktop computer with full-size Dell KB212-B keyboard and Dell P2412H 24” LCD display with 1920x1080 pixel resolution was used for the typing task. The participants wrote on a Microsoft Office Word document with the window open to 132 percent, using Calibri Body 11 point font. For touch screen measurements, a third generation iPad running IOS 9.2.1 with Microsoft Office Word document and Calibri 11 point font was used. This size of iPad was chosen for this study due to the fact that this is one of the most popular sizes[16] and used in many schools and preschools around the world. For handwriting assignment, a pencil and A4 sized white paper were provided.

4.6 Analysing method

The WMS-R logical memory subtest stories had twenty-five details each to be recalled. For each recalled detail one score was obtained. The analysis of WMS-R logical memory subtest scores, and the analysis of the quantified information collected from the questionnaire, was performed by using descriptive statistics. The main statistical approach was repeated measures analysis of variance carried out with IBM Statistics SPSS 22 (Statistical Package of Social Sciences SPSS Inc., Chicago, IL) analysing program. Degrees of freedom were corrected by the Greenhouse-Geisser values whenever appropriate. Pairwise comparison was performed using Bonferroni adjustment, and correlations were investigated with Pearson’s correlation coefficient. Additionally, whenever considered necessary, partial correlation analysis was conducted. Detailed description of analysing methods for retrieving results for each research question, are found in table 3.

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[16] http://bit.ly/YpU0oa

Table 3. Analysing methods of the study according to the research questions.

Research question	Analysing method
RQ1: How is the logical memory performance affected by a 30-minute and 1-week delay after handwriting and typing tasks?	• Frequency analysis, percentages • Correlation analysis (Pearson) • Mauchly’s Test of Sphericity • Test of within subjects Effects • Repeated measures variance analysis • Greenhouse-Geisser correction
RQ2: How is the logical memory performance affected by delay after handwriting and typing tasks if the factor of time spent for the task completion is considered?	• Frequency analysis, percentages • Correlation analysis (Pearson) • Mauchly’s Test of Sphericity • Test of within subjects Effects • Repeated measures variance analysis • Greenhouse-Geisser correction
RQ3: How is the logical memory performance affected by age after handwriting and typing tasks?	• Frequency analysis, percentages, mean values • Correlation analysis (Pearson) • Scatter plot • Partial correlation analysis
RQ4: How do recall results of handwriting and typing tasks compare among each other?	• Frequency analysis, percentages • Correlation analysis (Pearson) • Mauchly’s Test of Sphericity • Test of within subjects Effects • Repeated measures variance analysis • Greenhouse-Geisser correction • Pairwise Comparisons Test with Bonferroni Adjustment
RQ5: How does the logical memory performance differ after handwriting and typing tasks?	• Frequency analysis, percentages, mean values • Correlation analysis (Pearson)

5 RESULTS

5.1 Logical memory performance and delay factor

In this chapter I answer the first research question: How is the logical memory performance affected by a 30-minute and 1-week delay after handwriting and typing tasks?

As each participant's logical memory was tested on all three writing modalities, handwriting, typing on a conventional keyboard and typing on a touch screen keyboard, after a 30-minute and 1-week delay, the repeated measures two-factor within subjects' variance analysis was conducted. This was to compare the effect of writing modality on recall scores after 30-minute delay and after 1-week delay in handwriting, typing on a conventional keyboard, and typing on a touch screen keyboard conditions. Mauchly's Test of Sphericity, Table 4, reported homogeneity of covariance.

Table 4. Mauchly's Test of Sphericity.

Measure: Score of recollection

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.
Writing modality	.980	.574	2	.751
Time delay 30min+1week	1.000	.000	0	.
Writing modality Time delay 30min+1week	.998	.057	2	.972

The chi-square values X^2 (2, N=31) = .57, p= .75, and p= .97) and their associated p-values showed significance, thus Tests of Within-Subjects Effects was conducted to further confirm these results, which The Tests of Within-Subjects Effects subsequently confirmed (Table 5).

Table 5. Tests of Within-Subjects Effects.

Measure: Score of recollection

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Writing_modality	Sphericity Assumed	157.559	**2**	78.780	**6.947**	**.002**	**.188**
Error(Writing_modality)	Sphericity Assumed	680.441	**60**	11.341			
Time_30m_1w	Sphericity Assumed	88.086	**1**	88.086	**24.564**	**.000**	**.450**
Error(Time_30m_1w)	Sphericity Assumed	107.581	**30**	3.586			
Writing_modality * Time_30m_1w	Sphericity Assumed	.785	2	.392	.279	.758	.009
Error(Writing_modality*Time_30m_1w)	Sphericity Assumed	84.548	60	1.409			

According to the results, writing modality has statistically significant effect on recollection (F(2, 60) = 6.95; p= .002). Additionally, time delay affects recollection statistically significantly (F(1,30) = 24.56; p< .001). Eta squares for both factors are larger than .14, confirming the large effect; for writing modality partial eta squared = .19 and for time delay partial eta squared = .45. The interaction, however, was not statistically significant (F(2,60) = 0.39; p = .76) (df=degrees of freedom). These results and the time delays' effect on recollection are more visually perceptible in the figure 6 with the mean values and standard deviation.

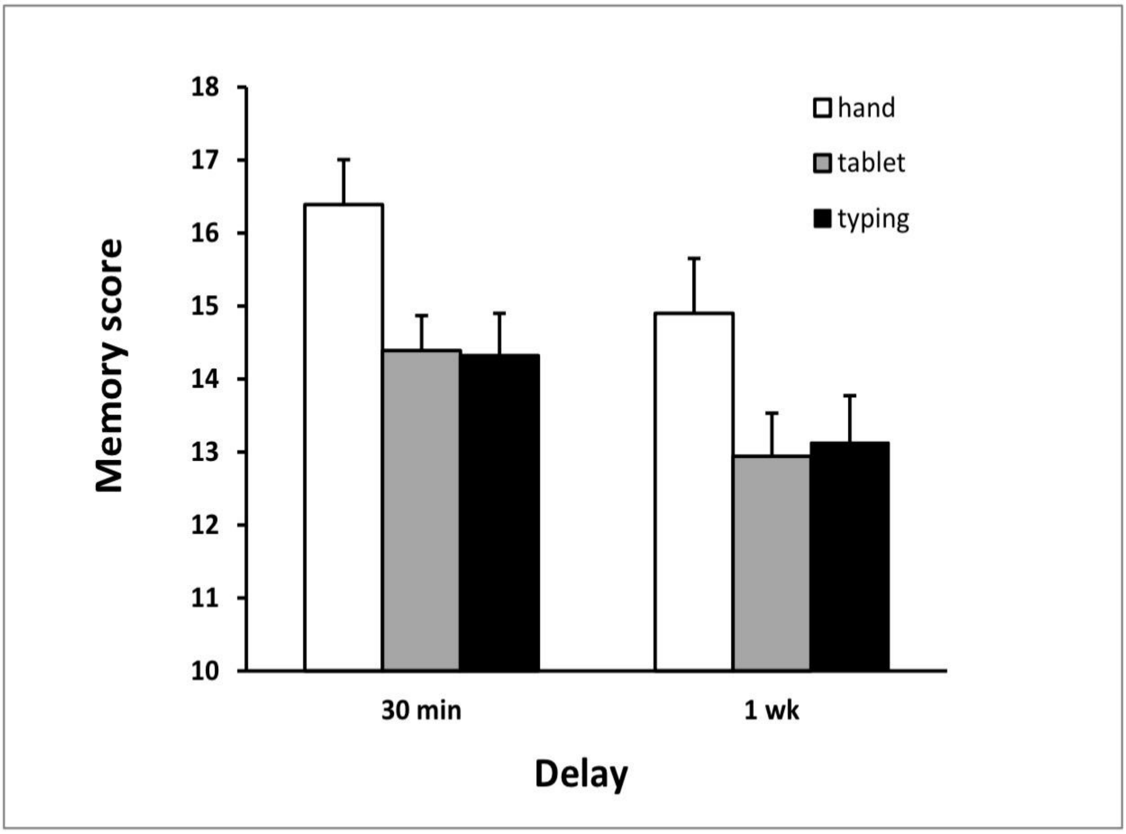

Figure 6. Delays' effect on recollection in each writing method.

