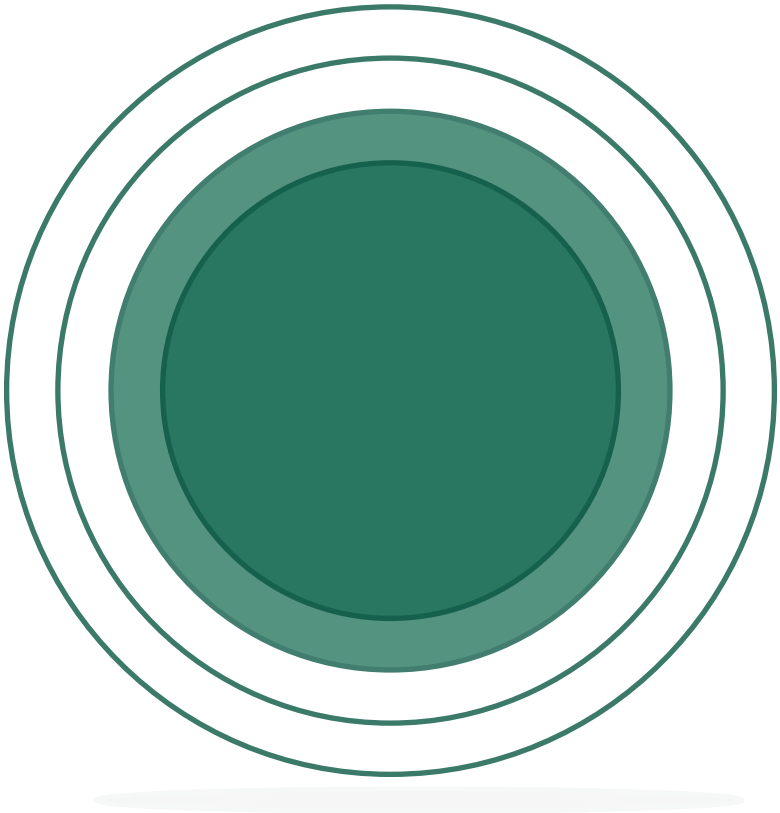
Satu-Maarit Frangou



Write to Recall — An Embodied Knowledge Construction Model of Affects in Writing

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SATU-MAARIT FRANGOU

Write to Recall – An Embodied Knowledge Construction Model of Affects in Writing

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"Literacy is the ability to identify, understand, interpret, create, communicate and compute, using printed and written materials associated with varying contexts. Literacy involves a continuum of learning in enabling individuals to achieve their goals, to develop their knowledge and potential, and to participate fully in their community and wider society."

(UNESCO 2004, pp. 13.)

Abstract

Satu-Maarit Frangou
Write to Recall
– An Embodied Knowledge Construction Model of Affects in Writing
Rovaniemi: University of Lapland 2020, 151 p.
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Writing skills and practices are constantly evolving due to the digitalisation of working, learning and living environments. This thesis presents new information regarding different writing modalities and recollections of written texts among different age groups: children, adolescents and adults. More specifically, the thesis investigates three writing modalities: (1) handwriting, (2) keyboarding on a computer or laptop, and (3) keyboarding on a touchscreen keyboard of an iPad or mobile phone. The thesis examines whether these writing modalities affect the recollection of stories and determines the latent affects influencing knowledge construction in writing. Therefore, the aim of this thesis is to understand the effects of the writing process and consequent knowledge construction. This research followed a cyclical educational design research (EDR) approach (McKenney & Reeves, 2018) whose principles and interventions are based on the actual needs of schools. These principles and interventions materialised in this study via the development of a theoretical model, study design and test battery for evaluating the effect of any writing modality on a writer's recollection and by generating new knowledge about the different age groups with respect to the three writing modalities and consequent recollection of written texts. The empirical experiments performed in this research followed an experimental within-subjects research design.

Sub-study I served as the starting point for researching the effect of writing modality on the recollection of short stories among a sample of university students ($N = 31$). In this sub-study, the research design for the three writing modalities was created using testing material. The main findings of this study were that writing modality has a statistically significant effect on recollection and that students can recall handwritten stories statistically significantly better than stories typed on a computer keyboard or touchscreen.

Sub-study II continued the investigation of the effect of writing modalities on recollection; this time, however, the age groups of participants differed: 10-11-year-old children ($N = 92$) and 16-year-old adolescents ($N = 43$). Refining the test battery for these age groups entailed three separate experiments. The findings indicated a statistically significant effect of writing modality on recollection among 16-year-old adolescents and 11-year-old children, with handwriting being the best-recalled writing modality compared to keyboarding on a laptop or touchscreen device.

Sub-study III compiled knowledge acquired from both the empirical studies conducted in this research and from the relevant literature examined throughout the research process. This sub-study sought to design a theoretical model for understanding cognition and affect in writing. Hence, an embodied knowledge construction model of affects in writing was developed and empirically tested, generating valuable information that deepened our understanding of knowledge construction in writing and the issues that affect it.

Data were collected from 172 participants. The principal empirical findings of sub-studies I and II were that writing modality has statistically significant effects on the consequent recollection of written texts starting from the age of 11, as these effects were not evident among 10-year-old children. In other words, for more experienced writers, the writing modality with which text is composed matters in terms of recollection.

The development of the embodied knowledge construction model of affects in writing is the culmination of the empirical and theoretical knowledge acquired from the entire research process and thereby answers the overarching research question: What are the components of embodied knowledge construction in writing? As a primary outcome of this research, the model implies cooperation between body, mind and brain by considering the environmental, cultural and contextual factors underlying memory functions, which are affected by perception and action sequences, prior experiences, emotions and motivations.

This thesis offers a test design and an embodied knowledge construction model for the quantitative and qualitative assessment of knowledge construction and affects in writing. The results of the research have several implications for scientific, cognitive and educational contexts and suggest future research directions and design principles. Importantly, this thesis provides several recommendations, including the systematic instruction of keyboarding, the balancing of writing instruction and practice from an early age for improving learning outcomes, and the improvement of keyboarding abilities among adolescents and adults so that they may function harmoniously in an increasingly digitised world.

Keywords: Writing, handwriting, keyboarding, recollection, educational technologies, embodied cognition, embodied knowledge construction model, affects

Tiivistelmä

Satu-Maarit Frangou
Kirjoita ja muista
– kehollisen tiedonrakentamisen malli kirjoittamisen affekteissa
Rovaniemi: Lapin yliopisto 2020, 151 s.
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Kirjoitustaidot ja niihin liittyvät käytännöt muuttuvat ja kehittyvät jatkuvasti työelämän, koulutuksen ja elinympäristöjen digitalisoitumisen myötä. Tämä tutkimus tuotti uutta tietoa eri ikäryhmistä kirjoitusmenetelmiin ja kirjoitettujen tekstien muistamiseen liittyen (lapset, nuoret ja aikuiset). Erityisesti tämä tutkimus keskittyy kolmeen kirjoitusmenetelmään: 1) käsin kirjoittamiseen 2) tietokoneen tai kannettavan tietokoneen näppäimistöllä kirjoittamiseen ja 3) iPadin tai matkapuhelimen kosketusnäytön näppäimistöllä kirjoittamiseen. Tässä tutkimuksessa selvitetään, onko eri kirjoitusmenetelmillä merkitystä muistamiseen liittyen tarinoita kirjoitettaessa. Samoin selvitetään, mitkä ovat taustalla olevia tiedonrakentamiseen vaikuttavia affekteja. Tässä tutkimuksessa käytettiin koulutuksellisen kehittämistutkimuksen, EDR, (McKenney & Reeves, 2018) lähestymistapaa, joka pohjautuu periaatteisiin, joissa ratkaisuja kehitetään sykleittäin koulumaailman todellisiin tarpeisiin. Nämä periaatteet konkretisoituvat tässä tutkimuksessa muun muassa teoreettisen mallin ja testimateriaalin kehittämisen avulla, joilla voidaan arvioida muistamista eri kirjoitusmenetelmien käytön jälkeen. Lisäksi tutkimus on tuottanut lisää uutta empiiristä tietoa kirjoitusmenetelmiin liittyen. Osatutkimusten tutkimusmenetelmänä käytettiin kokeellista tutkimusotetta.

Ensimmäisessä osatutkimuksessa tutkitaan eri kirjoitusmenetelmien yhteyttä yliopisto-opiskelijoiden (N = 31) muistiin liittyen. Tässä artikkelissa luodaan tutkimusmalli kolmelle kirjoitusmuodolle yhdessä testimateriaalin kanssa. Ensimmäisen osatutkimuksen päätulos oli, että kirjoittamisen menetelmä vaikuttaa muistiin tilastollisesti merkitsevästi ja että yliopisto-opiskelijat muistavat käsinkirjoitetut tarinat tilastollisesti merkitsevästi paremmin kuin tietokoneen tai iPadin kosketusnäytön näppäimistöllä kirjoitetut tarinat.

Toisessa osatutkimuksessa tutkitaan kirjoitusmenetelmien yhteyttä muistamiseen 10–11-vuotiailla lapsilla (N = 92) ja 16-vuotiailla nuorilla (N = 43). Testimateriaalin kohdentaminen ja muotoilu näille koululaisten ikäryhmille sisälsi kolme erillistä kokeilua. Tulokset osoittivat, että 16-vuotiailla nuorilla ja 11-vuotiailla lapsilla kirjoitusmenetelmällä oli tilastollisesti merkitsevä yhteys, jolloin käsinkirjoitetut tarinat muistettiin paremmin kuin tietokoneen näppäimistöllä tai kosketusnäppäimistöllä kirjoitetut tarinat.

Kolmannessa osatutkimuksessa koko tutkimusprosessin aikana hankittu empiirinen ja teoreettinen tieto kulminoituu kehollisen tiedonrakentamisen mallin rakentamiseen kirjoittamisen affekteihin liittyen. Tässä osatutkimuksessa kootaan olemassa oleva tieto ja pyritään ymmärtämään kehollista tiedonrakentamista ja kirjoittamiseen yhteydessä olevia affekteja. Siten artikkeli esittelee kehollisen tiedonrakentamisen mallin, jota myös testataan empiirisesti 16-vuotiaiden nuorten koululaisten tutkimusjoukossa (N= 6). Mallin avulla saatiin syventävää tietoa kirjoittamisen ja siihen yhteydessä olevien tietojen rakentumisesta.

Tutkimukseen osallistui yhteensä 172 lasta, nuorta ja aikuista. Keskeisin tutkimustulos osoitti, että kirjoitusmetodit vaikuttavat tilastollisesti merkitsevästi kirjoitettujen tekstien muistamiseen 11 vuoden iästä lähtien. Kiinnostavaa on, että 10-vuotiaiden lasten käyttämällä kirjoitusmenetelmällä ei ole vielä yhteyttä muistamiseen.

Väitöskirjatutkimuksen keskeisin kysymys oli, millaisista osatekijöistä kehollinen tiedonrakentaminen kirjoittamisessa rakentuu? Tulokseksi saatiin ensinnäkin harmoninen ja samanaikainen kehon, mielen ja aivojen yhteistyö, joka piirtyy huomioimalla ympäristö-, kulttuuri- ja kontekstuaaliset tekijät. Lisäksi tässä yhteistyössä ovat tärkeässä asemassa muistitoiminnot, joihin vaikuttaa havainto ja toimintasekvenssi yhdessä aiempien kokemusten ja motivaation kanssa. Nämä yhdessä kiteytyvät kehollisen tiedonrakentamisen mallissa kirjoittamisen affekteihin liittyen.

Toisena keskeisenä tuloksena syntyi testimateriaali sekä kvantitatiivisen ja kvalitatiivisen arvioinnin kehykset kirjoittamiseen liittyvään muistamisen tutkimiseen ja siihen vaikuttaviin tekijöihin. Tutkimustulosten perusteella voidaan tehdä johtopäätöksiä opetuskäytäntöihin, joihin suositellaan systemaattista näppäilytaitojen opetusta sekä eri kirjoitusmenetelmien tasapainoista harjoittelua. Kirjoituksen opetuskäytäntöjen ja kirjoitusmenetelmien tasapainottaminen jo varhaisessa vaiheessa on välttämätöntä oppimistulosten parantamiseksi. Samalla tulee muistaa tarve parantaa nuorten ja aikuisten näppäilytaitoja, jotta he pystyvät toimimaan vaivattomasti digitalisoituvassa maailmassa.

Avainsanat: Kirjoittaminen, käsin kirjoittaminen, näppäilytaidot, muistaminen, oppimisteknologiat, kehollinen kognitio, kehollinen tiedonrakentamisen malli, affektit

Acknowledgements

This dissertation is the culmination of my PhD journey which has been part of my life for three years. During this time, I have had the opportunity to grow and mature as a teacher and as a researcher. Even though my name appears on the cover of this thesis, concomitantly, I have had the privilege to have had many wise people by my side throughout this research process to whom I am in deep gratitude.

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I also appreciate everyone who read and commented on my articles and this thesis manuscript in the doctoral research seminars, particularly Sanna Ruhalahti and Solja Upola for their peer support and invaluable friendship during this research process. Solja also designed the main figures in this thesis. I would also like to thank Anitra Arkko-Saukkonen, Lauri Palsa, Sanna Brauer and Liping Sun for all their support in this common process of ours; our mutual encouragement and support has been amazing.

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Last, I would like to dedicate this book to my sons Theodoros and Stefanos. Your love and patience during these years of doing this research has been endless. You are remarkable young men and I am forever proud of you. You are my everything.

November 2019
Rovaniemi, Finland

Satu-Maarit Frangou

List of Original Articles

This thesis is based on three articles, which are hereafter referred to as sub-studies I to III:

Sub-study I
Frangou, S-M., Ruokamo, H., Parviainen, T., & Wikgren, J. (2018). Can you put your finger on it? The effects of writing modality on Finnish students' recollection. *Journal of Writing Systems Research, 10*(2), 82–94. https://doi.org/10.1080/17586801.2018.1536015

Sub-study II
Frangou, S-M., Wikgren, J., Sintonen, S., Kairaluoma, L., & Vasari, P. (2019). The effect of writing modality on recollection in children and adolescents. *Research in Learning Technology*, *27*, 2239. https://doi.org/10.25304/rlt.v27.2239

Sub-study III
Frangou, S-M. (2018). Embodied knowledge construction in writing. *Education in the North, 25*(3), 89–105. https://doi.org/10.26203/1QC6-2B14

The articles can be found at the end of the summary.

Lists of Figures and Tables

Figures

Tables

List of Abbreviations

ACC = Anterior Cingulate Cortex
antCB = Anterior Cerebellum
DBR = Design-Based Research
EDR = Educational Design Research
fMRI = Functional Magnetic Resonance Imaging
GMFA = Graphemic/Motor Frontal Area
ICT = Information and Communication Technology
IFG = Inferior Frontal Gyrus
IPS = Intraparietal Sulcus
MFG = Middle Frontal Gyrus
SFG = Superior Frontal Gyrus
SFS = Superior Frontal Sulcus
UNESCO = The United Nations Educational, Scientific and Cultural Organization
WMS-R = Wechsler Memory Scale Revised Edition

Contents

1 INTRODUCTION

This thesis focuses on writing methods used in the twenty-first century and their influence on memory. In particular, recollections of texts produced via handwriting, keyboarding on a computer or laptop, and touchscreen keyboarding on a tablet computer or smartphone are compared. The study on which the thesis is based examined embodied knowledge construction in writing by identifying conscious and unconscious embodied factors that influence the writing process and consequent recollection of written text and knowledge construction regarding the writing topic.

Competent writing with any modality is a complex cognitive activity integrating conceptual, linguistic and physical processes (van Wijk, 1999). This means that content knowledge and the means by which to express this knowledge with words are encoded into grammatically logical sentences, which are then processed into a motor activity to produce legible text. Furthermore, the competence to handle and manipulate abstract symbols, such as letters, and concepts requires skills in reasoning, logical thought and mathematical deduction (Tynjälä, Mason, & Lonka, 2001).

In the field of writing research, Christina Haas (1996) introduced the hypothesis of the indistinguishable connection between writing and writing mediums – since writing is always achieved using a medium – because each medium affects the writing process differently depending on its fundamental nature. Today, the nature of writing tools is ubiquitously changing, as the use of information and communication technologies (ICTs) is increasingly preferred for working and learning, bringing computers and touchscreen devices with various types of keyboards into workplaces and schools (Kontkanen, 2018). Even though adolescents are expected to be competent in multiple methods of writing after finishing their basic education, according to the renewed Finnish National Core Curriculum for Basic Education (Opetushallitus, 2014), common procedures for facilitating or measuring such competence do not yet exist (Kontkanen, 2018).

This research addresses issues at empirical, practical and theoretical levels: The first sub-study developed a study design and test battery for examining the effect that different writing modalities have on recollection, which were subsequently tested on adults. In the second sub-study, the study design and a pilot test were administered to adolescents and then refined among children. The third sub-study merged two theoretical frameworks: the framework for understanding cognition and affect in writing by Hayes (1996), and the six aspects of embodied cognition by Wilson (2002). The resulting theoretical model enabled qualitative research and empirical testing on multiple writing modalities and devices.

In this thesis, the author applies two central terms: *keyboarding* and *typing*. *Keyboarding* is a synonym of *typing* that refers to the action of digital writing (Wollscheid, Sjaastad, Tømte, & Løver, 2016), and the term *typing* is mostly used in conjunction with *models and theories of keyboarding*; therefore, this research used the term *typing* in conjunction with *models and theories* and the term *keyboarding* for *contexts of action*. Furthermore, the topic of this thesis was explored within an educational framework from a behavioural and cognitive psychological perspective.

1.1 Research Context and Prior Research

The progressive introduction and application of ICTs in learning environments has profoundly changed the ways in which people interact within these environments (Vesisenaho & Dillon, 2013; Vesisenaho et al., 2017). At the same time, younger generations are constantly developing new digital cultures in which literacy and the ways in which learning occurs are ceaselessly evolving (Sintonen, 2012). Furthermore, owing to the prevalence of technology, writing mediums and processes have developed, changed and multiplied (Morgan, 2014). Subsequently, ICTs have engendered new skills essential to multiliteracy, such as retrieving, interpreting, producing and integrating information (Genlott & Grönlund, 2013; Kallionpää, 2017; Mullis, Martin, Foy, & Drucker, 2012).

The multi-dimensional concept of multiliteracy has been part of Finnish education for many years (Kupiainen, Sintonen, & Suoranta, 2008), yet the new Finnish National Core Curriculum (Opetushallitus, 2014) has further defined multiliteracy as not only the competence to read and write but also the ability to acquire, produce, edit and mix information for self-expression, as well as the capacity to critically evaluate multiple types of information. In this sense, multiliteracy is the expected outcome of the new curriculum (Palsa & Ruokamo, 2015). Hence, these new writing skills differ from the academic, creative and compositional writing skills provided by official education (Kallionpää, 2017). In Hill's (2005) research project, it was revealed that the traditional content of reading and writing had to be broadened to include multiple sign systems to represent meaning, which Finland accounted for in its renewed National Core Curriculum for Basic Education, implemented in 2016 (Opetushallitus, 2014). The new curriculum removed cursive handwriting instruction and introduced ICTs in all subjects (Finnish National Board of Education, 2014; Vahtivuori-Hänninen, Halinen, Niemi, Lavonen, & Lipponen, 2014). Concurrently, multiliteracy has become a core competence, transversing the entire education system (Kallionpää, 2017) and promoting competent communication with multiple modalities and devices. Hence, literacy has changed from a subject of learning to a lifelong object of learning (Sulkunen, 2013; Sulkunen & Malin, 2018). However, the definition of multiliteracy and the

concrete steps needed to achieve it remain unclear; consequently, these issues have been left to local curricula in municipalities and individual schools to clarify (Palsa & Ruokamo, 2015), raising questions about how and according to which standards multiliteracy is being implemented at the local level.

Generally, literacy, meaning reading and writing, has been proven to have multiple benefits, including strengthening and supporting thinking processes (D'On Jones, Reutzel, & Fargo, 2010). Furthermore, research by Myrberg (2007) on 10,632 third graders in Sweden demonstrated that the development of reading skills during the first few years of school is particularly important. For children who have difficulties developing literacy skills, it will become increasingly difficult to catch up in later grades due to increasingly complicated tasks (Myrberg, 2007). In these circumstances, supplementary exercises with supportive instruction during the first years of literacy learning are essential, not only for the children's eventual reading and writing competence but also for their later academic achievement (Dinehart, 2015; Limpo, Alves, & Fidalgo, 2014; Snow, Burn, & Griffin, 1998; Stevenson & Just, 2014).

Furthermore, each writing modality has its own unique benefits. Handwriting has multiple benefits, such as supporting the development of reading skills by recruiting brain areas known to be crucial for successful reading (James & Engelhardt, 2012; Longcamp, Zerbato-Poudou, & Velay, 2005). Moreover, merely perceiving letters after writing them produces significantly more neural activation than keyboarding the letters (James & Engelhardt, 2012). Nevertheless, keyboarding has become essential in the modern world. It is generally faster and more productive compared to handwriting, and good notetaking strategies can lead to better recall of typed and transcribed texts (Bui, Myerson, & Hale, 2013). In their research, Weigelt Marom and Weintraub (2015) discovered that keyboarding was beneficial to all students, particularly those experiencing difficulties in handwriting and learning. This is consistent with research findings on touchscreen devices, which were found to enhance handwriting and spelling skills, as well as the ability to compose sentences, in children with specific learning challenges (Berninger et al., 2015; Tanimoto et al., 2015).

However, the process of forming letters differs between handwriting and word-processing computer programmes. In handwriting, letters are manually written, one by one, with attention alternating between the writing instrument and the written text until the process becomes automated (Alonso, 2015; Mangen, Anda, Oxborough, & Brønnick, 2015; Mangen & Velay, 2010); in keyboarding, all 10 fingers can be used, and attention shifts from the keyboard to the screen as the process becomes automated (Alonso, 2015; Sormunen & Wickersham, 1991; Weigelt Marom & Weintraub, 2015); on touchscreen devices, the number of fingers used for keyboarding varies with the size of the screen; and on smart phones, thumbs are commonly used to interact with touch interfaces (Nicolau & Joaquim, 2012). With regard to learning writing skills, Erthal (1998) believed that keyboarding instruction should begin at 8 or 9 years of age. At this age, children have already

acquired the fine motor skills and hand-eye coordination, together with some reading competence, needed to learn keyboarding, since text is produced in the motor space of the keyboard, and its perception occurs in the visual space of the screen (Erthal, 1998; Mangen & Velay, 2010).

Additionally, an ergonomic difference exists between conventional or laptop keyboards and touchscreen devices, since the latter involve no tactile feedback, as opposed to the former. Conventional keyboarding requires increased flexor and extensor muscle activity in the fingers, whereas virtual keyboards on touchscreen devices require less typing force and therefore less muscle activity in the fingers. Notably, reduced typing force and muscle activity have been correlated with decreased productivity, text quality and comfort (Kim, Aulck, Bartha, Harper, & Johnson, 2014; Nicolau & Joaquim, 2012). The tension created by holding one's hands above the touchscreen to avoid accidental key activation can also result in muscle pain (Kim et al., 2014), while the excessive use of thumbs for writing on touchscreens can result in swollen median nerves, which can in turn lead to decreased pinch strength and other hand functions (İnal, Demİrcİ, ÇetİntürkAkgönül, & Savaş, 2015). That said, handwriting can also be strenuous (Fairbank, 2018), particularly when learning to write, as learners have not yet developed the capacity to regulate the pressure they exert on the pen or other writing instrument (Bara & Gentaz, 2011).

Furthermore, the motor actions of different writing modalities activate different brain regions. Figures 1 and 2 show the regions activated during handwriting and keyboarding.

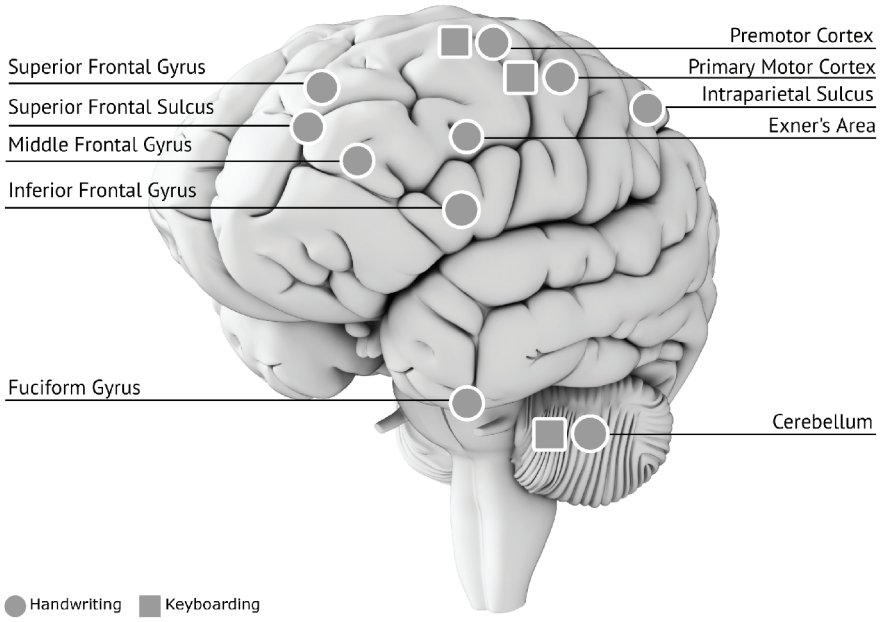

Figure 1. Lateral view of the brain and writing-related areas.

During handwriting, the activated brain areas are the left *superior frontal sulcus* (SFS) or the *middle frontal gyrus* (MFG) region, the left *intraparietal sulcus* (IPS) or the superior parietal region, and the *anterior cerebellum* (antCB; Planton, Jucla, Roux, & Démonet, 2013). This finding is consistent with earlier findings by Sugihara, Kaminaga and Sugishita (2006), which recognised the posterior part of the *superior frontal gyrus* (SFG) and the anterior area of the left IPS as key areas for the writing process (Figure 1). A study by Vinci-Booher, Cheng and James (2019) provided further evidence of the simultaneous functioning of *motor components* and visual perception during handwriting. The motor components used for letter production were linked to the *frontoparietal* system and particularly the *left intraparietal sulcus*, whereas the visual perception of letters was linked to *temporoparietal* systems and *posterior regions of the left intraparietal sulcus*. Both the motor action of handwriting and visual perception, particularly of one's own handwritten letters, received a response from the *right fuciform gyrus* and *left posterior intraparietal sulcus* (Vinci-Booher, Cheng, & James, 2019).

A later study by Planton, Longcamp, Péran, Demonet and Jucla (2017) connected the *graphemic/motor frontal area* (GMFA), situated close to *Exner's area* (Roux et al., 2009), with clear left lateralisation and activation during handwriting (Figure 1). By contrast, keyboarding is a motor skill in which the *motor cortical regions* function in parallel with the *cerebellum* and *striatum* (Figure 2; Underleider, Doyon, & Karni, 2002).

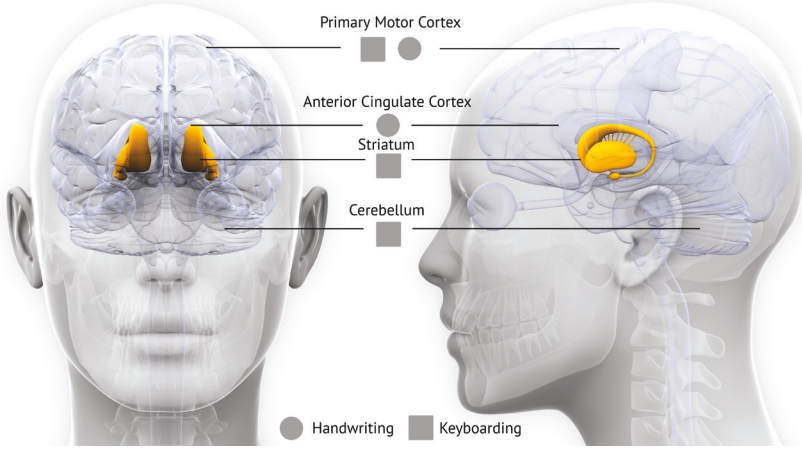

Figure 2. 3D view of the brain and writing-related areas.

In this parallel process, the contralateral *motor cortex* is activated with the inhibitive reaction of the ipsilateral *motor cortex* (Pinet, Hamamé, Longcamp, Vidal, & Alario, 2015; see Figures 1 and 2).

Research on writing that addresses the issue of recollecting what one has written with different writing modalities is scarce. Even though the objective of education is generally to ensure recall of learned topics, and although writing is considered a method for learning and retaining key concepts (Gingerich et al., 2014) as well as for learning to read (Genlott & Grönlund, 2013; Graham & Hebert, 2011; Tunks & Giles, 2016), previous research has focused mainly on recollecting single letters or words. This focus could be due to a lack of tools and methods needed to conduct research on a subject as multidimensional as writing, which is an ensemble of complex cognitive processes, such as text production, long-term memory retrieval and lexical access, as well as a method for learning and self-expression consistent with one's sociocultural background (Levy & Olive, 2002). The majority of research presented here is from the cognitive psychological, cognitive neuroscientific and multidisciplinary educational and behavioural psychological perspectives, focusing on the relationship between writing and recollection, rather than on the qualitative dimensions of writing. Studies from the sociocultural perspective were not included because of their qualitative and exploratory approach, which is mostly concerned with the content of the text produced or with attitudes towards writing. One such example is the study conducted by Genlott and Grönlund (2013) in Sweden. In their study, social interactions were found to improve the learning of reading and writing skills among 1st graders that learned to write by keyboarding on a computer compared to those that learned to read and write by hand with a pencil and without interaction among the students (Genlott & Grönlund, 2013).

Several studies have investigated the retention of single letters, which has been shown to be facilitated better by handwriting than keyboarding for both adults (Longcamp, Anton, Roth, & Velay, 2003, 2005; Longcamp, Boucard, Gilhodes, & Velay, 2006; Longcamp et al., 2008) and children (James & Engelhardt, 2012; Longcamp, Zerbato-Poudou, & Velay, 2005). The studies on adults by Longcamp et al. in 2003 and 2005, which compared the premotor activation of letters and pseudo letters that were visually presented to the participants, confirmed that activation occurred when observing letters, not pseudo letters, thus inspiring further research on the subject. In 2006 and 2008, Longcamp and colleagues compared handwriting and keyboarding in adults using characters modified from the Bengali and Guanjarati alphabets. In a study on children's letter recognition (Longcamp et al., 2005), uppercase Latin letters were written via handwriting and keyboarding, and the results were similar to those for adults (Longcamp et al., 2006, Longcamp et al., 2008) – handwriting enhanced the recognition of letters better than keyboarding. Furthermore, James and Engelhardt (2012) measured letter perception among preliterate children using functional magnetic resonance imaging (fMRI). The children in this study learned letters through keyboarding, tracing and drawing, with each medium pertaining to different motor experiences responsible for activating different brain regions. The results of their study supported the

notion that handwriting practice with letters enhances their visual processing and recognition in brain regions strategic for successful reading acquisition (James & Engelhardt, 2012). These regions involve the left *fuciform gyrus*, the left *inferior frontal gyrus* (IFG; see Figure 1) and the left *anterior cingulate cortex* (ACC; see Figure 2). Together, these studies concerning children demonstrate that older children recognise letters more accurately than do younger children, which establishes the significance of their developing memory and sensorimotor skills.

Thus far, research on the recollection of words written with different modalities has been conducted on adults (Mangen et al., 2015; Smoker, Murphy, & Rockwell, 2009). Smoker et al. (2009) assessed the recollection and recognition of words written by handwriting and keyboarding among 61 participants. After a distraction task, the participants were given a recall task followed by a recognition task. The results of the recognition test were statistically significantly better for the handwritten words; the results of the recall test were not statistically significant. Nevertheless, Smoker and colleagues (2009) claimed that their results presented sufficient evidence that a connection between the psychomotor actions of writing modalities and memory existed. Mangen et al. (2015) investigated the recollection of words written not only by hand and laptop keyboards, but also by touchscreen keyboards. Immediately after writing, the 36 participants were asked to recall as many words as possible, and a word recognition test was administered. The handwriting condition produced statistically significantly better recollection scores, and a positive correlation was found between the recall scores after using touchscreens and years of experience using touchscreen devices.

Since studies concerning the recollection of more than single letters or words are scarce, Mueller and Oppenheimer's (2014) study of the processing and comprehension of substance texts is especially valuable. In their experiments, the researchers asked university students to take lecture notes by keyboarding or handwriting, after which their subject comprehension was examined. The students who used keyboarding for their notes produced more text; however, those who took handwritten notes seemed to better comprehend the subject matter, suggesting that handwriting involves deeper information processing and encoding. Hence, this study supported the hypothesis that handwriting facilitates conceptual knowledge construction. Research by Igo, Bruning and McCrudden (2005) corroborated this finding in the context of verbatim and non-verbatim notetaking. Their results indicated that non-verbatim notetaking was more beneficial for conceptual knowledge construction than verbatim transcription (Igo et al., 2005). However, regarding notetaking and recall, several other studies have suggested that verbatim notetaking on a laptop is more effective than verbatim handwriting (Bui, Myerso, & Hale, 2013; Igo et al., 2005; Kiewra, 1989; Van Meter, Yokoi, & Pressley, 1994; Mueller & Oppenheimer, 2014). In Bui et al.'s (2013) experiments, which investigated notetaking strategies and both immediate and delayed recall, support was found for the facilitative effect

of organised notetaking on recollection. However, as the test was only 11 minutes long, the results are not directly transferrable to longer lectures.

Nevertheless, the above-mentioned studies suggest that writing modalities, and one's competence in them, have an effect on recollection. The studies relying on cognitive psychological or cognitive neuroscientific approaches seemed to support the notion that handwriting has a memory-enhancing effect, one which is not generated by keyboarding. The studies that took a multidisciplinary educational and behavioural psychological approach viewed the facilitative function of keyboarding as verbatim notetaking. That said, their results concerned single letters, single words or short notetaking sessions, and hence the generalisability or transferability of these results is questionable. The narrow focus on letters, words and shorter texts common to such studies exposes the research gap concerning longer texts and their recollection, thus warranting further research.

1.2 Objectives, Process and Scope of the Thesis

This study developed a research design and test for assessing post-writing recollection with different modalities, the results of which culminated in the creation of an embodied knowledge construction model of affects in writing. The study not only pursued the epistemological objective of explaining writing-related cognition but also sought to capture the multidimensionality of such cognition. The value of this pursuit was its contribution to writing research and to understanding, explaining and conceptualising writing as a linguistic medium of cognition. When the skill of writing, with any modality, is automated after sufficient training, the cognitive load of the writing process shifts and resources can be allocated to other tasks (Berninger & Swanson, 1994; Klein, 1999; Ungerleider, Doyon, & Karni, 2002; Yeganeh Doost, Orban de Xivry, Bihin, & Vandermeeren, 2017), such as planning a written work and its topics and aiding its recollection. This process was corroborated by Limpo and Alves (2013) and Limpo, Alves and Connelly (2017), who confirmed the fluency of handwriting in writing performance via improved planning skills in grades 1 through 6 (2013) and grades 7 and 8 (2017). Fluency, in other words, means the automaticity and speed needed to transcribe and convert language and ideas into visible symbols and written text (Connelly, Gee, & Walsh, 2007). Another value of the current research was its bold attempt to comprehend the human mind's inestimable learning environment by approaching writing as a cognitive process of perception and action involving all levels of physical and mental activity, which are affected by environmental, contextual and cultural surroundings.

This thesis contributes, on a general level, to research on writing by addressing issues of concern in contemporary society, where writing modalities are constantly multiplying and evolving. More specifically, the thesis provides knowledge and

practical tools for developing instructional writing practices suitable for the present day. On a more focused level, the extensive review of previous empirical and theoretical studies on this topic revealed several research gaps, each of which was addressed in a sub-study, as presented in Figure 3.

Figure 3. Research process.

The first research gap was found on an empirical level, pertaining to experiential research. The research described in previous empirical articles (James & Engelhardt, 2012; Longcamp et al. 2003, 2005; Longcamp et al., 2006; Longcamp et al., 2008; Longcamp et al., 2005; Mangen et al., 2015; Smoker et al., 2009) concentrated mostly on letter or word recollection. To create a common ground, sub-study I produced a study design and test battery addressing adults' recollection after handwriting, keyboarding on a conventional computer and keyboarding on a touchscreen tablet computer. Sub-study I comprised one round of data collection on adult university students.