The white bars indicate the handwriting, the grey the touch screen keyboard results, and the black bars the conventional keyboard typing results after a 30-minute and 1-week delay. For all writing methods the recollections scores have dropped visibly in this figure after one week. Also the Greenhouse-Geisser corrected values in Appendix C, Table 1 (F(1.38, 41.43)=6.92, p= .006) confirm the above time delay effect.

5.2 Logical memory performance and time factor

In this chapter I answer the second research question: How is the logical memory performance affected by delay after handwriting and typing tasks if the factor of time spent for the task completion is considered?

As the time used to write each story had been recorded, it was possible to evaluate if the time spent to write the stories was a factor in recollecting the written stories afterwards. Hence, The Tests of Within-Subjects Effects (Appendix D, Table 2) was repeated with an additional variable that was made from the measured times that the participants had used to write each story. The results confirmed the omnibus effect of time spent to write the stories having statistically significant effect on recollection, or non-recollection, indicating that the stories written on the conventional keyboard, which was the least time consuming writing modality, demonstrated accelerated forgetting after 1-week delay.

Mauchly's test indicated that the assumption of sphericity had been violated ($\chi2(2) = 26,47$, $p < .001$), therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = 0.63$), as they were smaller than .75. Then, by using an ANOVA with repeated measures Greenhouse-Geisser correction, the mean scores for recall scores concentration gave statistically significant values ($F(1.77, 53.06)=7.68$, $p= .002$). The figure 7 shows visibly the above mentioned accelerated forgetting after tasks in typing on a conventional keyboard.

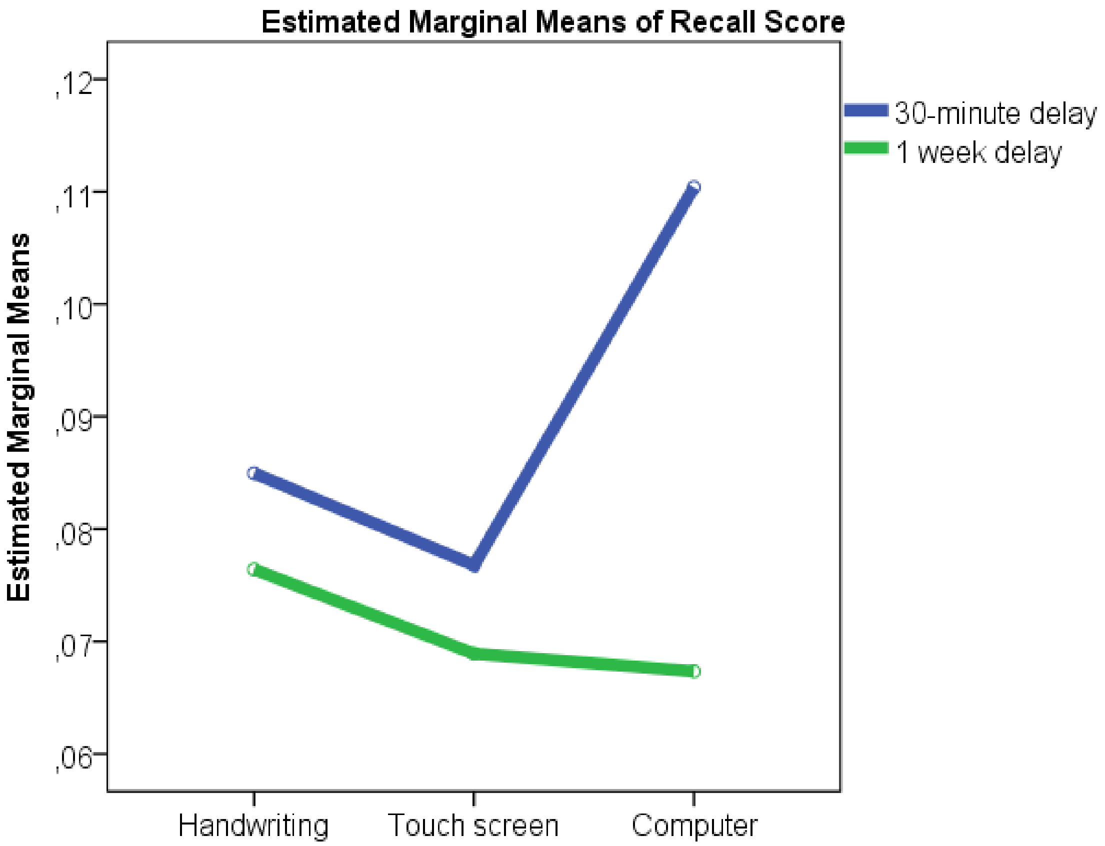

Figure 7. The effect of time delays and time spent to write tasks on recollection in each writing method.

The figure 7 also shows the mean scores for each writing modality after 30-minute and 1-week delays and the effect of time used for writing task completion on recollection. Typing on a conventional keyboard was forgotten more than typed text on a touch screen virtual keyboard, which indicates the relative slowness of new media touch screen devices to be a memory retention factor.

5.3 Logical memory performance and age factor

In this chapter I answer the third research question: How is the logical memory performance affected by age after handwriting and typing tasks?

A Pearson product-moment correlation coefficient was computed in the effort to assess the relationships between the age of the participants and the recall scores, as well as time used for different tasks, as well as the years the participants had used conventional keyboard or touch screen device keyboard. These results do not indicate cause and effect, but associations between variables. Age had a positive correlation with both, the best score after a 30-minute delay [r(31)= .49, p= .005], and the worst scores after a 30-minute delay [r(31)= .54, p= .002]. The scatter plot (Fig. 8) shows the moderate positive association between the age and the best scores after a 30-minute delay indicating linear increase in scores together with age. This means that within this group of participants, the recall scores were better among the older participants. Same kind of linear increase was found also between the participants' age and the worst scores after a 30-minute delay, meaning that in this group of participants the worst scores increased with the decrease of the participants' age. This result, however, cannot be generalised as the sample size was small.

Furthermore, Pearson product-moment correlation coefficient indicated that age had no association with the amount of fingers used for neither typing, nor how many years the participants had been using touch screen devices. Only a small correlation was found between the age of the participants, and the years that the participants had used a keyboard, but this was to be expected considering the age range of the participants.