The second research gap was identified on a practical level, pertaining to practicalities and applications in educational settings. The literature review, as well as discussions with in-service teachers, highlighted the lack of methods available to assess the effects of different writing modalities on recollection. Such knowledge would assist in the adjustment of instructional practices, thereby enabling the achievement of the expected competences. Hence, sub-study II refined the study design and test battery for the quantitative assessment of recollection after writing with different writing methods from sub-study I. Sub-study II comprised three experiments on two datasets from 10-year-olds combined with two datasets from 11-year-olds and one dataset from 16-year-olds.

The third gap was found on the theoretical level, since the handwriting and keyboarding writing methods have fundamental kinaesthetic and proprioceptive differences (Hepp-Reymond, Chakarov, Schulte-Mönting, Huethe, & Kristeva, 2009). Even though the research on handwriting has shifted since the 1970s from a rhetorical approach of investigating the written product to a cognitive approach of investigating the writing process (Levy & Olive, 2002), the theoretical models of

typing (Crump & Logan, 2010; Logan & Crump, 2009, 2011; Rumelhart & Norman, 1982) typically focus on keystroke execution in the process of producing words. Hence, developing a theoretical model that could be used for the qualitative study of any method of writing became necessary during this research process. The embodied knowledge construction model was tested on one small group of six 16-year-old adolescents, as outlined in sub-study III. Table 1 describes the contributions of each author to the articles derived from the sub-studies in this research.

Table 1. Description of the Authors' Roles and Contributions in Each Sub-study and Article

	S-M. Frangou's Contribution	Other Authors' Contributions
Sub-study I → Article 1	• collected and analysed the data (1 dataset, 31 participants) • interpreted the results • wrote the majority of the manuscript • wrote up and finalised the article • revised the article based on the review process	• second author provided general guidance • third and fourth authors provided methodological guidance and contributed to the analysis of the results and the revision of the theoretical background
Sub-study II → Article 2	• collected and analysed the data (3 datasets, 135 participants) • interpreted the results • wrote the majority of the manuscript • wrote up and finalised the article • revised the article based on the review process	• second and fifth authors revised the results of the analysis and provided methodological guidance • third and fourth authors provided theoretical guidance
Sub-study III → Article 3	• collected and analysed the data (1 dataset, 6 participants) • interpreted the results • wrote the manuscript • revised the article based on the review process	

On a personal level, this research was derived from the author's view of the significance of literacy skills; a view which, in turn, is based on a decade of experience with organising the teaching and learning of the Finnish language for Finnish children living permanently abroad. Subsequent years as a primary school teacher in Finland further increased the author's interest in literacy. This teaching experience was invaluable, enabling not only a better understanding of the general school context but also of data collection situations. In particular, the removal of cursive handwriting from the renewed National Core Curriculum for Basic Education, implemented in 2016, gave the author the impetus to investigate different writing modalities and their effects on recollection. During this research process, the author drew from memorable experiences as a teacher; later, during the multidisciplinary research process, the author matured as a teacher, educator and researcher.

On the whole, this thesis argues that competent handwriting and keyboarding are constitutive elements needed to function in contemporary society, and therefore their systematic instruction is essential. The proposed research design and test combined with the embodied knowledge construction model of affects in writing yielded a well-rounded conceptual framework for identifying potential avenues for further empirical research and development.

1.3 Research Questions and Outline of the Thesis

Each of the three sub-studies in this research addressed one question (Table 2) which, when taken together, worked to answer the overarching research question: *What are the components of embodied knowledge construction in writing?* The three sub-studies investigated writing and the subsequent recollection of written texts among different age groups via different writing modalities, contributing to our primary understanding of the differences between age groups and between writing modalities in terms of recollection. Furthermore, each sub-study was aimed at generating better comprehension of embodied knowledge construction in writing by identifying conscious and unconscious embodied factors that influence the writing process, the recollection of written text and subsequent knowledge construction regarding writing.

Table 2. Summary of Research Themes for Each Sub-study

	Overarching research question: What are the components of embodied knowledge construction in writing?		
	Sub-study I Theme: Creating and developing study design for writing research	**Sub-study II Theme: Iterating and revising study design for writing research**	**Sub-study III Theme: Constructing theoretical model for writing research**
Research questions	*Does the writing modality influence students' recollection of dictated stories?*	*Do different writing modalities have differing influences on children's and adolescents' recollection?*	*How can affects be considered in knowledge construction during writing?*
Data	University students (n = 31)	Pilot experiment: 10-11-year-old children (n = 29) Experiment 1: 10-11-year-old children (n = 63) Experiment 2: 16-year-old adolescents (n = 43) Total of 135 participants	16-year-old adolescents (n = 6)
Method	Quantitative methods, mainly repeated measures ANOVA and pairwise comparison tests with Bonferroni adjustment	Quantitative methods, mainly repeated measures ANOVA and pairwise comparison tests with Bonferroni adjustment	Merging of Hayes' framework (1996) for understanding cognition and affect in writing *with* Wilson's (2002) six aspects of embodied cognition to develop the embodied knowledge construction model for the qualitative assessment of affects
Publication	Frangou, S-M., Ruokamo, H., Parviainen, T., & Wikgren, J. (2018). Can you put your finger on it? The effects of writing modality on Finnish students' recollection. *Writing Systems Research.*	Frangou, S-M., Wikgren, J., Sintonen, S., Kairaluoma, L., & Vasari, P. (2019). The effect of writing modality on recollection in children and adolescents. *Research in Learning Technology.*	Frangou, S-M. (2018). Embodied knowledge construction in writing. *Education in the North.*

As shown in Table 2, all of the sub-studies have been published in peer-reviewed international scientific journals.

This thesis is divided into six chapters. This introductory chapter is followed by Chapter 2, which describes two theoretical frameworks: Hayes' (1996) framework for the cognitive process of writing, and Wilson's (2002) six aspects of embodied cognition, which were merged in sub-study III to develop the embodied knowledge construction model of affects in writing. Chapter 3 explains the methodological principles of this research, which drew from the educational design research (EDR) approach and the quantitative methods deployed in each sub-study. Chapter 4

provides an overview and evaluation of the three sub-studies: The first sub-study involved one empirical assessment of 31 adult participants; the second sub-study comprised three empirical experiments with 135 children and adolescents; the third sub-study merged the two above-mentioned theories into a single framework, which was subsequently tested on six adolescents. Chapter 5 discusses the findings of this research, and Chapter 6 provides its implications.

2 THEORETICAL FRAMEWORK

This chapter begins by discussing the general background of theoretical frameworks for writing and keyboarding. This is followed by the presentation of the two theoretical frameworks used to underpin the embodied knowledge construction model of affects in writing, developed in this research. This model was developed during the research process by merging two theoretical frameworks: Hayes' (1996) framework for the cognitive process of writing, and the six aspects of embodied cognition originated by Wilson (2002). The embodied knowledge construction model of affects in writing was initially developed in sub-study III before being refined, the results of which are discussed in Chapter 5. Ultimately, the model serves as a framework that addresses and links all three sub-studies.

2.1 Theoretical Frameworks of Handwriting and Keyboarding

During the research process, the need emerged for a conceptual framework and heuristics to guide the research on cognition in writing with multiple writing methods. This need arose because the purpose of both handwriting and keyboarding is communication, with the result being the production of written text. Neither writing method reveals much in the way of underlying perspectives. Therefore, theoretical frameworks for handwriting and typing were sought to explore the methods from different perspectives. During the writing process, various skills and actions are needed to produce legible text. Studies in the theoretical tradition of cognitive writing have investigated these skills and actions in an effort to define and explain the writing process (Deane et al., 2008). Notably, writing research, particularly handwriting research, has changed from being product-oriented to being cognitive process-oriented (Levy & Olive, 2002). Nonetheless, extant research on keyboarding and typing deal more with peripheral aspects and practical applications, such as locating and striking the correct keys (Pinet, Ziegler, & Alario, 2016).

The cognitive process of handwriting is generally investigated from the viewpoint of processing stages and memory functions, combined with motor components, towards the production of letters and text (Bereiter & Scardamalia, 1985; Berninger & Swanson, 1994; Chenoweth & Hayes, 2001, 2003; Flower & Hayes, 1981; Hayes, 1996; Hayes & Chenoweth, 2006; Hayes & Flower, 1980; Scardamalia & Bereiter, 1987; van Galen, 1991). The shift from a product-oriented to a process-oriented research approach to handwriting occurred in the mid-1970s and particularly in

1980 with the publication of Flower and Hayes' *The Cognition of Discovery: Defining a Rhetorical Problem*. Cognitive process theory, introduced by Flower and Hayes (1981), clarifies the earlier cognitive process model they developed (Hayes & Flower, 1980) and proposes that compositional writing is a recursive action. The model has been modified several times over the intervening decades from different viewpoints, mainly because it provides an excellent description of the basic cognitive process of writing (Alamargot & Chanquoy, 2001). For example, Berninger and Swanson (1994) concentrated on the writing process of novice writers while Berninger et al. (1992) and Berninger, Cartwright, Yates, Swanson and Abbott (1994) conducted research on spelling abilities and orthographic knowledge in the writing process. Berninger and Swanson (1996) highlighted the significance of transcription skills for developing writers because transcription requires correctly spelled words and orthographically correct text.

Transcription skills were further studied by Chenoweth and Hayes (2001, 2003) and Hayes and Chenoweth (2006). Bereiter and Scardamalia (1985) and Scardamalia and Bereiter (1987) took a different approach, digging further into the capacity to write by designing a developmental model with two writing strategies: a knowledge-telling strategy and a knowledge-transforming strategy. The model holds that novice writers can only write about what they know, whereas expert writers deploy a knowledge-transforming strategy, combining and comparing accumulated knowledge and concepts and consequently elaborating on the resulting corpus of information more deeply. Reflective thinking, which is more evident among expert writers, helps them to plan and modify their writing during the writing process. By contrast, van Wijk (1999) used Levelt's (1989) framework for speaking to develop a model of written production. For his part, Kellogg published models in 1996 and 2001 that depicted the relationship between writing production and working memory components with different information-processing capabilities. Meanwhile, Galbraith (1999, 2009a, 2009b) proposed a dual process model which holds that writing is a knowledge-constituting process. These models all address the cognitive process of writing from different, yet complementary, standpoints.

By contrast, typing frameworks conceptualise writing as a process of constructing words by executing keystrokes (Logan & Crump, 2009, 2011; Rumelhart & Norman, 1982; Yamaguchi & Logan, 2014) instead of planning or reflecting on text. Rumelhart and Norman (1982) focused on the mechanisms by which information about the location of each key as well as which ones to press is retrieved. Seminal work by Logan and Crump (2011) described the typing process as two separate loops that function in parallel. The outer loop represents the individual's conscious processing of letters, words and sentences, while the inner loop represents his or her unconscious, automated pressing of appropriate keys, as instructed by the outer loop. This suggests that competent typists do not know which keys they are pressing at any given time (Liu, Crump, & Logan, 2010; Logan & Crump, 2009; Snyder,

Logan, & Yamaguchi, 2015). Logan and Crump's (2011) two-loop model has been further studied and refined by Yamaguchi and Logan (2014), who discovered three sequential forms of action in typing that control linguistic-level associations: (1) the association between the words to be typed and the appropriate letters from which the words will be constructed; (2) the association between the appropriate letters and the corresponding keys; and (3) the association between the keys to press and the appropriate fingers for pressing them.

As explained above, the major difference between the typing and handwriting models is one of perspective: While handwriting models seek to understand the cognitive process of producing text, typing models aim to clarify the mechanical process by which letters and words are produced. Hence, it is challenging to study several writing methods at the same time. In response, this study developed a research design that allowed the simultaneous examination of several writing methods along with associated knowledge constructions.

2.2 Cognition and Affect in Writing

The motivation to take a cognitive approach to writing research was given through the design and introduction of the cognitive process model by Hayes and Flower (1980) and cognitive process theory by Flower and Hayes (1981), both of which propose that writing constitutes a recursive action of planning, translating and revising. These seminal works, together with Baddeley's general model of working memory (1986), formed the basis of Hayes' individuo-environmental framework for understanding cognition and affect in writing (1996). The model by Hayes and Flower (1980) introduced three components vital to the writing process: the first component was the task environment, encompassing that which exists outside the writer's mind, the topic addressed and the text produced, the possible audience for whom the text is written, and the writer's motivation to write. The second component is the cognitive writing process, which is constantly monitored and functions according to three sub-processes, including the planning of writing by retrieving relevant information from long-term memory, translating the retrieved information into sentences according to the plan, and reviewing and editing the written text. The third component is the long-term memory of the writer, which contains the writer's knowledge of the topic, audience and linguistics rules concerning the planned text style. The information retrieved from long-term memory must often be reflected upon and organised before writing. All three components can work simultaneously and automatically (Hayes & Flower, 1980).

The model by Hayes and Flower (1980) has served as the inspiration for a series of studies and other models of writing, including those of Chenoweth and Hayes (2001, 2003) and Hayes (2009, 2012), which both developed writing models

involving revising, transcribing and producing text and compared first- and second-language writers. The three components of Hayes and Flower's (1980) model considered the extensive knowledge required for writing and the complex information retrieval process that occurs during writing. Nevertheless, Hayes (1996) further refined the architecture of this model by proposing that the writing process occurs in two different dimensions: the dimension of the task environment and the dimension of the individual, thereby taking into account the effect of sociocultural differences and different writing tools (Figure 4). The current research used Hayes' (1996) model because it provides a holistic framework, incorporating individual, environmental, motivational and affectual factors, for researching writing in light of embodied cognition.

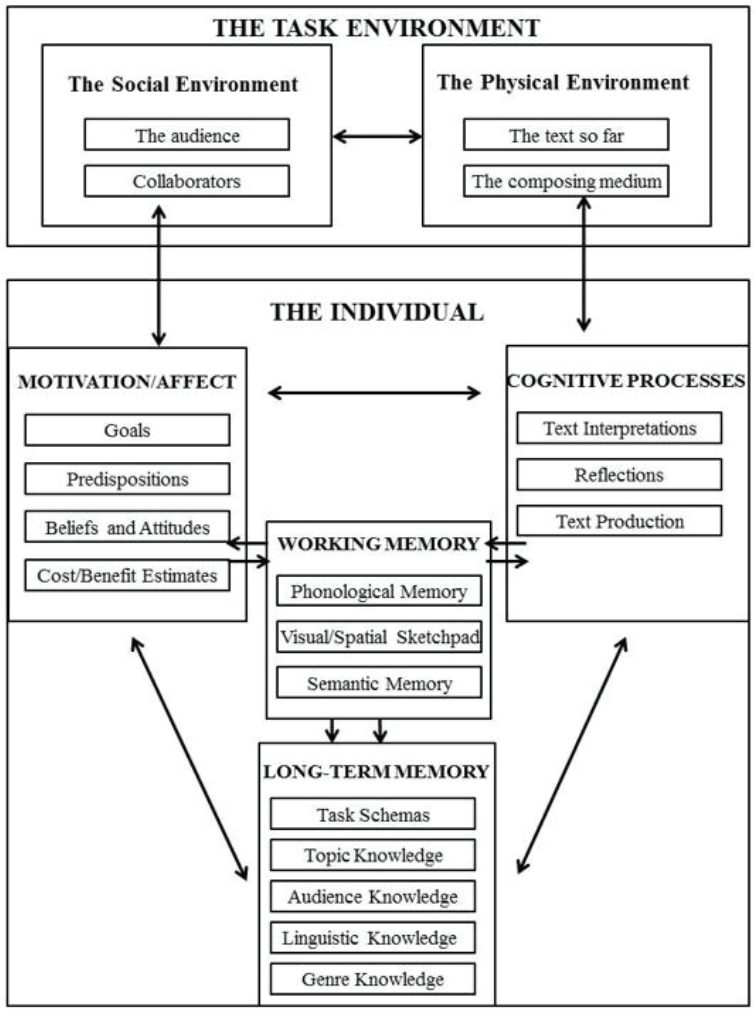

Figure 4. Hayes' (1996) individuo-environmental framework for understanding cognition and affect in writing (Copyright © by Lawrence Erlbaum Associates. Used with permission).

As shown in Figure 4, the task environment in Hayes' (1996) refined model includes the social environment, highlighting the significance of contextual and social factors in affecting writing, and the physical environment. The social environment represents not only the possible collaborators and audience for which the text is written, but also the general cultural and social environment, which influences what and how the individual writes. The physical environment entails the writing medium and the text produced so far.

Hayes' (1996) individuo-environmental framework for understanding cognition and affect in writing also refines the dimension of the individual and explores four different internal processes and factors that influence the writing process. Working memory, which lies at the epicentre of the individual's dimension, thereby emphasising its significance, involves visuospatial representations with phonological and semantic memory, manages non-automated task performance and retrieves information from long-term memory. Long-term memory is also crucial in the writing process because it stores the task schema or plan; linguistic knowledge of vocabulary, grammar and genre; and knowledge of the topic and target audience. Hayes' (1996) refined model also includes motivation and affect as integral parts of the individual. The writer's goals, predispositions, beliefs and benefit estimates can all influence his or her choices and motivations to engage in writing. Furthermore, affective responses in writing can be linked to the writer's beliefs about his/her competencies as a writer. If one perceives him/herself as non-gifted writer, they might be reluctant to write. Cognitive processes have also been redefined in the refined model by subsuming planning and translating into a more general cognitive function of reflection. Additionally, in the refined model, text interpretation replaces reviewing, maintaining text interpretation and text production as the primary cognitive function.

The refined framework for understanding cognition and affect in writing (Hayes, 1996) incorporates the spatial dimension of writing as well as the role of motivation, affect and reflection throughout the writing process. Furthermore, Hayes (1996) emphasised the social environment and its influence on the writing process, which can be understood as the effect of the external social world on an individual's internal world and motivations. The physical environment now situates the writing medium as an important component of the writing task, raising awareness about different cognitive processes related to different writing mediums. These aforementioned factors of Hayes' framework provide the ideal underpinnings for the inclusion of the six aspects of embodied cognition developed by Wilson (2002). Taken together, these models can be used to examine embodied knowledge construction in the context of writing.