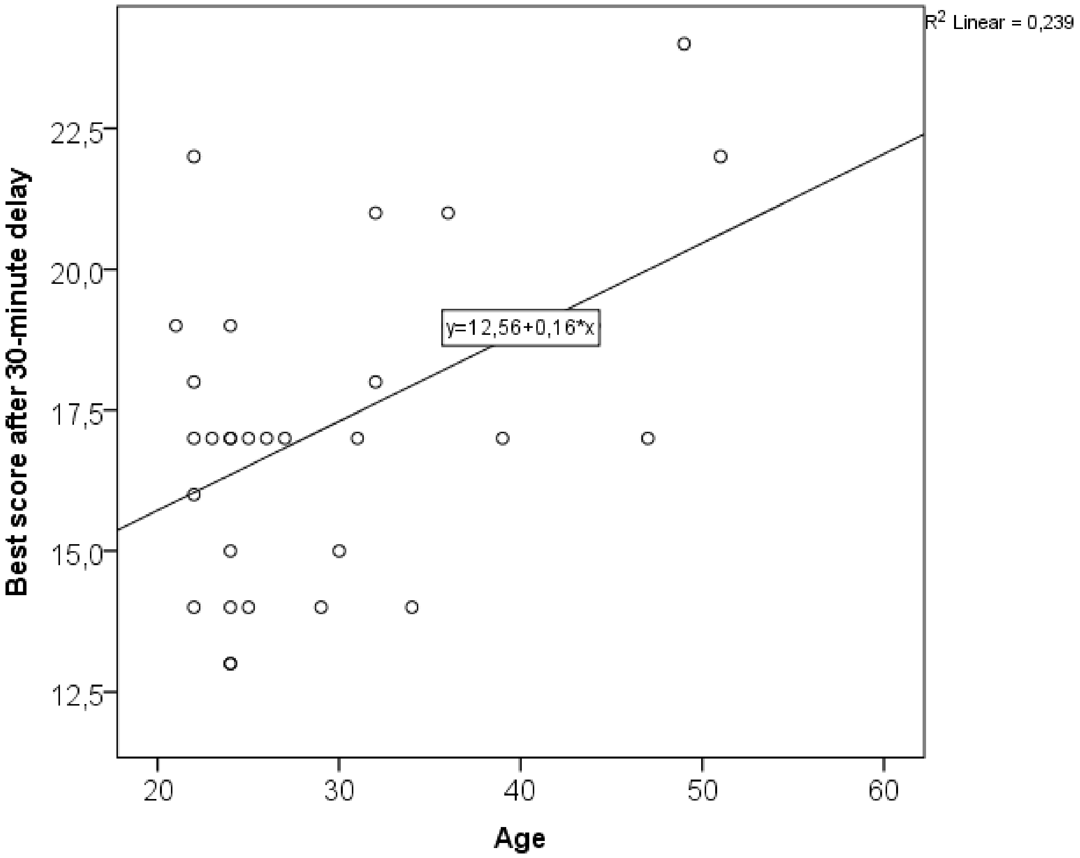

Figure 8. Scatter plot with age and best results after a 30-minute delay.

Further based on the results, age was strongly related to the time used for tablet task [r(31)= .46, p= .009], as well as the tablet score after a 30-minute delay [r(31)= .57, p= .001]. Moreover, time used for the handwritten task and the keyboard task were related [r(31)= .42, p= .018] as well as the time used for the touch screen task and keyboard task [r(31)= .57, p= .001]. However, time used to complete handwritten tasks and touch screen tasks did not indicate any correlation. In order to determine if the association of time used for task completion by hand and keyboard would remain after accounting for participants' age, partial correlations were run. The partial correlation between the time used for task completion by hand, and the time used for task completion by typing whilst controlling for age, indicated that age had no influence in controlling for the relationship between times used for handwritten or typed tasks (Table 6).

Table 6. Partial correlation of age with time used for handwritten task and for keyboard task.

Correlations

Control Variables			Time used for hand written task	Time used for keyboard task	Age
-none-[a]	Time used for hand written task	Correlation	1.000	.422	-.306
		Significance (2-tailed)	.	.018	.094
		df	0	29	29
	Time used for keyboard task	Correlation	.422	1.000	.139
		Significance (2-tailed)	.018	.	.456
		df	29	0	29
	Age	Correlation	-.306	.139	1.000
		Significance (2-tailed)	.094	.456	.
		df	29	29	0
Age	Time used for hand written task	Correlation	1.000	.492	
		Significance (2-tailed)	.	.006	
		df	0	28	
	Time used for keyboard task	Correlation	.492	1.000	
		Significance (2-tailed)	.006	.	
		df	28	0	

a. Cells contain zero-order (Pearson) correlations.

Partial correlation was run also to determine whether time used for task completion by touch screen, and time used for task completion by keyboard was influenced by the participants' age. Also in this case age had not influenced the relationship between the times used for completing touch screen and keyboard tasks [r = r(partial) = .58, p = .001]. This can be interpreted that the variables are naturally dependent, and a person who writes quickly by hand, or on a touch screen keyboard, is also likely to type quickly on a conventional keyboard. Consequently, when one writes slowly by hand, or touch screen keyboard, one probably types slowly on a conventional keyboard, regardless of age. The writing speed was not age dependent in this study.

5.4 Comparison of writing methods

In this chapter I answer the fourth research question: How do recall results of handwriting and typing tasks compare among each other?

In order to analyse differences among writing modalities and to determine which modality had statistically significantly better scores, pairwise comparisons were conducted. The Bonferroni adjustment was selected for guarding the effects of repeated testing and thus, enhancing the accuracy of the test. The table 7 presents the results that strongly suggest handwriting to be statistically significantly better recalled compared to touch screen typing ($p= .001$) and computer keyboard typing ($p= .004$), even if these values are the result of a two-way analysis. Therefore, it can be concluded that handwriting elicits statistically significant recollection not only after a 30-minute delay, but also after 1-week delay.

Table 7. Pairwise Comparisons Test.

Measure: Score of recollection

					95% Confidence Interval for Difference[b]	
(I) Writing_modality	(J) Writing_modality	Mean Difference (I-J)	Std. Error	Sig.[b]	Lower Bound	Upper Bound
Handwriting	Touch screen	1.484*	.359	**.001**	.574	2.394
	Computer keyboard	2.000*	.562	**.004**	.574	3.426
Touch screen	Handwriting	-1.484*	.359	.001	-2.394	-.574
	Computer keyboard	.516	.700	1.000	-1.259	2.291
Computer keyboard	Handwriting	-2.000*	.562	.004	-3.426	-.574
	Touch screen	-.516	.700	1.000	-2.291	1.259

Based on estimated marginal means

*. The mean difference is significant at the ,05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Interestingly, the participants own perceptions about the best writing method varied considerably which can be seen in the figure 9.