2.3 Embodied Cognition

To challenge and deepen our knowledge about the complexity of human cognition (Garson, 1996), various disciplines have united under the banner of cognitive science, including philosophy, psychology, neuroscience, artificial intelligence, computer science and linguistics. The mind's complex architecture and information-processing features have been studied since the 1950s (Friedenberg & Silverman, 2011; LeDoux, 2012; Thomson, 2010); however, the theory of embodied cognition has not yet been clearly conceptualised (Hommel, 2015; Mahon, 2015). Varela, Thompson and Rosch's (1991) pioneering work is widely considered to be the beginning of the development of a modern perspective on embodied cognition.

The focus of studies has shifted in recent decades with the discovery of unexplored areas of cognition, growing from deductive reasoning to perceptual properties to, finally, an embodied approach to cognition. In the past, cognitive science was primarily concerned with the theory of mind, overlooking the issue of consciousness (Roy, Petitot, Pachoud, & Varela, 1999). Furthermore, researchers have recently expressed their view that these disciplines have yet to consider the entirety of cognition, as they tend to overlook not only emotions and affect but also motivation, subjectivity and consciousness (LeDoux, 2012; Thomson, 2010). In 1996, Varela investigated the correlates of emotions, providing a better understanding of emotional processing in the brain. The segregation and separate investigation of human cognitive functions, be they conscious or unconscious, paved the way for a perspective within the field of cognitive science in which emotions and motor functions are seen as collaborative, embodied cognitive processes, encompassing an individual's material sociocultural environment (Thomson, 2010). In short, embodied cognition examines the issue of perceiving and processing surrounding stimuli *within* our bodies via our previous experiences alongside conscious and unconscious sensations, thus generating new insights into the action–perception sequence (Roy et al., 1999).

Embodied cognition theory has gained support from the discovery of a process in humans similar to the mirror neuron system described by Mukamel, Ekstrom, Kaplan, Iacoboni and Fried (2010). According to this process, performing an action and observing its outcomes activate certain brain areas, suggesting the interrelation of perceptual and motor properties (Aziz-Zadeh & Damasio, 2008; Jirak, Menz, Buccino, Borghi, & Binkofski, 2010; Keysers & Gazzola, 2010; Mukamel et al., 2010) and of different writing modalities. Presumably, networks related to action production may be involved in action understanding, with actions and their subsequent perception activating the brain within the same sensory and motor circuits (Aziz-Zadeh & Damasio, 2008). However, the perceived action must be purposeful; imitation without a goal does *not* activate this system (Lohmar, 2006). This could point to the significance of having different perceptions while using different writing methods; for example, during handwriting, one perceives the

actions and productions of one's hand with a pen, whereas a typist perceives the text as appearing on the computer screen.

The significance of self-performed actions in cognition was highlighted in the action perception theory of cognition and communication developed by Marc Jeannerod and his colleagues (Jacob & Jeannerod, 2005; Jeannerod, 1994, 2001, 2006; Jeannerod, Arbib, Rizzolatti, & Sakata, 1995). Several studies have derived from this theory, consequently deepening our knowledge about the action–perception sequence by examining the interdependence of action and perception circuits (Pulvermüller & Fadiga, 2010), as well as their role in cognition, communication, language (Pulvermüller, Moseley, Egorova, Shebani, & Boulenger, 2014) and the context of action verbs (Boulenger et al., 2008). In this theory, particular emphasis is placed on the cooperative sensory and motor functions of the brain, meaning that actions have sensory and motor properties, and that perceptions also process motor information, not just sensory information. This reciprocal processing of motor and sensory information facilitates the consolidation of action-related memories, which can be seen as a theoretical link to the cognitive process of writing. Notably, motor activation is bidirectional; thus, actions have been seen to be influenced by perception, and vice versa (Blaesi & Wilson, 2010). Furthermore, motor regions of the brain (see Figures 1 and 2) have been shown to be capable of activation while processing action words and comprehending language (Boulenger et al., 2008; Vucovic, Feurra, Shpektor, Myachykov, & Shtyrov, 2017; Jacob & Jeannerod, 2005; Pulvermüller & Fadiga, 2010; Pulvermüller et al., 2014). We also use our bodies to facilitate communication via gesturing (Rizzolatti, Graighero, & Fadiga, 2002) and facial expressions (Studdert-Kennedy, 2002).

Notably, reading written text symbols activates the same motor areas of the brain involved in actually writing those symbols (Heimann, Umilta, & Gallese, 2013). Some accounts also propose that perceptual–motor integration has a general role, especially in short-term memory (Macken, Taylor, & Jones, 2014), and that sensory-motor features are involved in knowledge construction (Barsalou, 2008). In other words, mirror neurons provide a sort of bridge between the perceptual, sensory and motor modalities. Thus, the science behind behaviour and cognition, alongside phenomenology – the associations and denotations that things have in our experiential existence – form an ever-developing process of elucidation (Ratcliffe, 2006). Therefore, each writing modality should influence knowledge construction, which would in turn require neuroimaging studies to examine the mechanisms underlying memory traces of writing that later facilitate recollection. Haptic perceptions and their connection to literacy have been extensively studied by Mangen and her colleagues (Mangen, 2008; Mangen & Van der Weel, 2016; Mangen & Velay, 2010), who have emphasised the interdependence of perception and motor action as well as changes in embodied experience and writing practice

due to shifts in writing technologies (Mangen & Velay, 2010). Writing by hand can thus produce solidified memories of the written text content, as well as its spatio-temporal depiction (Haas & McGrath, 2017).

To build the embodied knowledge construction model of affects in writing, the following six aspects of embodied cognition (Wilson, 2002) have been extended and refined: situated cognition, temporally pressured cognition, cognitive load distribution, environment's effect on cognition, action's effect on cognition and offline body-based cognition. Figure 5 is based on Wilson's (2002) view of the six aspects of embodied cognition, each of which is explained below the figure.

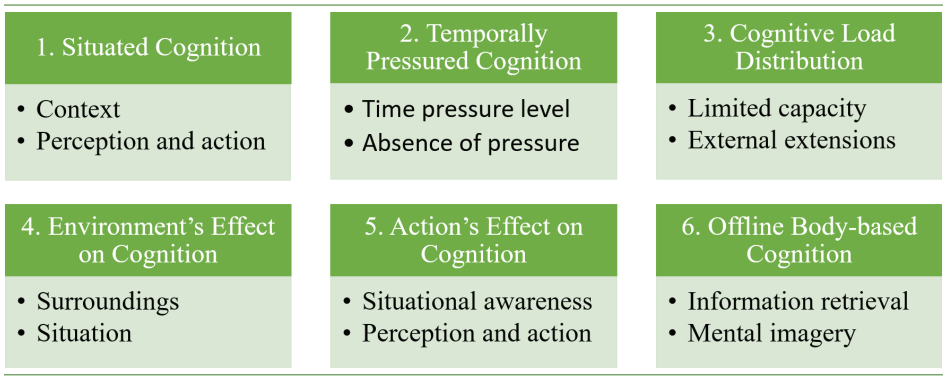

Figure 5. Six aspects of embodied cognition, adapted from Wilson (2002).

Aspect 1. Situated Cognition: Situated cognition means that cognitive processes take place in a certain context, which can encompass equipment and tools as well as the environment. In addition, information about motor activity and the perceived situation are processed, and actions are modified according to the affected environment, pointing to the inherent capability for perception and action.

Aspect 2. Temporally Pressured Cognition: Temporally pressured cognition refers to the fact that the cognitive process is also sensitive to time pressure, or the lack thereof. People are aware of time pressure, which subsequently affects their behaviour and actions.

Aspect 3. Cognitive Load Distribution: Cognitive load distribution means that since people have a limited cognitive load capacity, external extensions are used, such as notebooks, to relieve the load.

Aspect 4. Environment's Effect on Cognition: The environment's effect on cognition refers to the fact that the surrounding environment and the circumstances in which cognition occurs are inherently involved in and affect the cognitive process, pointing to interaction between individuals and situations.

Aspect 5. Action's Effect on Cognition: Action's effect on cognition signifies the situational awareness and perception of actions which are part of the cognitive process and contribute to the behaviour of the individual.

Aspect 6. Offline Body-based Cognition: The last aspect of embodied cognition, offline body-based cognition, concerns offline cognition, meaning that humans have the automated ability for reasoning, using mental imagery and retrieving information from memory (Wilson, 2002). This aspect has been further discussed in Wilson's (2013) work in conjunction with synaesthesia, pointing to the innate ability to experience sensations in modalities other than those with which a stimulation was initially received.

In sum, the six aspects of embodied cognition (Wilson, 2002) suggest the harmonious cooperation of the mind and body, opening new avenues for discussion on writing and affect. Embodied cognition represents a theory for making sense of and understanding knowing-in-action through emotional aspects, highlighting the implicit and tacit knowledge conveyed by embodied cognition (Groth, 2017). This perspective encourages novel explorations of knowledge construction in writing with multiple modalities. Tactile motor action with audial, visual and sensory perception might therefore be interconnected with the cognitive learning process (Mangen et al., 2015). Furthermore, the haptic affordances of different writing modalities are distinctly dissimilar, with each modality possessing its own properties, possible uses and movements associated with different tactile perceptions (Mangen & Velay, 2010). As a consequence, the six aspects of embodied cognition (Wilson, 2002) offer a compelling argument for recognising the influence that writing techniques might have on cognitive processes.

3 RESEARCH METHODOLOGY

This chapter outlines the research approach and methodological principles of this study, which were based on EDR (Kelly, Baek, Lesh, & Bannan-Ritland, 2008; McKenney & Reeves, 2012; McKenney & Reeves, 2018; Van den Akker, Gravemeijer, McKenney, & Nieveen, 2006), and discusses how these principles materialised during the research process. The chapter first provides the epistemological and ontological foundations of the research, followed by a justification of the methodological choice. This is followed by a detailed description of the research phases in each of the sub-studies. The quantitative data collection procedure is then defined, and an explanation of the research instrument and data analysis methods is provided. The chapter also outlines the process by which a new theoretical model for qualitative writing research emerged.

3.1 Epistemological and Ontological Foundations of the Research

Research dealing with knowledge and learning establishes certain concepts and methods drawn from the researcher's meta-theoretical framework. The ontological and epistemological foundations that guided the present research were derived from the postpositivist research paradigm and from quantitative experimental methodology, culminating in a qualitative model for affects in writing that can be used as a general theoretical framework in writing research. The postpositivist worldview recognises the complexity of studying human beings and how difficult it is to reach definitive conclusions about knowledge and its acquisition (Creswell, 2014). This worldview also suggests testing, developing and refining theories to obtain a better understanding of the world (Creswell, 2014), which was ultimately the fundamental aim of this research. The ontological dimension of knowledge refers to the researcher's perception of knowledge and its nature. Epistemology refers to perceptions regarding how this knowledge is acquired, forming a paradigm that inherently refers to and reflects the general theoretical framework of the research (Creswell, 2014; Kivunja & Kuyini, 2017). Ontological and epistemological foundations consequently influence and result in methodological decisions made during the research process, encompassing approaches, the research design and process, and the methods and tools used to collect data (Creswell, 2014; Keeves, 1997). In addition to these three elements, the paradigm has a fourth element,

axiology, which considers the ethical issues of the research (Creswell, 2014; Kivunja & Kuyini, 2017). The aforementioned elements all need to be in agreement and they were, therefore, carefully considered in this research. Furthermore, the present research drew from the cognitive learning paradigm, which considers learning as the active acquisition and construction of new knowledge. A cognitive learning paradigm seeks to explain the architecture of the mind as well as cognitive processes, while at the same time accounting for the significance of context, prior experiences and knowledge, and the effect of emotions (Rothermund & Koole, 2018; Šešok & Jensterle, 2001).

3.2 Research Approach

This study used the EDR approach as a methodological principle, first to gain a holistic and versatile understanding of the writing research field through the iterative phases of design, testing, analysis, reflection and refinement, and second to develop and improve educational practices involving writing. In other words, the empirical interventions discussed in this thesis constituted a significant vehicle for generating profound theoretical understanding. The framework presented here was adapted from the design-based research (DBR) model, conceptualised by Reeves (2006) and modified by McKenney and Reeves (2012) to become an EDR model, which was then further refined by McKenney and Reeves (2018) for educational settings. DBR research can be considered a systematic research approach, one which seeks to determine and refine solutions to real-life problems and challenges (McKenney & Reeves, 2012, 2018; Reeves, Herrington, & Oliver, 2005), as well as an exploratory sequential design in which a measurement instrument is developed with quantitative and qualitative methods to better address the research problem. In this sense, qualitative research deepens the general information yielded by quantitative methods (Creswell, 2014).

In light of the ultimate objectives of DBR, EDR aims to develop new theories and practices to meet the real needs of education providers (Barab & Squire, 2004; Juuti & Lavonen, 2006; Design-Based Research Collective, 2003). DBR incorporates a succession of methodological approaches to develop, test and improve practices (Barab & Squire, 2004; Design-Based Research Collective, 2003), which in EDR are targeted to educational settings. Brown (1992) introduced the DBR approach in an educational setting to highlight the significance of the adaptability of experimental interventions in average classrooms. Brown (1992) used the term *design experiment*; however, in the 20 years that followed, this term has evolved to become *development research* (Conceição, Sherry, & Gibson, 2004), *design research* (Oh & Reeves, 2010) and finally, *EDR* (McKenney & Reeves, 2012). This research adopts EDR to denote the field of education, the main characteristics of which are the synergistic,

simultaneous advancement of practice and theory, as described by McKenney and Reeves (2018). The importance of co-developing solutions for educational purposes with all actors involved corroborates the research findings by Vesisenaho and Dillon (2013). Reeves, Herrington and Oliver (2005) added that the fundamental aim of DBR, and EDR (McKenney & Reeves, 2018), is to develop theory throughout the project via experiences based on practice or experiments, further pointing to the suitability of the EDR research approach in this study.

Moreover, in EDR, the researcher leads the research process by initiating, designing and refining the research (McKenney & Reeves, 2012, 2018). EDR intertwines theory, empirical research, experience and practice, and thereby produces a dual goal of practical and theoretical contributions (McKenney & Reeves, 2018) – a goal that matched the objectives of this research quite well. Often in design research, more than one theory is required for the explanation or description of the subject under investigation (Halmarson & Lesh, 2008). Furthermore, theories derived from studies of cognition and perception that take into account issues of motivation, interpersonal communication and neuropsychological functions (Kelly et al., 2008) strongly suggest the suitability of the developed embodied knowledge construction model of affects in writing in this research.

In the EDR approach and process, researchers must be aware of their position on the epistemological continuum and consider the influence that a particular position might have on the study (Kelly, 2006). As a learning designer and researcher in this study, the author was extensively involved with each participant's memory tests and with actively developing, testing, analysing and refining the study design and test battery for the different age groups based on existing scientific research, signifying total immersion in the research context and process (McKenney & Reeves, 2018). The subjective role and intense involvement of the researcher in EDR stems from the characteristic by which the researcher also becomes the initiator of the research idea (Barab & Squire, 2004; Kelly et al., 2008; McKenney & Reeves, 2018). The researcher must evaluate and reflect on the developing solutions throughout the research process. In the process, potential solutions are tested in a real-life context, and the researcher thereby gains not only a more academic and theoretical understanding, but also a contextual and personal understanding of those to whom the solutions are created (Kelly et al., 2008; McKenney & Reeves, 2018; Sloane & Kelly, 2014).

This research adopted an experimental and quantitative research approach in all three sub-studies to develop a research design and pilot study to investigate recollection after using different writing modalities. Furthermore, sub-study III merged two theoretical approaches and provided a new theoretical model to address the qualitative dimension of writing as a memory-enhancing medium. These sub-studies were performed to determine a way in which writing could be holistically examined, with multiple modalities, and counterbalanced against any potential

weaknesses in either the quantitative or qualitative methods (Leech & Onwuegbuzie, 2010). The overall EDR process, as well as the EDR processes for each sub-study, are described below in sub-chapter 3.3.

3.3 Phases of Research

This study comprised three empirical sub-studies, all of which relied on quantitative data. The first and second sub-study were experimental and quantitative, while the third sub-study was both quantitative and qualitative, with its theoretical foundation derived from the experiences and reflections generated in the other two sub-studies. Subsequently, in the third sub-study, a theoretical model for qualitatively researching writing was tested to more fully investigate the accompanying quantitative data. Each sub-study contributed to the development of not only the research design and pilot study for assessing recollection after writing using multiple modalities, but also to the development of the embodied knowledge construction model of affects in writing. In McKenney and Reeves' (2018) generic model for conducting design research in education, there are three core phases, each of which has an iterative and malleable structure. Each phase occurs in a cyclical process and thus constitutes a single sub-cycle. The phase of analysis and exploration refers to the empirical process of identifying a problem and reviewing relevant literature to gain more knowledge about the issue. In the generative phase of design and construction, focus is placed on developing and generating the conceptual model or intervention, but not testing it. Then, in the empirical phase of evaluation and reflection, the intervention is tested and assessed. Following these phases, two outputs are produced: maturing intervention and theoretical understanding, which both develop over time (McKenney & Reeves, 2018). This process requires an implementation perspective in real contexts as well as a dissemination plan for the resulting findings. As McKenney and Reeves (2018) described, the entire EDR process consists of a series of sub-cycles and multiple sub-cycles. Figure 6 shows all sub-cycles of the EDR process, followed by an explanation of the multiple sub-cycles of each sub-study.

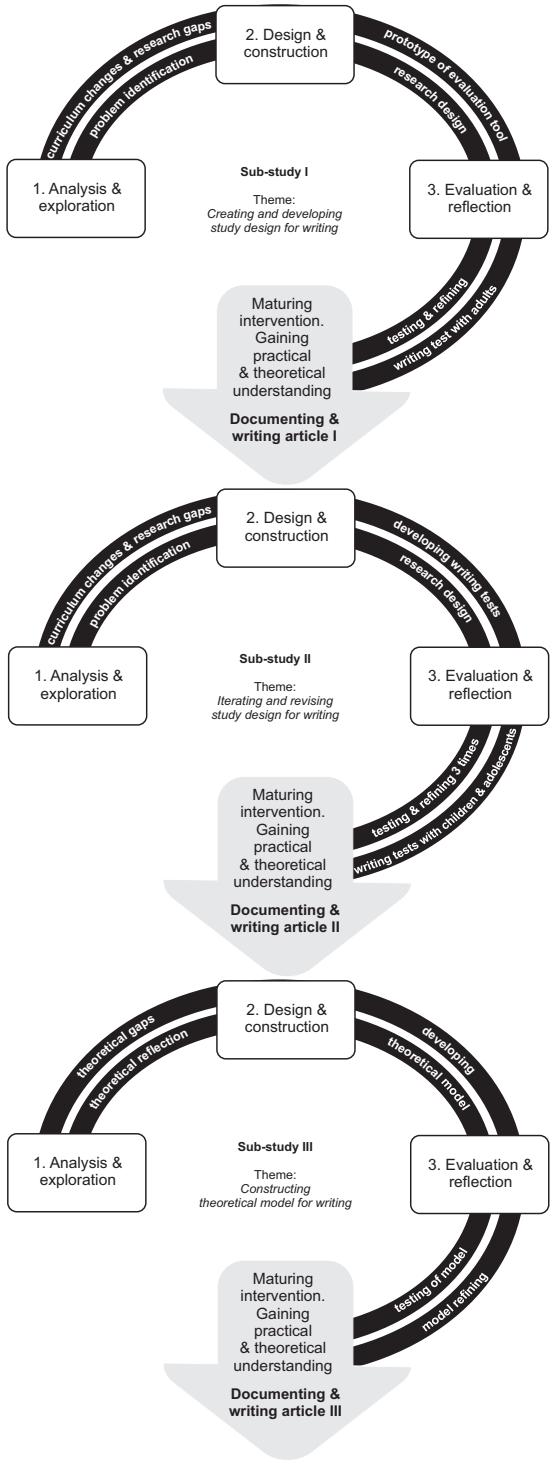

Figure 6. Overall EDR process in this research, adapted from McKenney and Reeves (2018).

As shown in Figure 6, each of the three sub-studies has its own sub-cycle, within which the research process occurred in smaller sub-cycles: analysis and exploration, design and construction, and evaluation and reflection. Through these smaller sub-cycles, a practical and theoretical understanding was gained and the intervention was matured in each sub-study. At the end of the EDR process of each sub-study, a scientific article was published to disseminate the results of the research. In the following sub-chapters, Figure 7 illustrates the research process undertaken in sub-study I and Figures 8 and 9 do the same for sub-studies II and III, respectively. When brought together, the three sub-studies comprise the overall research process shown in Figure 6 above.

3.3.1 Phases of Sub-study I

In the first phase of sub-study I (Figure 7), a problematic issue was identified in a real school environment, which was then examined by the researcher with the cooperation of education professionals.

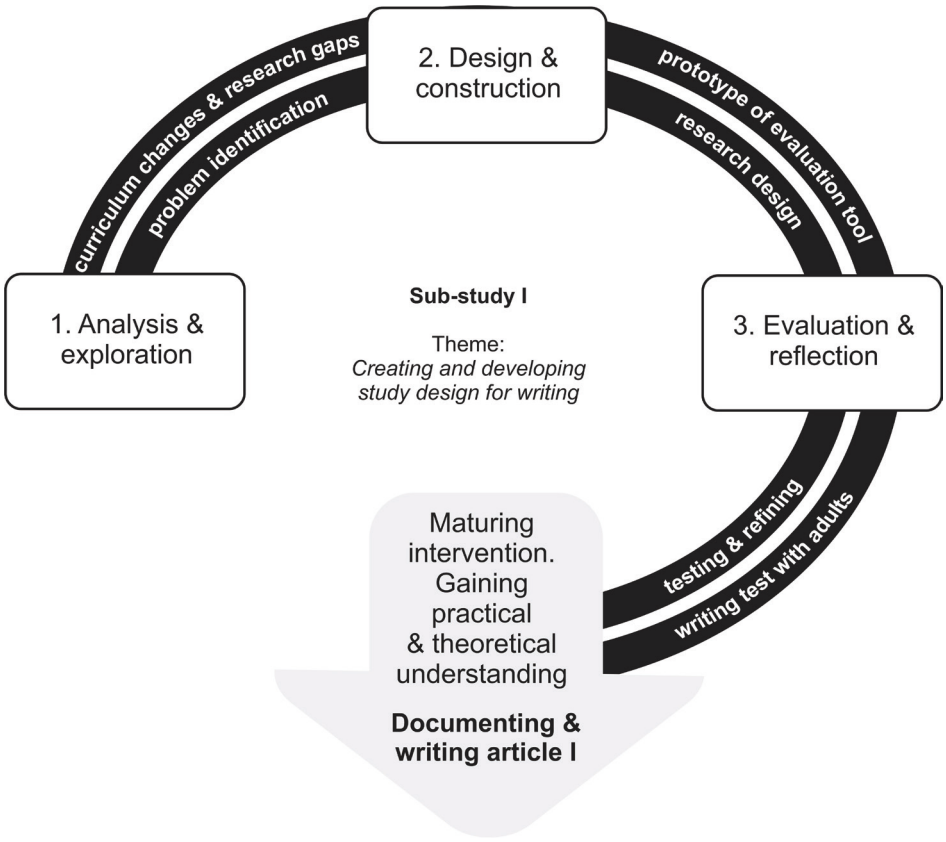

Figure 7. The EDR process of sub-study I conducted with university students, adapted from McKenney and Reeves (2018).

In this research, the initial problem identification occurred with the announcement of the removal of cursive handwriting from basic education with the renewal of the Finnish National Core Curriculum (Opetushallitus, 2014), which was implemented in 2016. The author was a primary school teacher at the time, and discussions among other professionals demonstrated their concern not only over this change but also in regard to the scant material available for teaching keyboarding, particularly for teachers who do not know keyboarding, and for assessing children's keyboarding competence. Furthermore, the need for an assessment tool that could measure competence in multiple writing methods arose from the fact that the new curriculum introduced multiliteracy as a transversal competence. The relevant literature was explored, and the first gap in the empirical research was discovered, concerning writing modality-related recollection. A literature review of writing theories also established an incongruity between handwriting and typing theories, thereby impeding their effective use in research on multiple writing modalities. Subsequently, sub-study I investigated a real university setting with adult university students to obtain a better understanding of their writing abilities and consequent recollection of written texts.

Phase 2 of the study involved the development and construction of a solution. Hence, the development of a test to compare different writing modalities and their effects on recollection occurred during sub-study I. At this stage, the methodological choice had not yet been determined. As sub-study I began yielding results, the iterative and reflective design of the EDR approach was shown to be the appropriate methodology for developing an assessment tool to address real-world school problems. Understanding was gained through the iterative cycles, which also refined the intervention that, in this case, became an assessment tool. The assessment tool was then used to determine whether further intervention was necessary.

In phase 3, the solution, meaning the study design and the writing process, was tested with adult university students to create common ground in the field. The test and its results were subsequently evaluated and reflected upon.

At the end of sub-study I, concerning the output of the study, a reflection of the entire process and the obtained results generated a new theoretical and practical understanding, which highlighted the need to investigate other age groups. Furthermore, familiarisation with additional literature highlighted the need to develop a theoretical model on which to reflect. Derived from the results of sub-study I, the first article in this thesis was written to disseminate the information gained from the study. The dissemination of information in the EDR process was depicted by McKenney and Reeves (2018) as one of its most important aspects.

3.3.2 Phases of Sub-study II

Figure 8 shows the EDR refining process of the study design and writing test conducted in sub-study II for children and adolescents.

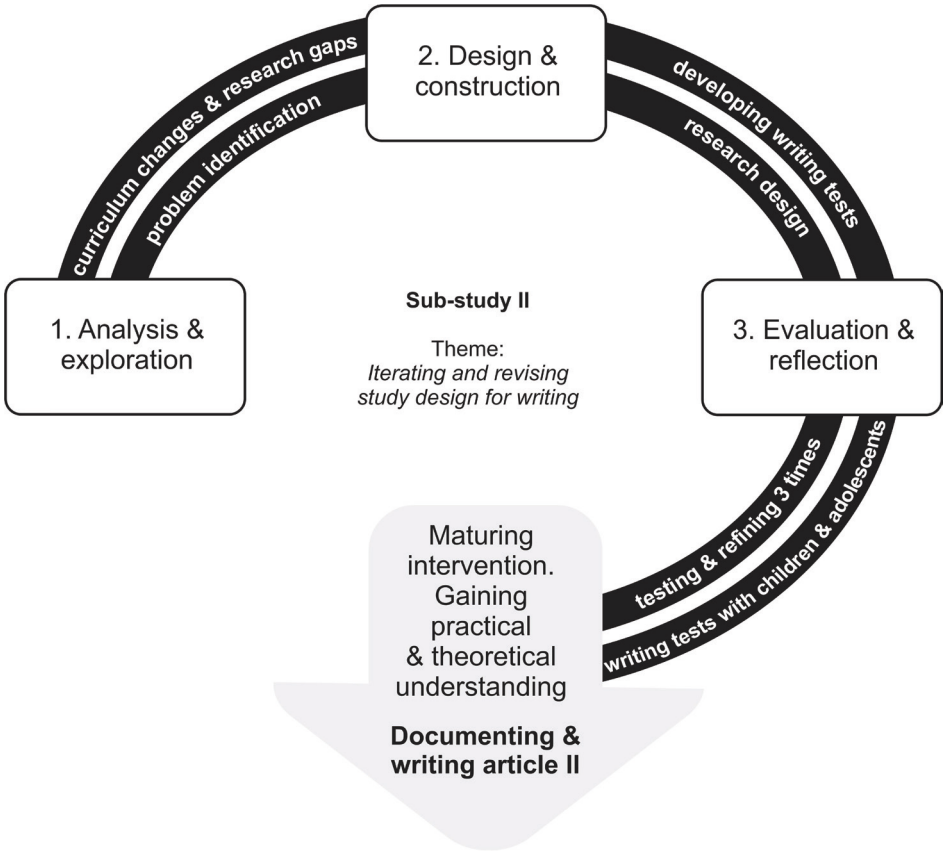

Figure 8. The EDR process of sub-study II conducted with children and adolescents, adapted from McKenney and Reeves (2018).

The first phase of sub-study II (Figure 8) explored the problematic issues that remained in a real school environment. Subsequently, phase 2 involved refining the test used in sub-study I to compare the effects of different writing modalities on recollection among adults, in the experiments of sub-study II for children.

In phase 3 of sub-study II, the writing test was administered in a real school setting. The test was administered in three separate experiments to different age groups. First, a pilot experiment in which the participants were 10- to 11-year-old children (3rd and 4th graders in primary school, spring 2017) evaluated and refined the original test. The refined test was then used in experiment 1 with 10- to 11-year-old participants (4th and 5th graders in primary school, autumn 2017). The test was then administered to 16-year-old adolescents (9th graders in secondary school, spring 2017) in experiment 2, and all the tests and their results were then evaluated and reflected upon. After the evaluation and final reflection upon the whole process of sub-study II and its results, new theoretical and practical understandings were

obtained. Moreover, sub-study II generated a further understanding of the need to develop a theoretical model on which to reflect. The second article disseminated the knowledge gained from sub-study II.

3.3.3 Phases of Sub-study III

The reflections and the three experiments from sub-study II yielded deeper theoretical understanding while highlighting the theoretical gap that exists in research on writing. As a result, the EDR process of sub-study III was used to develop the embodied knowledge construction model, as shown in Figure 9.

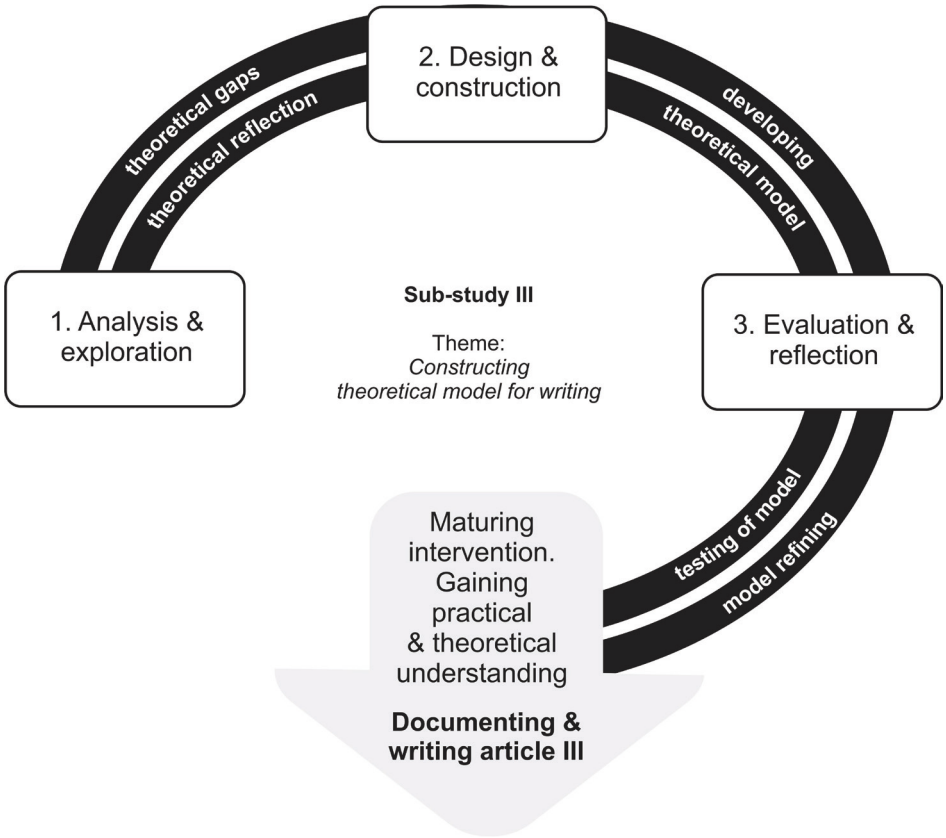

Figure 9. The EDR process of sub-study III conducted with adolescents, adapted from McKenney and Reeves (2018).

The first phase of sub-study III (Figure 9) reflected upon the earlier experiments in light of the issues identified in the school environment. It was considered that a qualitative approach for researching writing would bring a more holistic view to the

results, particularly if combined with quantitative data. A solution was designed, redesigned and constructed in phase 2 by merging Hayes' (1996) framework for understanding cognition and affect in writing with Wilson's (2002) six aspects of embodied cognition into an embodied knowledge construction model for researching the qualitative aspects of writing. The developed embodied knowledge construction model was designed as a conceptual guideline for researching any writing method and associated knowledge construction from several perspectives of affect. In phase 3, the earlier developed study design and writing test were administered to a small group of 16-year-olds (9th graders in secondary school, spring 2017); however, this time, in addition to using the quantitative methods to analyse the data, the results were examined through the embodied knowledge construction model. The third article documents the experience of testing the embodied knowledge construction model in practice based on the knowledge gained from sub-study III.

McKenney and Reeves' (2018) generic model depicts the connection of all phases to implementation and dissemination, highlighting the importance of developing something for actual use from actual needs. Cooperation with education professionals was crucial, and this meant anything from clarifying problems to offering ideas. This cooperation was subsequently followed by the dissemination of the information. In this research, the data were collected from nine different classrooms at three different schools and one university by making connections and exchanging ideas with service practitioners and by refining the author's understanding of evolving school environments and needs. After completing each sub-study, an article was written. Furthermore, an important factor in the EDR process is not only gaining a theoretical understanding through practice, but also generating theory, which can be presented via design principles when the research process is finished (McKenney & Reeves, 2018). Chapter 5 presents and discusses the design principles produced in this research.

3.4 Participants and Ethical Considerations

Empirical sub-studies (sub-studies I, II and III) were carried out in a primary school, secondary school and university setting with 172 participants from three different schools and nine classes in Finnish Lapland during the years 2016-2017. University students were first chosen as participants in this research because the Wechsler Memory Scale Revised Edition (WMS-R) logical memory subtest (Wechsler, 1987), which was used as the starting point of the study, was designed for adults, although it can be used for individuals aged 15 and up. Hence, experiment 2 of sub-study II and sub-study III was conducted with adolescents who were either 16 years old or turning 16 years old in 2017. Furthermore, at this stage of their education, 9th graders must make important decisions about whether to continue

their education in upper secondary school or vocational school, and they should have the necessary competences to pursue such an education, with the capacity to use multiple modalities of writing being one of them (Opetushallitus, 2014). Another significant issue for this age group was the implementation of the digital matriculation examination at the end of upper secondary school. The process of digitalisation began in 2016, and the entire examination will be fully digital by spring 2019 (Ylioppilastutkintolautakunta, n.d.), highlighting the significance of competent keyboarding skills. Further, higher education institutions' student admission reforms, beginning in 2020, will mean that the main admission route to higher education will be matriculation certificate-based (Ministry of Education and Culture, n.d.). Children aged 10-11 years were chosen because this age represents the turning point in their ability to write. At the age of 10, children are generally still learning to write and to refine their writing by developing composition and transcription skills with correct punctuation and capitalisation. However, at the age of 11, children become more competent in writing and can start writing to learn, meaning that writing can be used as a tool for learning (Christie & Derewianka, 2010; Knipper & Duggan, 2006; Sedita, 2013).

The data were obtained first hand, meaning that the author collected all the data (for sub-studies I, II and III) with the exception of some assistance from teacher students (sub-study II, experiments 1 and 2). Legal guardians of participating children gave their written consent (Appendix A) for the children to participate in the research, and all participants provided information about their writing experiences prior to the test for demographic purposes. All participants were proficient Finnish speakers.

Concerning ethical issues, permission was granted before performing any data collection on minors younger than 15 years old, first from the Research Ethics Committee of the University of Lapland (Appendix B), which stipulates that research should be conducted according to the guidelines of the Finnish Advisory Board on Research Integrity (2012), second from the Educational Department of the Municipality of Rovaniemi (Appendices C and D) and third from the principals of the schools in question; permission was also obtained from legal guardians of the participants and from the participants themselves (Appendix A). All participation was voluntary and participants had the right to withdraw from the study, should they wish to do so, at any stage. All consent forms, which also included details and information about the study, such as its aims and procedures, were obtained in writing according to the guidelines of the Finnish Advisory Board on Research Integrity (2012). Furthermore, in all sub-studies involving participants younger than 15, the participants and their legal guardians received information about the research, its aims and its procedures (Appendix E) through Wilma, a communication platform between schools and legal guardians. If the consent form from the legal guardian was not returned within one week of the test yet the child voluntarily participated in the

test, his or her data were excluded. This happened only in sub-study II, experiment 1, in which there were initially 92 participants; ultimately, data from only 63 participants were used due to missing consent forms from their legal guardians. The data are stored on a secure server and the data files are accessible only to the authors of the current study. In all the sub-studies, anonymity and confidentiality were ensured, meaning that the data and findings did not contain direct or indirect identifiers, as required by the Finnish Advisory Board on Research Integrity (2012).