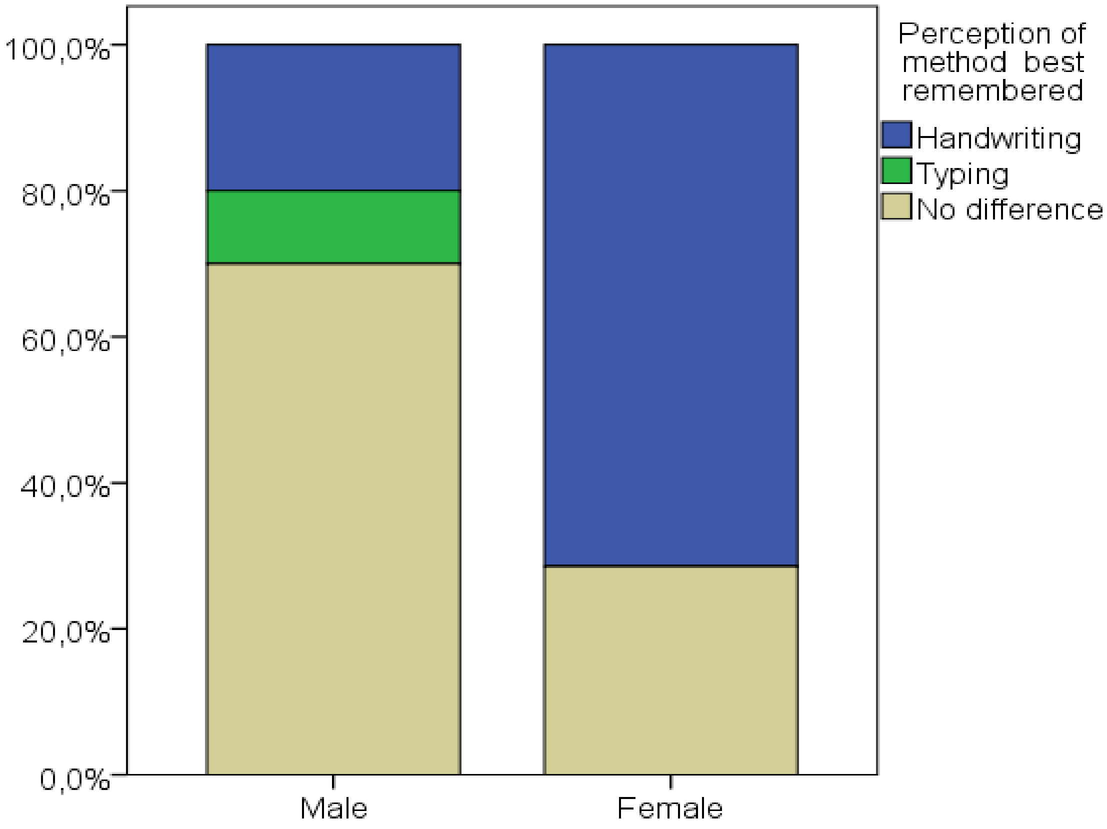

Figure 9. Perception of writing method best remembered (N=31).

In the participants’ own perception of the best remembered writing method (Fig. 9) there were distinct gender differences; while most of the female participants believed handwriting to be the best recollected writing method, whilst most of the male participants did not believe the writing method to make any difference or affect the recollection of the written text.

5.5 Comparisons of logical memory performance delay scores

In this chapter I answer the fifth research question: How does the logical memory performance differ after handwriting and typing tasks?

In order to get a holistic view how memory performance differs after handwriting and typing tasks, all recollection scores for all participants (N31) were calculated and are visible in the figure 10 after both delay times: 30-minute, and 1-week delay. Additionally, the figure 10 shows the minimum and maximum scores obtained, together with the median, 25th percentile, and 75th percentile values for each writing method after a 30-minute delay and after a 1-week delay. The mean value for scores obtained from recollection after handwriting was 16.39 (SD 3.42) after 30-minute delay and 14.90 (SD 4.15) after 1-week delay. Interestingly, the mean values for typing on a conventional keyboard and typing on a touch screen keyboard were very close to each other, approximately 2 points lower from handwriting results. The mean values for scores obtained from recollection after typing on a conventional keyboard and typing on a touch screen keyboard were 14.32 (SD 3.23) and 14.39 (SD 2.67) respectively, after 30-minute delay, and 13.13 (SD 3.57) and 12.94 (SD 3.29) respectively, after 1-week delay.

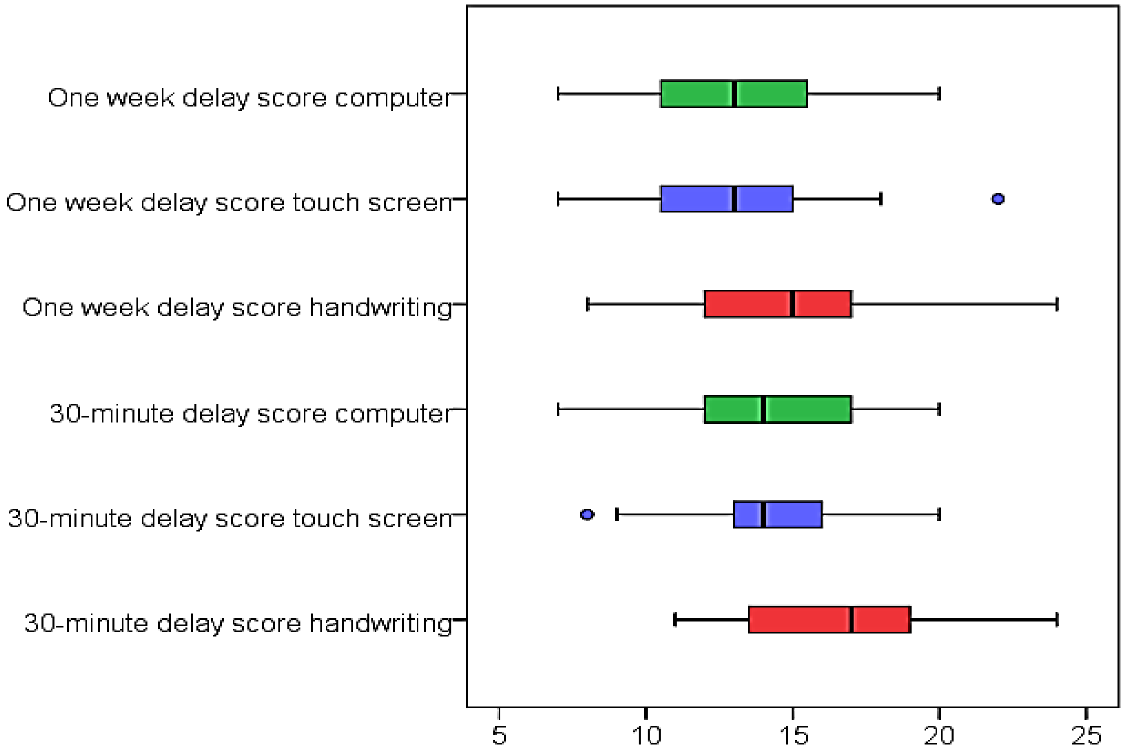

Figure 10. Distribution of all the participant's scores after a 30-minute delay and after a 1-week delay.

In the figure 11 the best writing methods are visible for all participants after both delay times. Handwriting has been found to be the best method for most participants after a 1-week delay at 41.9 percent, dropping from 51.6 percent after a 30-minute delay. Touch screen keyboard tasks were the second best remembered by 25.8 percent of the participants after a 1-week delay, climbing up from 19.4 percent after a 30-minute delay. The conventional keyboard task recollection was not far behind. This was the best method for 19.4 percent of the participants after one week, rising from 12.9 percent after a 30-minute delay. It is notable that the touch screen keyboard experienced an increase as the best method for some participants after a 1-week delay. However, touch screen keyboard was also considered the worst writing method for many. This is possible due to the fact that some participants got equal scores for two of the writing modalities.