3.5 Methods and Analysis

Sub-studies I and II generally aimed to test the long-term retention of texts that participants had written down verbatim using different writing modalities, although sub-study I also tested short-term memory. In addition to measuring long-term memory, sub-study III investigated the underlying effects on the recollection results after writing using the three different modalities. Hence, three short stories were required to enhance the validity of the test. Two stories were used from the WMS-R logical memory subtest (Wechsler, 1987) and are addressed here as stories A and B. These stories test episodic memory and have a logical storyline, one of which does not require any prior knowledge, hence providing the same starting point for all participants. The stories have a story schema, as put forward by Mandler (1984, 2014), through which they are recalled. Stories generally have a structure that incorporates the theme, setting, event and resolution, which are recalled in a logical sequence (Mandler, 2014). The third story, story C, was created with the same principles as those used in stories A and B; it had a logical sequence and was the same length, around 60 words. These stories were used in all except experiment 1 of sub-study II, in which the test parameters were refined for this age group.

All three empirical studies (sub-studies I, II and III) used an experimental within-subjects research design. This research design was particularly fitting for this research, since all participants were tested in all three writing modalities, requiring a considerably smaller pool of participants than would have been needed for a between-subjects design. Table 3 shows the exact material used, the gender distribution and the measurement of short-term and/or long-term memory (30-minute and/or 1-week delay) for each data collection.

Table 3. Material and Data Collection for the Sub-studies

	Participants	Material	Data collection
Sub-study I	*N* = 31 adult university students (10M, 21F)	Desk top computer, iPad & pencil	After 30 minutes and 1-week delay
Sub-study II	Altogether *N* = 135		
Pilot Experiment	*N* = 29 children; 19 born in 2007 (8M, 11F)	Laptop computer, iPad & pencil	1-week delay
Experiment 1	10 born in 2006 (6M, 4F) *N* = 63 children; 31 born in 2007 (14M, 17F)	Laptop computer, iPad & pencil	1-week delay
Experiment 2	32 born in 2006 (12M, 20F) *N* = 43 adolescents; born in 2001 (21M, 22F)	Laptop computer, phone & pencil	1-week delay
Sub-study III	*N* = 6 adolescents (5M, 1F)	Laptop computer, phone & pencil	1-week delay

All participants were asked to write verbatim dictated stories by hand, using a conventional keyboard (desktop in sub-study I, laptop in sub-studies II and III) and using a touchscreen keyboard (iPad in sub-study I [adults] and sub-study II pilot experiment and experiment 1 [children], and mobile phones in sub-study II experiment 2 [adolescents] and sub-study III [adolescents]). An iPad was chosen as the touchscreen device for the adult and child participants because not all of them owned a smartphone with a touchscreen, unlike the adolescents. All three writing tasks with different modalities were executed in a random order using story A, B or C, selected randomly. Before starting to write, the participants were instructed to write down three different stories with three different writing modalities from dictation. They were also informed that the speed of dictation would be adjusted to their writing speed and that they were allowed to ask for the sentence to be repeated if they did not hear it correctly the first time.

The recollection of the written stories was documented with word lists from each story, incorporating 25 details per story. Each item recalled earned one point, making the maximum score 25. For the refined stories for the children in sub-study II, experiment 1, there were only 20 details. The participants were not given any cues; they merely told the stories and relayed the details as they recalled them.

The main statistical analysis method was repeated measures variance analysis (ANOVA), which was carried out using IBM's Statistical Package for the Social Sciences (SPSS Inc., Chicago, IL, USA), version 23. The data analysis consisted of frequency analysis, Pearson's correlation analysis, Mauchly's test of sphericity, tests of within-subjects effects and repeated measures variance analysis ANOVA with Greenhouse-Geisser correction. A factorial design and ANOVA have a high level of efficiency and precision even with fewer cases, thus yielding generalisable results that are examined over several conditions or factors at the same time, such as in this

research. A factorial design can also be used to detect an interaction between one or more factors (Howitt & Cramer, 2011). Tests of within-subjects effects measure the variability between the means of the factors, whereas Mauchly's test of sphericity is used to investigate whether the sphericity between the within-subject factors is equal and can thus validate the analysis (Landau & Everitt, 2004). Greenhouse-Geisser corrected degrees of freedom were used in cases where the sphericity assumption was violated to enhance the accuracy of the analysis. Subsequent multiple comparisons used pairwise comparison tests with Bonferroni-corrected adjustment were conducted to maintain the confidence interval for multiple testing (Landau & Everitt, 2004). A paired samples *t*-test was also performed to determine any differences between the group means.

4 OVERVIEW, RESULTS AND EVALUATION OF THE STUDIES

This chapter summarises the three sub-studies, evaluates each study based on its methodology and results, and discusses the contribution of the studies to each research theme and the overarching research question.

4.1 Sub-study I Theme: Creating and Developing Study-design for Writing Research

Can you put your finger on it? The effects of writing modality on Finnish students' recollection
Journal of Writing Systems Research
Satu-Maarit Frangou[a], Heli Ruokamo[a], Tiina Parviainen[b] and Jan Wikgren[b]
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4.1.1 Overview

Sub-study I represented the starting point for the investigation of writing with multiple modalities and the beginning of the EDR process. The increasing use of digital devices as writing tools compelled the author to examine the effects of writing modality on adults' recollection. The goal was to develop a study design and test for this purpose and to investigate the adults' recollection after writing with a pencil, a computer keyboard and a touchscreen keyboard. The research data were collected from 31 university students aged between 21 and 51 in 2016. The study design was developed based on the idea that the three writing methods should be comparable and encompass digital writing devices, since the impact of technology has shaped the contemporary world (UNESCO, 2011). Hence, the research material was developed from the WMS-R Logical Memory Subtest (Wechsler, 1987) and a third story (Appendix F) was created as described in sub-chapter 3.5. After writing from dictation using different writing modalities, the participants were asked to recall three stories of equal length. The students' degree of recollection for each writing modality was recorded after 30 minutes, and again one week after the writing session. Both times, the participants were asked to recount the stories in as

much detail as they could, in any order. There were 25 details in each story to recall, giving a maximum score of 25. No cues were given.

The recollection scores were saved into SPSS, along with the time the participants spent on each writing task; the results were analysed as described in sub-chapter 3.5. Notably, handwriting and keyboarding on a touchscreen device seemed to be equally slow writing methods ($t[30] = 0.03$; $p = .98$), whereas writing with computer keyboard was significantly faster than both aforementioned writing modalities ($t[30] = 7.72–9.76$; $p < .001$; Figure 10A).

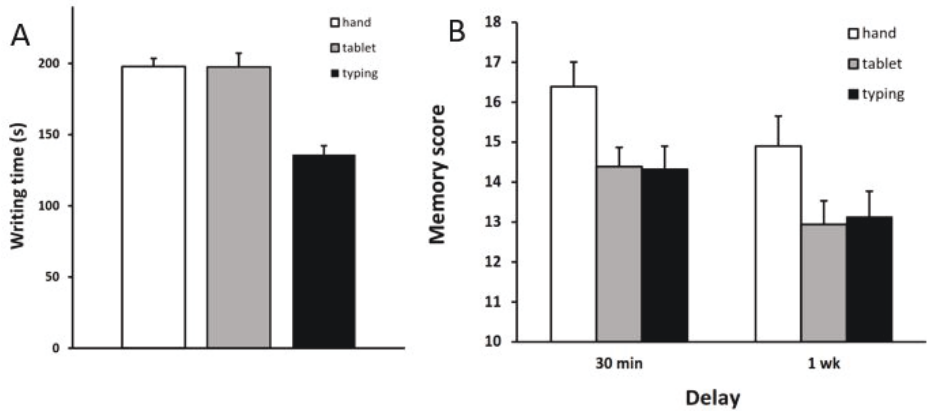

Figure 10. Results of sub-study I with adults' mean times spent on writing tasks and recollection scores (+SEM) for handwriting, touchscreen keyboarding and computer keyboarding, and time delay after writing (Frangou, Ruokamo, Parviainen, & Wikgren, 2018, p. 88).

The mean recollection scores for all three writing modalities were examined. Figure 10B shows a comparison of the three writing modalities' mean recollection scores 30 minutes and one week after writing the texts, indicating that handwriting produced better recollection scores after both time delays. As the ANOVA with repeated measures tests of within-subjects effects showed a main effect ($F[2, 60] = 6.95$; $p = .002$) of writing modality, a pairwise comparisons test was conducted to compare the three writing modalities with each other.

The results of the pairwise comparisons test revealed that handwritten texts were recalled significantly better than the touchscreen keyboarded texts ($p < .001$) and computer keyboarded texts ($p < .004$). The eta-squared values for both factors, the writing modality and the time delay were larger than 0.14, confirming a large effect: For the writing modality, the partial eta-squared value was 0.19; while for the time delay, the partial eta-squared value was 0.45. Eta-squared measures the degree of association between the dependent variable and the independent variable, and

the eta-squared value represents the proportion of the total variance (Richardson, 2011).

Hence, the main finding is that handwriting led to statistically significantly better recollection in tests after 30 minutes and after one week. Furthermore, the recollection scores for conventional keyboarding and touchscreen keyboarding yielded similar results; neither modality was significantly worse than the other. Additionally, the effect of writing speed was examined to determine whether it had a combined effect with writing modality on recollection. Keyboarding on a computer was significantly faster than handwriting and touchscreen keyboarding, which were equally slow writing modalities. However, the time spent writing did not significantly affect recollection. The participants' age was also examined to determine correlations with the recollection scores. In this group of participants, a positive correlation was evident between the participants' age and best scores, meaning that the recollection scores increased with the participants' age.

The research question for sub-study I asked: *Does the writing modality influence students' recollection of dictated stories?* The results of the study support the claim that writing modality influences the students' recollection of the dictated and written stories, with handwriting being the statistically significantly best recalled modality compared to computer keyboarding and touchscreen keyboarding.

4.1.2 Evaluation

The purpose of this sub-study was to investigate whether different writing modalities influence adult university students' recollection. The strength of this sub-study was that the methodology, research design and data collection method provided the appropriate means not only for conducting and answering the research question, but also for creating effective guidelines for refining, conducting and answering research questions in future empirical sub-studies. In addition to answering the research question posed in this sub-study, information about the possible effects of age or writing speed on recollection could be examined.

The limitation of this sub-study was its small sample size, particularly the small number of male participants, which precludes the possibility of making generalisations or strong claims based on the findings. It was challenging to find participants willing to spend time participating in memory testing without any reimbursement. However, the findings were significant in this group of participants, providing significant implications for further research (sub-studies II and III) and on the development of the embodied knowledge construction model (Frangou, 2018) and its further refinement in this thesis. Another weakness of this sub-study was the wide age range of the participants, even though it presented the opportunity to investigate the issue of age and how it affected recollection in the sub-study.

The results of this sub-study are particularly significant, suggesting a deeper discussion about the educational and cognitive implications of marginalising

handwriting and the increasing use of digital technologies for writing. Manual dexterity is altered with reduced manual activity; however, we have yet to learn the consequences of this change, which might affect different age groups in different ways. Further, keyboarding competence could affect consequent recollection, since attention would not be paid to finding the appropriate keys to strike (Berninger & Swanson, 1994; Klein, 1999; Ungerleider et al., 2002; Yeganeh Doost et al., 2017). Keyboarding skills could also lighten the students' workload. In all, this sub-study revealed the need for further research on writing among different age groups as well as the need to conduct multidisciplinary research on multiple writing modalities with educational and cognitive psychological underpinnings.

4.2 Sub-study II Theme: Iterating and Revising Study-design for Writing Research

The effect of writing modality on recollection in children and adolescents

Research in Learning Technology

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4.2.1 Overview

The aim of sub-study II was twofold: first, to test and refine the study design and test battery developed in sub-study I for use with younger age groups; and second, to investigate whether different writing modalities affect the recollection of written stories in younger age groups. The study was carried out as an EDR with several iterations to study the results and refine the developed test battery for children. The study design was similar to that of sub-study I: all participants were asked to write down three stories from dictation using different writing modalities. At the beginning of the session, the participants were informed that they could ask that any information be repeated should they not hear it. They were also informed that they would be asked one week later what they had remembered about the stories they wrote. Reading pace was adjusted according to the participant's ability to write. After each writing task, the story was read aloud once again so that the participants could check their written text before changing to another writing method. In total,

135 Finnish children and adolescents participated in sub-study II, none of whom had received systematic keyboarding instruction.

Pilot Experiment: In the pilot experiment, the participants comprised 29 children born in 2006 (4F, 10M) and 2007 (11F, 8M) who were turning either 11 or 10 years old, respectively, in 2017, at the time of data collection. The stories were the same as those in sub-study I: two stories (A and B) from the WMS-R Logical Memory Subtest (Wechsler, 1987) and a third story, story C (Appendix F), which was created to be of similar length and needed no prior knowledge. In this experiment, Asus Chromebooks were used for keyboarding, iPads for touchscreen keyboarding and pencils for handwriting. After completing the three tasks, the participants continued with normal school activities and were met one week later, at which time they were orally requested to divulge everything they remembered about the stories they had written, in a free recall condition. As in sub-study I, there were 25 details to be recalled. The participants were allowed to use as much time as they needed for the task. As the participants were children, it was necessary to use coaching sentences without cues, such as 'what happened then' or 'what did they do then' to encourage the children to speak.

The results revealed that the children's scores were quite similar for all three writing modalities. After examining the recollection scores and reflecting on the testing day, it was evident that the test had been too demanding and needed to be modified. After this experiment, the parameters were modified for experiment 1 because the test seemed to be too long and challenging for this age group.

Experiment 1: In experiment 1, the 63 participants were also Finnish children born in 2006 (20F, 12M) and 2007 (17F, 14M) who were turning 11 and 10 years old, respectively, in 2017, when the data were collected. For this experiment, the three stories, story A (Appendix G), story B (Appendix H) and story C (Appendix I), used for dictation were revised and shortened to 40 words, leaving only 20 details to recall the following week. As for experiment 1, Asus Chromebooks, iPads and pencils were used for the writing tasks. In the meeting one week later, the children's recollection of the stories was recorded. Each of the three stories had one clue word, which was used for encouragement if a child could not recall anything or was too shy to speak. The clue was a key concept in the story, such as a bear.

To assess the three writing modalities, the time that the participants consumed for writing with each modality (Figure 11A) and the recollection scores for each modality (Figure 11B) were compared.

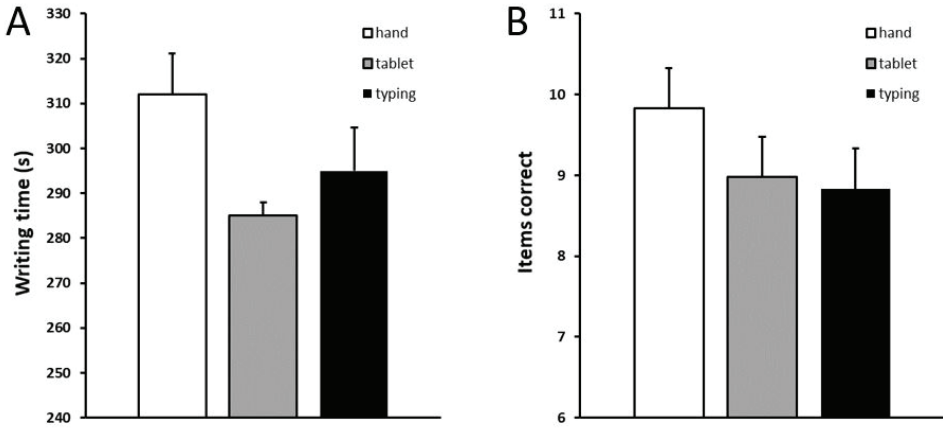

Figure 11. Results of experiment 1 with children's mean times spent on writing tasks and recollection scores (+SEM) for handwriting, touchscreen keyboarding and computer keyboarding (Frangou, Wikgren, Sintonen, Kairaluoma, & Vasari, 2019, p. 6).

Repeated measures ANOVA was conducted; the three writing modalities' time measurements (Figure 11A) were used as within-subjects factors, and age and gender were used as between subjects factors. The analysis exposed a significant interaction between writing modality and age [$F(2,118) = 63.79, p < .001$]; to examine this further, for both age groups paired samples *t*-tests were conducted, which revealed that the 10-year-old children spent considerably more time handwriting than keyboarding on a computer [$t(30) = 3.92, p < .001$] or keyboarding on a touchscreen device [$t(30) = 23.87, p < 0.001$]. Notably, the 10-year-old children wrote fastest when using touchscreen device and slowest when handwriting. The 11-year-olds spent most time keyboarding with a touchscreen device than handwriting [$t(31) = 14.86, p < 0.001$] or keyboarding on a computer [$t(31) = 4.76, p < .001$].

Another similar repeated measures ANOVA was run on the correct number of items recalled (Figure 11B), which again yielded a significant age related main effect [$F(1,59) = 9.24, p < .01$] and the following analysis revealed a significant writing modality related main effect [$F(2, 62) = 4.28, p < .05$)] for the 11-year-old children, but not for the 10-year-old children [$F(2, 60) = .001, p = .99$]. The results of the following *t*-test revealed that the 11-year-old children recalled their handwritten texts better than their keyboarded texts [$t(31) = 3.32, p < .01$] and the texts that had been keyboarded on a touchscreen device [$t(31) = 2.15, p < .05$].

In all, the results of experiment 1 were interesting because, while the 10-year-old children received similar scores for all three writing methods, writing modality had a statistically significant effect on the recollection of the 11-year-old children, with handwriting recollection scores being statistically more significant when compared with keyboarding on a laptop computer and touchscreen device.