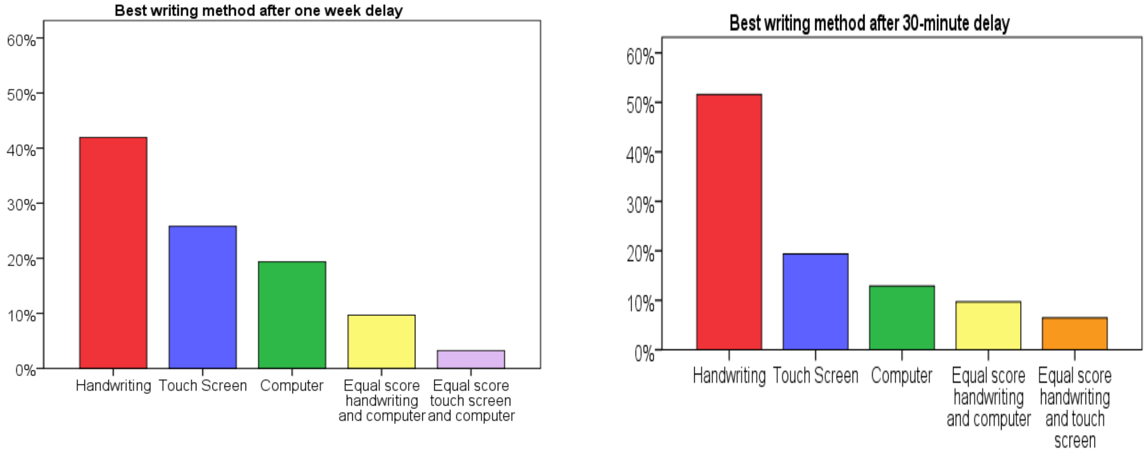

Figure 11. Best writing method after 1-week and 30-minute delays.

Touch screen keyboard tasks were worst recalled (Fig. 12) by 45.2 percent after 1-week delay, whereas they were the worst recalled tasks by 38.7 percent of the participants after a 30-minute delay.

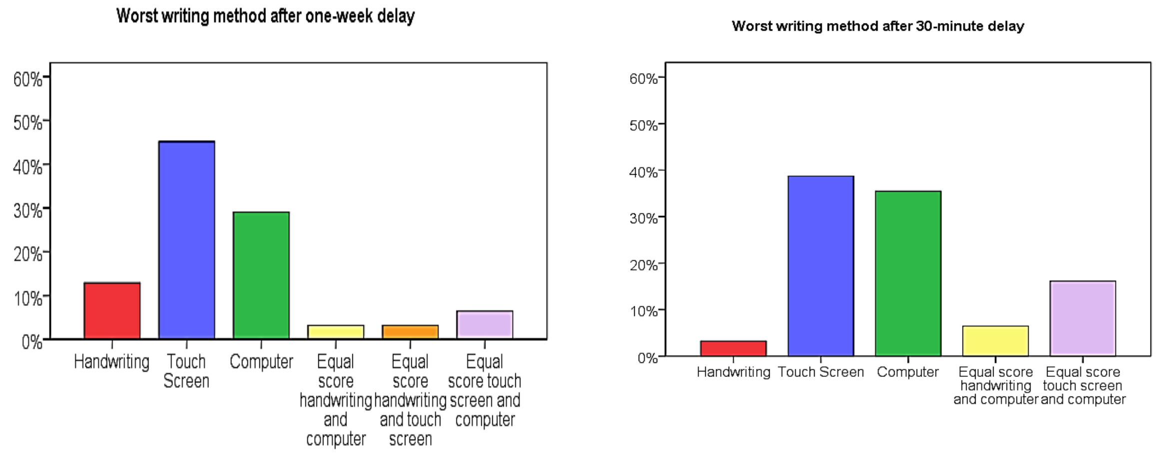

Figure 12. Worst writing method after 1-week and 30-minute delays.

The second worst recalled tasks were written on a conventional keyboard by 29.0 percent of the participants after a 1-week delay when it was found to be the worst writing method by 35.5 percent of the participants after a 30-minute delay. Handwritten tasks were worst recollected by 12.9 percent after a 1-week delay, whereas it had been the worst writing method for only 3.2 percent after a 30-minute delay.

In the figures 13 and 14, the scores of all participants are visible for all three writing modalities after a 30-minute and 1-week delay. These figures make it apparent how large differences there were in the scores, the lowest being 7 and the highest being 24 from the 25 scores.

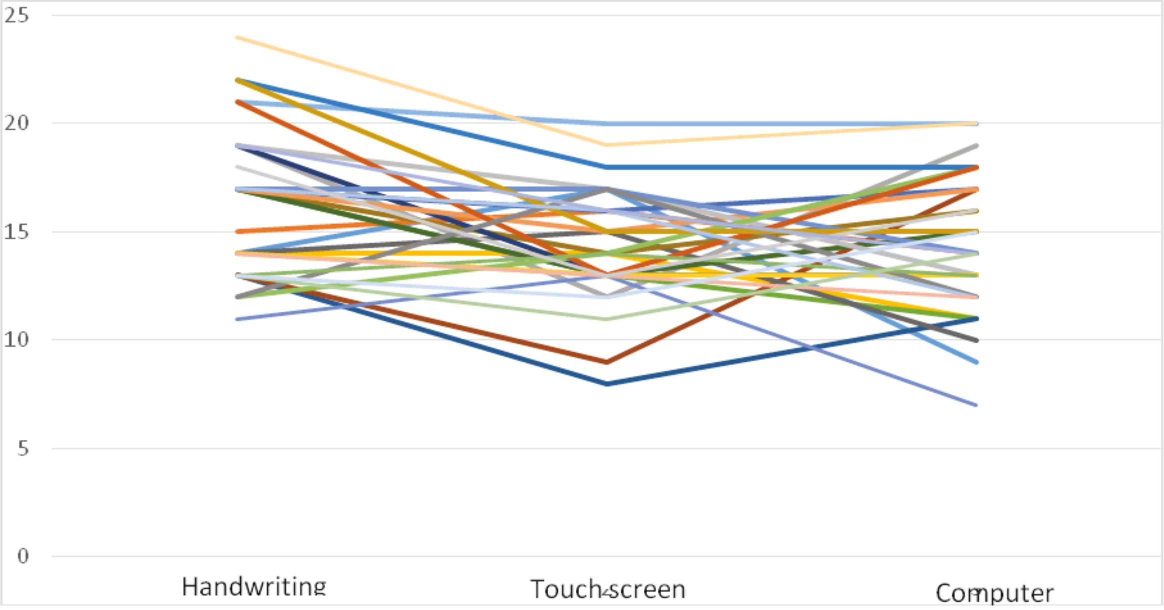

Figure 13. Scores for all writing modalities for all participants after 30-minute delay.