Experiment 2: In experiment 2, the participants were 43 adolescents born in 2001 (22F, 21M) who were turning 16 years old in 2017, when the data were collected. The materials and procedures used were identical to those in the pilot experiment, with the exception that touchscreen keyboarding was accomplished using the participants' phones. All participants used only their thumbs to write on the phones' touchscreens.

The means for the participants' time measurement (Figure 12A) for writing each task and the means for the recollection scores (Figure 12B) for each writing modality were compared.

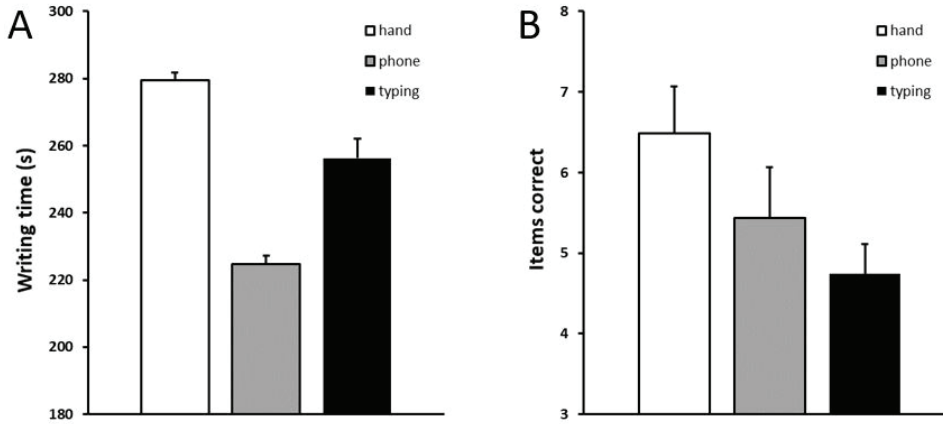

Figure 12. Results of experiment 2 with adolescents' mean times spent on writing tasks and the recollection scores (+SEM) for handwriting, touchscreen keyboarding and computer keyboarding (Frangou, Wikgren, Sintonen, Kairaluoma, & Vasari, 2019, p. 8).

The following data analysis with ANOVA with repeated measures indicated a significant writing modality-related effect on time measurement [$F(2,82) = 77.39, p < .001$]. In the paired samples *t*-test, the mobile phone [$t(42) = 18.52, p < .001$] and computer keyboard [$t(42) = 9.17, p < .001$] were both faster writing modalities than handwriting for the adolescents (Figure 12A). Furthermore, even if the adolescents used only their thumbs to write the texts on their mobile phones, they still wrote faster on the mobile phone compared to keyboarding on a computer [$t(42) = 3.68$, $p < .01$]. The ANOVA with repeated measures tests of within-subjects effects was then used with the recollection scores (Figure 12B). The analysis revealed that the modality with which the texts were written had a significant main effect on recollection [$F(2,84) = 4.24, p = .018$].

Following the significant results of the tests of within-subjects effects, the analyses were continued to determine which writing modality was recalled the best. Pairwise

comparisons were made, which yielded significantly better recollection results for handwriting compared to laptop-keyboarding (p = .011) with Bonferroni adjustment. The scores for recollection were further analysed using a paired-samples t-test, which supported that handwriting results in significantly better recollection compared to laptop keyboarding [$t(42) = 3.09$, $p < .01$]. When the recollection scores of handwriting and keyboarding using thumbs on a mobile phone were compared, the results approached a significance in favour of handwriting [$t(42) = 1.76$, $p = .085$].

The research question for sub-study II asked: *Do different writing modalities have differing influences on children's and adolescents' recollection?* The findings indicated that for children who were turning 10 years old during the year of the data collection, the writing modality did not matter or influence the results. However, for 11-year-old children, differences started to emerge, and writing modality had a statistically significant main effect on recollection. Among the 11-year-old participants, handwriting received statistically significantly better recollection results than keyboarded texts or touchscreen keyboarded texts, with a greater difference between handwriting and laptop keyboarded texts. For 16-year-old adolescents, handwriting received statistically significantly better recollection scores compared to laptop keyboarded texts. However, only borderline significant differences in favour of handwriting were discovered in terms of recollection scores between handwriting and mobile phones.

4.2.2 Evaluation

This sub-study examined whether different writing modalities influence children's and adolescents' recollection and established how to refine the test battery for younger ages. Hence, the sub-study had a dual orientation: (1) research on the intervention, meaning generating knowledge about the intervention itself; and (2) research *through* interventions, meaning knowledge generation about a phenomenon related to the intervention (McKenney & Reeves, 2018), which in this case was recollection. The evaluation of the design is a constant process, one which must adapt to changes of design and context (Cobb & Gravemeijer, 2008; McKenney & Reeves, 2018). The strength of this sub-study can be seen in this adaptation process and in the EDR methodology by developing and refining the test battery according to the children's abilities after considering the results and experiences of the initial experiments. During the data collection, discussions held with education professionals at the schools guided and supported the refining process of the testing instrument. Furthermore, in EDR, it is vital that the researcher interprets the participants' activities and the learning environment in which the data collection occurs (Cobb & Gravemeijer, 2008). The prior teaching experience of the author was of vital importance in interpreting the behaviour and understanding the abilities of the different age groups in these experiments.

Some challenges and weaknesses of this sub-study are worth mentioning. While the experiments were carefully designed and planned, and cooperation with the teachers was smooth, it was challenging to organise time for lengthy tests for the children and adolescents within the school schedule. Additional challenges concerned the use of technology, particularly the laptops and iPads provided by the schools, which did not always function according to plan, with some needing to be replaced at the beginning of the test. Such occurrences took time away from the already limited timeframe available for the study. The participants' mobile phones in experiment 2 did not pose any issues. The clear weakness of this study was its small sample size; however, the study produced significant findings that may give a direction for further studies.

A particular strength of this sub-study was its multiple experiments among different age groups, concurrently increasing the validity and reliability of the sub-study (Design-Based Research Collective, 2003). The significance of the results of this sub-study lies in their potential contribution to scientific discussions of writing research and in practical discussions about developing evaluation methods for different age groups and multiple writing modalities. This is essential in today's world, where the use of technologies is being integrated into all levels of education (Finnish National Board of Education, 2014). This sub-study provided useful information for educators who are balancing different writing modalities and instructions in their daily work. Hence, the key advantage of this sub-study was that it addressed real needs in contemporary schools and among educators. Furthermore, the present sub-study highlighted the link between writing modalities and recollection and therefore provided a test battery for evaluating the three different writing modalities. The experiments in this sub-study improved empirical knowledge, revealing the need to understand the qualitative dimensions of learning as a result of writing. Hence, this EDR process served as the impetus for and consequently led to the following EDR cycle of sub-study III, in which the embodied knowledge construction model of affects in writing was developed and refined.

4.3 Sub-study III Theme: Constructing Theoretical Model for Writing Research

Embodied Knowledge Construction in Writing
Education in the North
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4.3.1 Overview

Sub-study III introduced a theoretical model and framework for researching knowledge construction in writing. This sub-study represented the final stage of the EDR process and contributed a theoretical understanding through the experiences from the previous sub-studies and experiments, and through a reflection on the entire process (McKenney & Reeves, 2018). The writing process is an incessantly debated area in the cognitive and educational sciences, particularly regarding new methods of writing, such as on keyboards and touchscreen devices. Despite such controversy, learning through writing with digital devices remains an overlooked area of cognition. Furthermore, the concept of embodied cognition represents another area of dispute, even though it offers holistic articulations about cognitive processes.

This sub-study aimed to fill both these gaps by proposing an embodied knowledge construction model that merged Hayes' (1996) framework for understanding cognition and affect in writing with Wilson's (2002) six aspects of embodied cognition. By reflecting on different writing modalities and individual differences affecting cognition, this model qualitatively investigated cognition as a result of writing. Most importantly, the presented embodied knowledge construction model considered the underlying spatial and temporal infrastructure as intertwined with the learning process and examined the significance of the mind's learning environment in terms of cognition. The model's first component concerns the writer's outer world, meaning their general background, culture, writing environment, and the context and time. The second component is the writer's inner world which includes their body and mind activity and long-term memory. The third component represents motivation and affect with action and perception experiences which can influence all components of the writer's inner and outer worlds.

The developed embodied knowledge construction model was tested for further development purposes on a small group of six participants who were turning 16 years old in 2017 when the data were collected. Data collection proceeded in a way similar to that employed in sub-studies I and II; all participants wrote down three stories from dictation using a laptop keyboard, a mobile phone touchscreen keyboard and by hand. The material used for data collection was similar to that for sub-studies I and II, experiment 2. At the beginning of the writing event, the participants were

instructed to write down everything from dictation. The participants were also told to ask for information to be repeated if they did not hear it the first time around, and they were informed that they would be asked to recount what they had remembered about the stories they had written one week later. The dictation pace was adjusted according to the participants' writing speed. After each writing task, the story was read aloud once again so that the participants could see that their written text was correct, after which the writing method was changed. There were 25 items to recall, giving a maximum score of 25. Figure 13 shows the results.

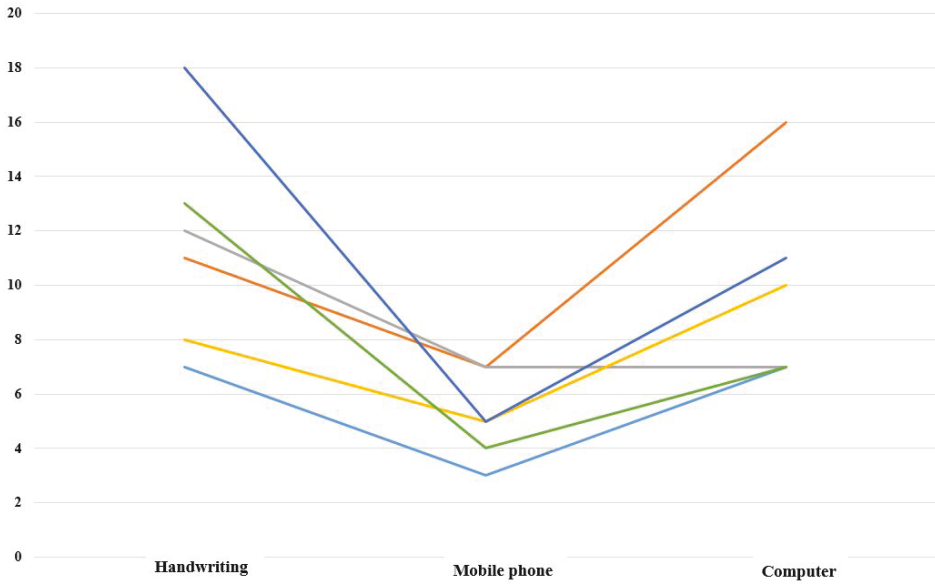

Figure 13. The recollection results of adolescents one week after handwriting and keyboarding on a mobile phone and laptop (Frangou, 2018, p. 97).

Five participants felt comfortable with computers and played games regularly. They also used mobile phones for instant messaging and social media throughout the day. The participants' years of gaming or of using computers or mobile phones did not seem to influence the participants' recollections, as only two obtained the best scores in computer keyboarding and one had the same recollection results for keyboarding and handwriting. Three of the six participants obtained best recollection scores for handwriting, even though all participants liked handwriting and taking notes by hand. The worst recollection scores for all participants were obtained from using mobile phones (see Figure 13).

Additionally, to test the functions concerning the outer world of the embodied knowledge construction model, a questionnaire about writing and keyboarding

experience was distributed to the participants at the time of collecting the recollection scores, one week after the writing test. This was a good time for supplementary data collection because the participants were already familiar with the author. During the testing and during the data collection, there was no element of hurry and all participants had eaten breakfast. For the best possible atmosphere, the test and data collection were conducted in a familiar place, in the participants' classroom and in a room used for group work with comfortable decoration.

The participants filled in their answers to the questionnaire's closed questions about their birth year, mother tongue, handedness, number of fingers they use for keyboarding, and the age at which they started computer and touchscreen keyboarding, even if the author and the participants had already discussed these issues. Additionally, the participants were asked to talk freely about their habits with mobile phones and computers, and their answers were recorded by the author. These simple questions were mostly concerned with the participants experiences and their feelings about writing with different modalities, the context and time, and the environment and school culture, which are part of the embodied knowledge construction model concerning the world outside of the participant.

One participant was not keen on mobile phones or computers: 'I only use computer if I have to at school, not at home. I have a smart phone, but I don't use it, unless somebody calls me' (Participant 6).

The school culture was especially positive towards written and artistic expression, and this was prominent in the students' responses. When asked, all six participants felt most comfortable writing by hand. All participants used computers for some school work, but handwriting was the most commonly used method for school work.

The following research question framed sub-study III: *How can affects be considered in knowledge construction during writing?* The findings indicated that the embodied knowledge construction model can be used for a multifaceted consideration of the different affects pertaining to knowledge construction in writing. The outer world dimension of the writer, his or her background and surroundings, and the present context and setting represented issues outside of the person which nonetheless can affect their performance. The inner world dimension of the writer involves affecting body, mind and brain activity during the writing task. Further, motivation and affect combined with action and perception form an all-pervasive ensemble that encompasses both inner and outer worlds, thus affecting all dimensions of the writer.

4.3.2 Evaluation

The purpose of this sub-study was to investigate how affects can be considered when researching writing with any modality. The sub-study sought to complement and extend the theoretical framework of Hayes (1996) for understanding cognition and affect in writing, and that of Wilson (2002) regarding the six aspects of embodied

knowledge. This sub-study drew upon the two frameworks – i.e. that cognitive processes are affected by a person's internal perceptions and experiences – to address the need to research cognition in writing with different writing modalities.

This sub-study has several weaknesses. The first is its small sample size, particularly the small number of female participants, for testing the model. Second, even though the questions and free discussion are targeted only at certain functions of the model, namely the outer world, they do not go into enough depth. However, the information obtained on how to approach the further development and refinement of the model, both theoretically and pedagogically, was valuable. Third, the author was unable to measure the issues influencing the person from inside, such as memory functions, heart rate and action perception sequences, thus pointing to an important direction for future studies with behavioural and physiological measures.

The strength of this sub-study were the two theoretical frameworks by Hayes (1996) and Wilson (2002) used in the design, while the strength of the frameworks themselves carried on to the developed embodied knowledge construction model. In EDR research, reflecting on the research outcomes and developments is vital for reaching an understanding about whether the core objective of producing new theoretical understanding has been achieved (McKenney & Reeves, 2018). The embodied knowledge construction model was developed based on reflections upon all the previous sub-studies and experiments.

The main significance of this sub-study was its contribution to scientific discussions on a theoretical level: a new model for researching writing with multiple modalities, one which considers how affects influence the writing experience. This sub-study may also be of significance to educational professionals because the developed model can be used to reflect on affect in any age group.

5 CONCLUDING RESULTS: THE EMBODIED KNOWLEDGE CONSTRUCTION MODEL OF AFFECTS IN WRITING

5.1 Summary of Empirical Findings

This research investigated writing among different age groups as well as the components of embodied knowledge construction in writing using three different modalities: handwriting, computer or laptop keyboarding, and touchscreen keyboarding with an iPad or mobile phone. The study aimed to determine the differences in the recollection of stories written using these writing modalities. Derived from this objective, the following overarching research question was asked: *What are the components of embodied knowledge construction in writing?*

To accomplish this objective, five empirical studies were conducted involving 172 participants of different age groups. These empirical studies led to an understanding of the influence of the writing methods, first on university students' recollection in sub-study I, in which handwriting was confirmed to be a statistically significantly better writing modality in terms of recollection; and second on adolescents and children in sub-study II, where handwriting was found to be statistically significantly better recalled by 16-year-old adolescents and 11-year-old children. Ten-year-old children recalled the stories they had written with the three different modalities equally well. It is noteworthy that even though the 11-year-old children's recollection was statistically significantly better when recalling a handwritten story over a touchscreen keyboarded story, it was even better when compared to a laptop keyboarded story.

There could be several factors underlying these results. For example, these results could mean that the 11-year-old children were more familiar with touchscreen devices than they were with computer keyboards, which would corroborate the findings of Mangen et al. (2015), who indicated a positive correlation between years of experience with touchscreens and the recollection of words written with touchscreen devices. Furthermore, cognitive resources needed by different writing modalities may vary (see Figures 1 & 2) and for participants older than 11-years-old, handwriting may be the most automated writing modality, allowing more attention to be given to the produced story (Baddeley, 2010; Cowan, 2005). It is also possible that the level of automation for the 10-year-olds was close to equal for all three writing modalities, and if handwriting was the slowest writing modality, it may have allowed more time for processing the story (McCutchen, 2006; McCutchen, Teske, & Bankston, 2008). However, this cannot be the case for the university students because even though keyboarding on a touchscreen device was as slow a writing

modality as handwriting among university students, their recollection scores after keyboarding on a touchscreen device were the worst after one week. It could be that a less used writing modality could burden the working memory of the participants and interfere concentration on the story (Chi & Ohlsson, 2005; Kane & Engle, 2000; Logie, 2011). Furthermore, the motor and sensorimotor network activation (Figure 1&2) can be more intense during handwriting compared to keyboarding and thus form a stronger interaction with memory, since learning to write requires adequate working memory (Baddeley, 2010). More multidisciplinary research is needed to clarify the reasons for differing results between different age groups.

The empirical studies culminated not only in significant results concerning writing modalities and recollection, but also in an understanding of the issues affecting knowledge construction in writing (sub-study III), the components of which are clarified below. The results of each sub-study were reported in international scientific articles. The studies were conducted within the framework of EDR, which supports iterative cycles of research (McKenney & Reeves, 2018). The EDR process generally has a dual goal, yielding theoretical and practical outcomes. This research achieved a deeper understanding of writing modalities and their connection to knowledge construction by reflecting on the methodological choices and empirical findings of sub-studies I and II, leading to the development of a theoretical framework in sub-study III. The amalgamation of a theoretical, embodied knowledge construction model was the outcome of reflections on the entire research process in the pursuit of ways to assess affects in writing practice.