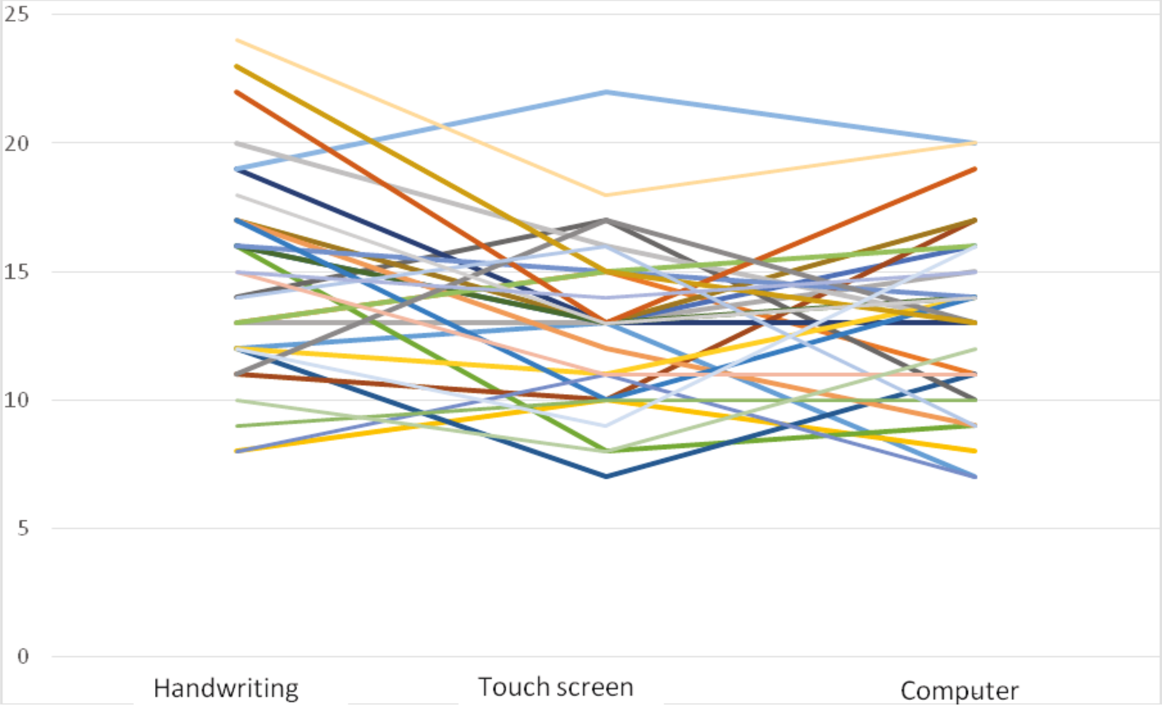

Figure 14. Scores for all writing modalities for all participants after 1-week delay.

In the figures 13 and 14 it is also visible that after 1-week delay the recall scores are distributed on a larger area, suggesting large individual differences in remembering the written stories.

6 DISCUSSION

6.1 The effects of writing modality to memory retrieval

The present study aimed to provide insights into the connection between writing modalities and memorizing. The results of this study confirm statistically significant effect of the writing modality to recollection, handwriting being statistically significantly better writing modality concerning recollection of written text. In other words, these results have established a strong connection between handwriting and better free recall results, whereas typing on a conventional keyboard and typing on a touch screen keyboard were similarly lower in their free recall scores. Interestingly, most individuals lost information between the recall tests, while some actually improved their memory performance over time. This study also confirmed statistically significant effect of time delay to recollection, and statistically significant effect of time spent for task completion together with time delay to the retention of the written texts. Hence, the current results support the particular correlation between the factor of writing speed and long-term information retention. The quickly typed stories on the conventional keyboard were subject to accelerated forgetting in the free recall test after one week delay.

In this group of participants the recall scores improved with the increase of the participants' age, however, due to the small sample size this result is not generalizable and concerns only this particular group of participants. Furthermore, participants that were speedy in handwriting tasks or touch screen typing task, seemed to be so also in conventional keyboard task, but the speeds with which the tasks had been completed were not influenced by the participants' age.

These results have been interpreted as carefully and truthfully as possible respecting the guidelines laid down by the Finnish Advisory Board on Research

Integrity, concurrently avoiding generalizations and hasty conclusions. In the effort to confirm this, the research process has been recorded and described in detail to the best of the researchers' ability. However, the strong evidence retrieved from the quantitative data of this study leaves no room for assumptions; handwriting has resulted in better recollection of the written stories.

Potential explanation for the positive findings of this study indicating handwriting practice's memory enhancing effect could be the embodied nature of handwriting. Learning and remembering that is based on sensory-motor experiences provide more rich, embodied and more durable knowledge than mere verbal description of on object (Kiefer & Trumpp 2012, 20). These findings indicate definite cognitive benefits of the arduous method of handwriting that can be explained by the dissimilar consolidation processes being pertinent to different sensorimotor functions of each writing modality, as well as the writing speed. Typing being speedy, requires no sensorimotor action that promotes embodied cognition, hence forgetting occurs more frequently. The kinaesthetically challenging and slow handwriting being more embodied experience than typing, has resulted in a more durable memory trace.

The research results of Longcamp, Boucard, Gilhodes and Velay (2006) on single letters and writing by adults, gave reason to assume that handwriting does facilitate the memorising of single characters. Further studies on adults and their recollection of writing have concerned words, the first by Smoker et al. (2009) and the second by Mangen et al. (2015). Both of these studies established the memory enhancing effect of handwriting compared to typing, even if the study by Smoker et al. (2009) did not produce statistically significant results on all aspects. All these results are consistent with the present study's results confirming handwriting having a positive effect on recollection, if it can be assumed that research results concerning handwritten single letters or words are applicable to the current study of recollection of longer texts. Therefore, it can be said that the results of this study have not only supported the results of the previously mentioned studies, but also brought to light new information about memorising longer texts, of which research did not previously exist. The consistency found in the studies by Gindrat et al. (2015) and Mangen et al. (2015) about the correlation between the years of experience with touch screen devices and enhanced potentials, or recall scores, indicating the more experienced with the touch screen device the better results, did not materialize in this study. This study did not find any indication of correlation between the years of experience with touch screen devices and the touch screen recall scores.

6.2 Validity and reliability of the research

Validity of the research refers to the fact that the chosen method of measurement is correct, and it measures issues relevant to the research question or questions. The validity has been further divided into internal and external validity, the internal validity referring to causalities as well as the consistency of the study. The external validity, on the other hand, concerns the generalizability of the results (Cohen, Manion & Morrison 2000, 109, 127; Kananen 2011, 118–124; Mertens 2010, 147; Schumacher & McMillan 1993, 179.) An effort was made to avoid confounding or extraneous variables potentially affecting the dependent variable (DV); a randomizer was used to set the order with which the stories A, B and C were written, as well as to set the order with which writing modality the stories were written by each participant. This enhanced the internal validity of the research (Cohen, Manion & Morrison 2000, 105; Krauth 2000, 37), however, some extraneous factors cannot be eliminated; The personal histories and events (Cohen, Manion & Morrison 2000, 126; Mertens 2010, 147; Schumacher & McMillan 1993, 173) that have occurred to the participants can naturally affect their abilities to write with one or another modality, as well as feel closer or relate more to one of the stories A, B or C.

Furthermore, as Schumacher and McMillan (1993, 173) point out, volunteering participants, as the participants of this study, may be somehow more motivated to participate in the study, and hence produce different results from non-volunteers. However, the extent of control over this effect was as high as possible; the volunteers of this study were recruited from six different university courses which are common for all faculties. This way the participants were as heterogeneous as possible. The study did not experience any experimental mortality (Cohen, Manion & Morrison 2000, 127), as all participants were retested after the 1-week delay, further confirming the internal validity of this study.

The external validity concerns more specifically the generalizability of the study results to the population and ecological factors (Cohen, Manion & Morrison 2000, 109, 127; Mertens 2010, 147; Schumacher & McMillan 1993, 179). In this study the results are limited in population external generalizability to other students of the age range of this study from a small university, possibly from Arctic areas. In addition, the stability of findings was confirmed by analysing the data in several ways which can all be repeated according to the detailed description of procedures constructing this study (Mertens 2010, 147). The ecological external validity concerns the conditions in which the data collection was conducted (Schumacher & McMillan 1993, 179). This study was conducted for all participants in the same office provided by the University of Lapland by only one researcher. Furthermore, the data was collected during daytime from end of February till the end of March 2016, which both are considered winter months in Lapland.

In quantitative research reliability generally refers to the replicability and consistency of the research (Cohen, Manion & Morrison 2000, 117; Kananen 2011, 118). Reliability concerns primarily the stability, equivalence, as well as the internal consistency of the study (Cohen, Manion & Morrison 2000, 117;

Schumacher & McMillan 1993, 227). The stability of this study was achieved to the highest possible degree by administering a standardised Wechsler Memory Scale test to the same individuals using three writing methods. Equivalence, on the other hand, refers to the comparability of the measurements of the same tasks at about the same time, which is achieved with reasonably large sample size (Schumacher & McMillan 1993, 228–229).

This study had thirty-one participants that were measured for their recollection of three different tasks repeatedly; first, after a 30-minute delay and then after a 1-week delay. The fact that the same individuals were measured for the same tasks over time establishes the reliability coefficient of equivalence and stability (Cohen, Manion & Morrison 2000, 118; Schumacher & McMillan 1993, 229). The internal consistency is particularly important when only one form of testing is used, as in the case of this study (Schumacher & McMillan 1993, 229). The correlations of different variables concerning this research have been confirmed with multiple methods, such as Pearson product moment correlation, with the SPSS analysing program using data from measurements after a 30-minute delay and 1-week delay (Cohen, Manion & Morrison 2000, 118; Mertens 2010, 381). Concerning the sample size, the adequate number of participants in a group of experimental research is twenty-one participants per group (Mertens 2010, 331). As this study has thirty-one participants, the reliability of this study and its results were established satisfactorily.

There are a few factors that may account for affecting this study. All participants had attended school at a time when cursive handwriting was still taught, thus handwriting was the first writing method they had acquired. The participants had started typing at approximately the age of ten; therefore, handwriting was by then already more or less automated. This is also the reason why these result are not applicable to children learning to write, hence, indicating an interesting issue for future research about children that learn both, handwriting and typing from the first grade. Moreover, the last question of the questionnaire that the participants filled in was unnecessary. The question inquired what the participants usually write with each method. Asking this question did not contribute to the knowledge of the participants' background, nor did it bring out any valuable information regarding the research questions about remembering written text. However, the answers did confirm a consistency with the study by Farinosi et al. (2016) that university students prefer to write longer texts with a keyboard, whereas they favour pen and paper for creative tasks and when writing shorter texts.

Furthermore, the fact that the participants voiced the written stories after a 30-minute delay, possibly affected their retention the following week. All respondents were asked their perception on this matter, and all of them supported this view by saying that describing the stories verbally after the 30-minute delay had aided in remembering the stories the following week. This issue could be addressed in a future research, by executing only one free recall test after a one week delay. Additionally, the current study could have benefited from a between-subjects research design with a control group which would simply have listened to the stories without writing them down, and consequently tested for their recall after a 30-minute and 1-week delay. This would have bought to light how much of the stories would have been retained without writing anything down and this in turn would have enabled the comparison of the two groups. However, this would have necessitated finding further thirty-one participants, which would have made this too large a study for Master's degree level. Alternatively, the participants of this study could have listened to a fourth story without writing it down and consequently including the measurements of recall of that story also to this study. For this study already one extra story was created, therefore it was in the researcher's discretion to opt not to modify the Wechsler Memory Scale Logical Memory test any further.

6.3 Potential usability of results and conclusion

The human brain and memory functions represent an eternal mystery to people. How the brain works, how the human mind functions, how people learn and think are just a few of the questions puzzling researchers' minds. The Greeks have an old adage that still holds true: the human mind is an abyss. This study has been an attempt to answer some of these questions with an approach that embraces the possibilities of combining different disciplines.

Learning occurs. It just might happen nowadays differently from before. Consequently, it would be rather bold to generalize these research results, as in human sciences we deal with people, and people are individuals with different abilities and talents. We must bear in mind that we mature differently, and in different surroundings from each other, learn in our own pace and in our own ways. According to Polit and Beck (2010, 1452) "generalization requires extrapolation that can never be fully justified because findings are always embedded within a context". Consequently, drawing conclusions and generalizing is complicated and challenging, and in this context not possible as such. In the studies explored in this paper, transferability to different setting has not been possible due to the participants' personal details, nevertheless, possible to certain extent in a group of similar characteristics. These articles are, however, valuable and significant in the field of education and particularly in the current classroom with all possible information and communications technologies at the disposition of teaching and learning. Teachers and policymakers should be aware of the possible long-term, as well as short-term, implications of the marginalization of handwriting, and of the increasing of typing practice on children and their development. It is of utmost importance that education professionals understand how to support children's sensitivity to learn certain things during certain periods. Furthermore, the importance of repetition cannot be ignored.

Combining the results of this study with the earlier findings of Smoker et al. (2009) and specifically those of Mangen et al. (2015), give significant cause for investigating the subject of writing modalities and memorising in order to comprehend their potential educational, epistemological and cognitive implications. Considering the inevitable shift from handwriting to typing, it is also important to understand the implications this shift will have to hand motor skills, not forgetting the educational implications of digitalization. Moreover, the urgency and relevance of these implications remain to be further studied, particularly on children due to the lack of research in this age group that is brought up in the age of new media, according to the new curriculum, without learning cursive handwriting. Neuroimaging and multidisciplinary cognitive studies can today provide vital information, and insights into individual memorizing and learning processes and strategies. This new perspective of information can be greatly beneficial in teacher education and other behavioural sciences. (Howard-Jones 2010, 8.) “Given that teachers are among the best cognitive enhancers on the planet (as are parents and siblings)—rewiring students’ brains on a daily basis to acquire literacy, numeracy, and reasoning skills (Butterworth et al., 2011; Dehaene et al., 2010)—we argue that teachers benefit from additionally understanding the neuroscience of learning and memory” (Dubinsky et al. 2013, 320).

For educators balancing between the old writing methods and new media approaches, the results of this study may provide valuable insights into writing and the consequent recollection. Maria Montessori expressed the matters wisely by saying that “the hands are the instruments of man’s intelligence” (1949, 37–38). Handwriting has its undeniable benefits, without undermining the benefits of information and communications technologies in teaching and learning. Maintaining equipoise between the old and new practices, digital technology use and handwriting, is therefore a possible solution in the effort to optimise the benefits from both practices. The future of education is literally, in the hands of the new generation.

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Appendix A

Consent form

Lapin yliopisto
Kasvatustieteiden tiedekunta, Mediapedagogiikkakeskus
Koehenkilötiedote ja suostumuslomake

<u>Muistitesti käsin, näppäimistöllä ja näyttönäppäimistöllä kirjoittaen</u>

TIEDOTE TUTKITTAVILLE JA SUOSTUMUS TUTKIMUKSEEN OSALLISTUMISESTA

1 Tutkijan yhteystiedot

Satu-Maarit Frangou
sfrangou@ulapland.fi
Puh: 0440350146

2 Tutkimuksen taustatiedot

Kyseessä on Lapin yliopiston Master of Media Education – linjan Pro Gradu – tutkimus, joka valmistuu vuoden 2016 aikana. Tutkimuksessani vertailen erilaisten kirjoitustapojen vaikutusta tekstin muistamiseen. Tässä tutkimuksessa vertailen kynällä kirjoittamista, tietokoneen näppäimistöllä kirjoittamista ja tablettitietokoneen näyttönäppäimistöllä kirjoittamista. Jokaisella kirjoitustavalla kirjoitetaan pieni tarina (noin 60–70 sanaa). Tämän jälkeen pidetään pieni tauko, jonka jälkeen katsotaan kuinka paljon yksityiskohtia tarinoista muistetaan.

3 Tutkimusaineiston säilyttäminen

Tutkimuksen vastuullinen tutkija vastaa manuaalisen ja ATK:lla olevan tutkimusaineiston turvallisesta säilyttämisestä.

4 Miten ja mihin tutkimustuloksia aiotaan käyttää

Tämän tutkimuksen tuloksia tullaan käyttämään opinnäytetyössä, sekä mahdollisesti kongressi- ja seminaariesityksissä, kansallisissa ja kansainvälisissä julkaisuissa ja opetuksessa.

5 Tutkittavien oikeudet

Osallistuminen tutkimukseen on täysin vapaaehtoista. Tutkittavilla on tutkimuksen aikana oikeus kieltäytyä mittauksista ja keskeyttää testit ilman, että siitä aiheutuu mitään seuraamuksia. Tutkimuksen järjestelyt ja tulosten raportointi ovat luottamuksellisia. Tutkimuksesta saatavat tiedot tulevat ainoastaan tutkimuksen tekijän käyttöön ja tulokset julkaistaan tutkimusraporteissa siten, ettei yksittäistä tutkittavaa voi tunnistaa. Tutkittavilla on oikeus saada lisätietoa tutkimuksesta missä vaiheessa tahansa tutkimuksen tekijältä.

6 Tutkittavan suostumus

Olen perehtynyt tämän tutkimuksen tarkoitukseen ja sisältöön, sekä tutkittavien oikeuksiin. Suostun osallistumaan muistitesteihin annettujen ohjeiden mukaisesti. Voin halutessani peruuttaa tai keskeyttää osallistumiseni tai kieltäytyä testeistä missä vaiheessa tahansa. Tutkimustuloksiani saa käyttää tieteelliseen raportointiin sellaisessa muodossa, jossa yksittäistä tutkittavaa ei voi tunnistaa.

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Päiväys Tutkittavan allekirjoitus

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Päiväys Tutkijan allekirjoitus

Appendix B

Questionnaire

Taustatiedot muistitestejä varten

Olen Lapin yliopiston Master of Media Education -linjalla tekemässä Pro Gradu –tutkimusta, jossa vertailen erilaisten kirjoitustapojen vaikutusta tekstin muistamiseen. Tässä tutkimuksessa vertailen kynällä kirjoitusta, tietokoneen näppäimistöllä kirjoittamista ja tablettitietokoneen näyttönäppäimistöllä kirjoittamista. Jokaisella kirjoitustavalla kirjoitetaan pieni tarina (noin 60-70 sanaa). Tämän jälkeen pidetään pieni tauko, jonka jälkeen katsotaan kuinka paljon yksityiskohtia tarinoista muistetaan. Tutkimustani varten tarvitsen alla mainittuja tietojasi. Näitä tietoja käytetään vain tilastollisiin laskelmiin, eikä näistä voi tunnistaa testeissä käyneitä henkilöitä. Jos haluat kysyä lisää muistitesteistä tai Gradustani, voit ottaa minuun yhteyttä sähköpostitse sfrangou@ulapland.fi

Suuri kiitos osallistumisestasi testeihin. Satu-Maarit Frangou

IKÄ:______________

ÄIDINKIELI:____

SUKUPUOLI:____

TIEDEKUNTA:____

OLETKO VASEN- VAI
OIKEAKÄTINEN?____

MISSÄ IÄSSÄ OLET ALOITTANUT KIRJOITTAMAAN
NÄPPÄIMISTÖILLÄ?____

KUINKA MONTA VUOTTA OLET KIRJOITTANUT
NÄPPÄIMISTÖLLÄ?____

KUINKA MONELLA SORMELLA KIRJOITAT TIETOKONEEN
NÄPPÄIMISTÖLLÄ?______

KUINKA MONTA VUOTTA OLET KIRJOITTANUT VIRTUAALISELLA KOSKETUSNÄPPÄIMISTÖLLÄ?____

OLETKO ITSE HUOMANNUT MUISTAVASI JOLLAKIN KIRJOITUSTAVALLA PAREMMIN, JOS OLET, NIIN MILLÄ TAVALLA?____

MITÄ KIRJOITUSTAPAA KÄYTÄT ENITEN?____

KERRO MITEN JA MISSÄ TILANTEISSA KIRJOITAT KÄSIN, TIETOKONEEN NÄPPÄIMISTÖLLÄ JA VIRTUAALISELLA NÄYTTÖNÄPPÄIMISTÖLLÄ?

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Appendix C

Table 1. Tests of Within-Subjects Effects, Greenhouse-Geisser.

Measure: Score_of_recollection

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Writing_modality	Sphericity Assumed	66.839	2	33.419	6.918	.002	.187
	Greenhouse-Geisser	66.839	**1.381**	48.398	6.918	.006	.187
	Huynh-Feldt	66.839	1.426	46.870	6.918	.006	.187
	Lower-bound	66.839	1.000	66.839	6.918	.013	.187
Error(Writing_modality)	Sphericity Assumed	289.828	60	4.830			
	Greenhouse-Geisser	289.828	**41.431**	6.996			
	Huynh-Feldt	289.828	42.781	6.775			
	Lower-bound	289.828	30.000	9.661			

Appendix D

Table 2. Tests of Within-Subjects Effects with the time used for all tasks.

Measure: Recall_score

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Writing_modality	Sphericity Assumed	.008	2	.004	7.678	.001	.204
	Greenhouse-Geisser	.008	**1.769**	.004	7.678	.002	.204
	Huynh-Feldt	.008	1.871	.004	7.678	.001	.204
	Lower-bound	.008	1.000	.008	7.678	.010	.204
Error(Writing_modality)	Sphericity Assumed	.031	60	.001			
	Greenhouse-Geisser	.031	**53.065**	.001			
	Huynh-Feldt	.031	56.144	.001			
	Lower-bound	.031	30.000	.001			
Delay30min_1week	Sphericity Assumed	.018	1	.018	74.269	.000	.712
	Greenhouse-Geisser	.018	1.000	.018	74.269	.000	.712
	Huynh-Feldt	.018	1.000	.018	74.269	.000	.712
	Lower-bound	.018	1.000	.018	74.269	.000	.712

Error(Delay30min_1week)	Sphericity Assumed	.007	30	.000			
	Greenhouse-Geisser	.007	30.000	.000			
	Huynh-Feldt	.007	30.000	.000			
	Lower-bound	.007	30.000	.000			
Writing_modality * Delay30min_1week	Sphericity Assumed	.013	2	.006	34.113	.000	.532
	Greenhouse-Geisser	.013	1.251	.010	34.113	.000	.532
	Huynh-Feldt	.013	1.279	.010	34.113	.000	.532
	Lower-bound	.013	1.000	.013	34.113	.000	.532
Error(Writing_modality*Delay30min_1week)	Sphericity Assumed	.011	60	.000			
	Greenhouse-Geisser	.011	37.532	.000			
	Huynh-Feldt	.011	38.384	.000			
	Lower-bound	.011	30.000	.000			

a. Footnote