5.2 The Components of the Embodied Knowledge Construction Model

The theoretical underpinnings of this research were the six aspects of embodied cognition by Wilson (2002) and the individuo-environmental framework for understanding cognition and affect in writing by Hayes (1996). The general hypothesis of embodied cognition is harmonious cooperation between the brain, mind and body in cognition and the direct influence of both an individual's inner body states and the external environment on cognition (Adam & Galinsky, 2012; Eerland, Guadalupe, & Zwaan, 2011). Concurrently, the individuo-environmental model by Hayes (1996) understands writing as a cognitive process, one which influences internal and external processing, e.g., of environmental factors, thus emphasising how the aforementioned frameworks complement and enrich each other. In this research, these frameworks were not regarded as separate entities; instead, they were merged into an embodied knowledge construction model, i.e. a framework that conveys the multifaceted, inter-individual differences between writers using different writing mediums. By reflecting on different writing modalities

and individual differences affecting cognition, this model anticipates changes in cognition as a result of writing. The model elucidates factors affecting the writing process and thereby knowledge construction through writing. Most importantly, the model considers the underlying spatial and temporal infrastructure intertwined with the writing and learning process, as well as the significance of the mind's learning environment in terms of cognition. This model, which was developed during the research process in sub-study III, has been further refined and is presented in Figure 14.

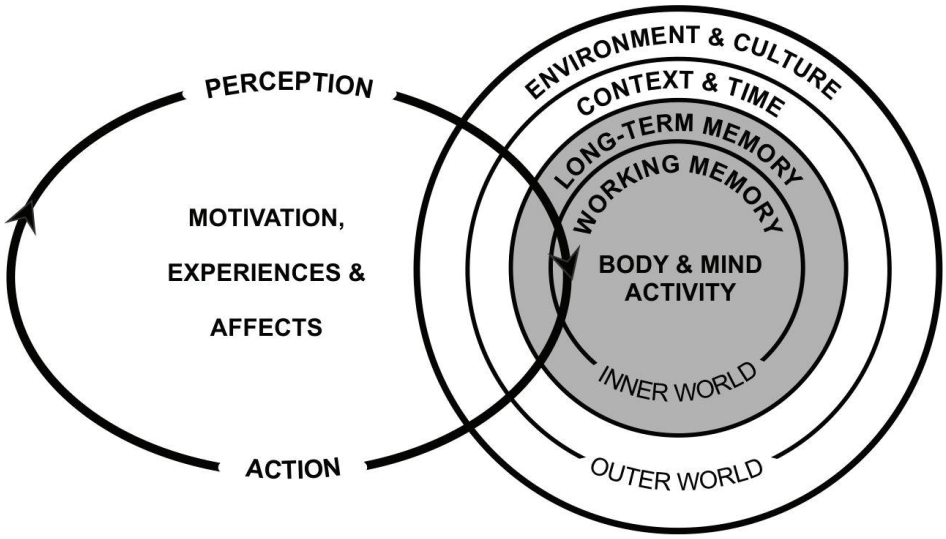

Figure 14. The embodied knowledge construction model of affects in writing.

Several factors affect, contribute and limit knowledge construction in writing. The embodied knowledge construction model acknowledges the influence of the theories (Hayes, 1996; Wilson, 2002) underlying its development. The model was constructed from the inner and outer worlds of individuals, which are affected by the all-pervasive action and perception sequences of these individuals, themselves influenced by a person's motivation, experiences and affects. The following text explains each of the model's rings from the perspective of both theories undergirding the model (Hayes, 1996; Wilson, 2002).

1. Perception and Action

In the ring of *Perception and Action*, the integral factors are motivation, experiences and affects. The component of motivation and affect (Hayes, 1996) from the dimension of the individual is combined with action perception experiences (Barsalou, 2008; Wilson, 2002; Wilson & Golonka, 2013) and defined as a crucial

part of embodied cognition. The component of motivation and affect (Hayes, 1996) takes into account the writer's predispositions, beliefs and benefit estimates, and goals, which all affect motivation and performance. The writer's self-perception of being a writer, including relevant capabilities and sense of self-efficacy, serve as either a motivator or inhibitor for writing, and thus result in affective response. These factors are considered fundamental in that they pervade every dimension of the rings representing the individual's inner and outer worlds. Hence, situational awareness, careful notetaking and background information are crucial for conducting objective and unbiased data collection involving knowledge construction through writing.

2. Outer World

The two outer rings of the embodied knowledge construction model are *Environment and Culture* and *Context and Time*. The former ring represents the dimension of the task environment in Hayes' (1996) framework for understanding cognition and affect in writing, which incorporates the social and physical environment of the individual, as well as aspects of cognitive load distribution together with the effect of environment on cognition from the six aspects of embodied cognition (Wilson, 2002). The latter ring incorporates the task environment in Hayes' (1996) framework, with more focused attention on the social and physical environments of the individual, in addition to the aspect of situated cognition and temporally pressured cognition from the six aspects of embodied cognition (Wilson, 2002).

In the research process, one should be aware of sociocultural factors impacting the general atmosphere and the context for writing. How a culture, society, family or social circle perceives writing might affect the attitudes of writers. In school contexts, this can also include the school culture and classroom culture. Furthermore, the physical environment might be defined by the writing modality, and the individual's experiences with and level of automaticity regarding that particular modality can affect knowledge construction. Additionally, the length, topic and genre of the text to be written, time pressure, or the lack thereof, can affect the writing process and its results. In the same context, individuals often perceive writing from their own personal viewpoints.

Environment and Culture

Environment and culture represent the first dimension of the outer world, which incorporates the aspects of cognitive load distribution and environment effects on cognition from the six aspects of embodied cognition (Wilson, 2002), meaning the individual's general background and the circumstances in which the individual interacts. If we use, for example, paper notes or a tablet computer as an extension of our memory as we write, then these tools also form part of the environment surrounding the writing event. This dimension supports that of the task environment by Hayes (1996), which also emphasises the significance of the physical environment

and understands the chosen writing medium and the text thus far written as part of this environment and as shaping the environment. The component of social environment by Hayes also demonstrates that differences in cultural and social circles are significant in writing because what, how or who we write to is largely defined by our personal history. Furthermore, the present environmental circumstances, such as collaborative writing or specific target audiences, affect the writing process.

Context and Time

The second dimension of the outer world is involved with the aspects of situated cognition and temporally pressured cognition from the six aspects of embodied cognition (Wilson, 2002). This dimension emphasises the significance of context and interactions in that context along with time constraints, if any. Furthermore, Hayes' (1996) component of task environment emphasises the contextual issue with respect to the physical environment; however, it might also be defined via the social environment component.

3. Inner World

The two inner rings of the embodied knowledge construction model represent *Long-Term Memory* and *Working Memory,* which surround the core of the model formed by *Body and Mind Activity*. The former ring represents the dimension of the individual in Hayes' (1996) framework for understanding cognition and affect in writing, with the component of long-term memory and the aspect of an action's effect on cognition from the six aspects of embodied cognition (Wilson, 2002). The latter ring includes, from the dimension of the individual in Hayes' (1996) framework, the components of working memory, cognitive processes and brain activation due to motor actions specific to each writing modality, as mentioned earlier in sub-chapter 2.2. This ring also includes the aspect of offline body-based cognition from the six aspects of embodied cognition (Wilson, 2002).

In the research process, one should consider the individual's constantly active brain, mind and body, in which motor systems and perceptions form the very core of the embodied cognitive process. The individual actively perceives not only their own body and mind sensations, but also their surroundings, along with the text they have written so far. The visually perceived text can inspire mental imagery of places and kinaesthetic imagery of physical interactions inside that mental image. Another significant issue is the diversity of writing methods and the associated motor-sensory and motor networks. These can be connected to cognition through memory functions, and thus also to knowledge construction.

Long-Term Memory

The first dimension of the inner world entails the component of long-term memory from the dimension of the individual in Hayes' (1996) framework for understanding cognition and affect in writing. This is a particularly important component because it incorporates cultural, social, experiential and contextual knowledge with knowledge of the genre, linguistics, audience and topic, and the task schema. Additionally, the aspect of action's effect on cognition from the six aspects of embodied cognition (Wilson, 2002) emphasises that actions are guided by the mind, and that memory contributes to situation-appropriate behaviour, which is guided by earlier experiences and consequently by long-term memory.

Working Memory and Body and Mind Activity

The core of the inner world incorporates the individual's body and mind activity, which specifically form the dimension of the individual in Hayes' (1996) framework as the components of working memory and cognitive processes. Additionally, this dimension takes into account the specific motor actions for each writing modality that subsequently activate certain brain regions, as described in sub-chapter 1.1. This dimension also encompasses the aspect of offline body-based cognition from the six aspects of embodied cognition (Wilson, 2002). The central role of working memory (Hayes, 1996) is to process and store phonological and visuospatial information with semantic representations of the moment, and the component of cognitive process (Hayes, 1996) is responsible for text production and interpretation, which is constantly reflected upon. Reflection implies reviewing retrieved knowledge and adapting it to new situations. However, if writing is not automated, fewer resources are allocated to reflection because working memory has a limited capacity. Offline-based cognition (Wilson, 2002), however, suggests the individual's built-in skill to use working memory and mental imagery, i.e. people can retrieve memories and reimagine them using episodic memory. People can also manipulate these memories or daydream about events that never occurred. From working memory, the aspect of offline body-based cognition from the six aspects of embodied cognition (2002) stresses the situational reasoning and problem-solving skills of the individual as well as the automated skills from which implicit memory is created.

The created theoretical framework for embodied knowledge construction provides a new viewpoint for researching writing and affects in writing. Chapter 6 evaluates the model and discusses its potential, practical, empirical and theoretical implications for research on writing.

6. DISCUSSION AND CONCLUSIONS

This research revealed the significance of writing methods on recollection in different age groups; however, the issues that affected the recollection outcome were manifold. By formulating the embodied knowledge construction model, three larger dimensions of an individual's being were found to affect the recollection outcome after writing: the inner and outer worlds of the individual, and action and perception experiences, which are prompted by motivational issues, previous experiences and affects. In other words, there is continual interplay between these factors, which are considered fundamental and pervasive in every dimension of the individual. Starting from the wider background of the individual, these dimensions constitute the general sociocultural environment of the individual, leading to the dimension of the specific context and time in which the individual is writing. Moving inside the individual, the dimension of body, mind and brain activity plays an integral part of the knowledge construction process, pointing to issues such as long-term memory, working memory and self-perception of one's own body and senses.

Even though the embodied knowledge construction model can be seen as yielding both theoretical and practical outcomes, some design principles are provided to guide future design attempts with similar topics (Kali, 2008; Reeves, 2006). These design principals are general guidelines that are intended to facilitate similar data collections; however, they are not claimed to be complete and can therefore be refined to fit the particular context. The principles derive from the practical experiences of the data collections, particularly in sub-study III. Through the reflective practice demonstrated throughout this research, four main design principles emerged:

1. Document carefully all background information according to the dimensions of the embodied knowledge construction model for a holistic understanding of the writing individual. By getting to know the participants at the beginning, the researcher can reflect with them on their performance and previous experiences, thereby achieving a deeper understanding of the knowledge construction experience.
2. Communicate clearly about the tasks at hand before starting any writing task; encourage questions and promote a positive writing atmosphere without stress. Being supportive can help participants cope with any stress or pressure, and the received data are more accurate.

3. Provide and organise a writing environment in which the writing modality can be easily changed to another. Doing so will make the participants' task activities easier, save time and energy – particularly for young participants – relieve pressure and enhance the quality of the received data.
4. Facilitate a calm and stress-free environment in which the participants can reflect on the writing event and recall written texts. Creating this positive environment can facilitate the creation of the best possible data collection setting, in which reflection, understanding and dialogue can be achieved.

These four design principles were operationalised to the highest possible degree in all sub-studies and experiments in this research and were acknowledged to have facilitated the writing setting and environment. Adhering to these principles can enhance the validity and reliability of the results.

6.1 Methodological Evaluation of the Research

The EDR framework places considerable weight on the reflection and evaluation of the research process with methodological and theoretical choices as well as with empirical findings through which theoretical and practical understanding are acquired (McKenney & Reeves, 2018). Ceaseless reflection retains in one's awareness not just the identified issues in need of improvement and refinement in the designed intervention, but also factors concerning methodology in general.

Oh and Reeves (2010) mentioned the rarity of DBR in doctoral research due to limitations on time and resources. However, DBR and particularly the EDR methodology have a number of potential benefits for educational research via their iterative refining of interventions designed not only for educational researchers' needs, but for those of education professionals as well. This research provided a foundation for mutual learning for the researcher, the participants and the education providers, thereby demonstrating an ideal framework for a reflective and collaborative design process (McKenney & Reeves, 2018). As mentioned, the EDR process improves and refines interventions through iteration (McKenney & Reeves, 2018; Oh & Reeves, 2010). However, as McKenney and Reeves (2018) and Oh and Reeves (2010) also expressed, it is difficult to establish whether a sufficient number of iterations have been conducted or to identify the adequate standards of the designed intervention. Subsequently, the appropriateness of the EDR methodology should be reflected upon in line with the objectives and contexts of each EDR project, while also ensuring its replicability (McKenney & Reeves, 2018). Moreover, the EDR methodology requires reliability, validity and transferability to be addressed to ensure scientific rigor (McKenney & Reeves, 2018). Reflecting on these factors concerning EDR, the methodological choice of this research met all these expectations.

The methodology in this research was consistent, consequently establishing its replicability and reliability, since all quantitative data collection was achieved using the standardised WMS Logical Memory Subtest, which was administered to participants in sub-studies I, II and III. The participants in experiment 1 of sub-study II were administered a test modified from the initial WMS test battery (Appendices G, H and I). The development of the embodied knowledge construction model of affects in writing further strengthened the quantitative measures by introducing a qualitative measure to understand the multidimensionality of knowledge construction through writing. The validity and reliability of the instrument, such as that used in this research, and its consistency ensured the replicability of the research as well as the meaningful interpretations of the received data (Creswell, 2014). Furthermore, design principles were provided for anyone wishing to replicate or widen the current research.

An experimental within-subjects research design was used in all quantitative experiments in this study, keeping the variables as consistent as possible and allowing the use of deeper statistical testing on the received data (Howitt & Cramer, 2011). Moreover, the reliability coefficient of equivalence and stability was reached by measuring the same individuals repeatedly for the same tasks (Cohen, Manion, & Morrison, 2002; Creswell, 2014). The above-mentioned consistency and causality in terms of both the research design and the data collection method ensured the internal validity of this study (Creswell, 2014). Potential threats to external validity, such as the characteristics of the participants or the setting (2014), were minimised by using the same setting for the participants in each experiment or sub-study, as well as by using a randomiser to set the order of the dictation of stories and the order of the chosen writing modality. However, some extraneous factors could not be controlled, such as personal history or the ability to personally relate to one of the dictated stories more than the others for any reason (Creswell, 2014; Mertens, 2014). External validity is particularly important when considering the generalisability of the results (Cohen et al., 2002; Creswell, 2014). In this research, the results of each sub-study and experiment were limited to people in the same age range in Finland. However, the findings were confirmed with several different statistical analyses, which can be replicated given the careful and detailed description of this study, thereby confirming the stability of the findings (Mertens, 2014).

When evaluating and reflecting on the findings of this study, certain limitations and strengths should be acknowledged. All data were collected from people who had various experiences with keyboarding, even within the same age range, thereby potentially affecting the results of the memory tests. However, the embodied knowledge construction model sought to address the issue of individual differences affecting writing and keyboarding and the subsequent recollection of written texts. Another shortcoming was the small sample size in all age groups. As the confidence interval for means was calculated in sub-study II (Frangou, Wikgren, Sintonen,

Kairaluoma, & Vasari, 2019), it was possible to determine that to make reliable conclusions from the results and to standardise the test, each age group should have 262 participants. However, a standardised test could not possibly represent the potential embodied affects in writing. Regarding this issue, the embodied knowledge construction model of affects in writing offers a solution. Further, from this study, participants' characteristics and self-evaluation of writing competences should have been considered during data collection and analysis; their omission, therefore, represents an additional limitation to this research. In addition, the stories were dictated once, but if a participant did not hear something, they could ask for a second read of that sentence. Therefore, some of the participants heard some parts of the stories twice. This issue could be addressed in future studies, for example, by using earphones to eliminate all external distractions. Moreover, the socioeconomic backgrounds of the participants could have yielded information about the diversity and proclivities of participants, information which could have been examined within and between genders (Koutsogiannis & Adampa, 2012), since socioeconomic background is considered a factor affecting children's cognitive function and life outcomes (Ristikari, Merikukka, Savinetti, & Malloy, 2018).

The particular strengths of this research are found in the empirical studies that have provided completely new and significant information on the connection of writing modalities to recollection in different age groups. Another strength of this research was the theoretical model developed herein, which can provide an excellent foundation for further research and development of theoretical and pedagogical models, and already provides important qualitative information in addition to quantitative findings. Since all phenomena have quantitative and qualitative aspects, research benefits from both aspects (Bergman, 2008; Ercikan & Roth, 2006; Wood & Welch, 2010). The quantitative and qualitative findings compete with each other and give the reader a more holistic understanding of the issues at hand (Trafimow, 2014). Another strength of this research was its design, which adhered to the principles of EDR by conducting several experiments using the designed intervention to progressively achieve a deeper understanding in terms of both practice and theory (McKenney & Reeves, 2018). Furthermore, iterative data collection from various participant age groups was a clear strength of this research, increasing its validity and reliability (Design-Based Research Collective, 2003).

6.2 Implications and Future Direction

This research offered empirical findings regarding completely new knowledge about writing modalities and their influence on recollection as well as aspects that affect writing and consequent recollection. It also provided practical contributions in the form of design principles that can guide any future efforts to develop studies in this

context. Furthermore, this study made a theoretical contribution in the form of the embodied knowledge construction model, which can be used when forming new hypotheses on issues concerning affects and knowledge construction in writing (Table 4).

Table 4. Contribution of this Research to Empirical, Practical and Theoretical Knowledge Generation

	Contribution of this Research
Empirical knowledge generated about the influence of writing modalities on	• adults' short-term and long-term recollection • adolescents' long-term recollection • children's long-term recollection
Practical methodological knowledge generated	• about how to conduct future research using design principles • by providing a research design on how to conduct future research • by providing a test battery for children aged 10 to 11 for future research based on sub-study II
Practical pedagogical knowledge generated	• by providing the embodied knowledge construction model for use by any education professional or researcher for reflecting upon and understanding affects in writing
Theoretical knowledge generated	• by providing the embodied knowledge construction model of affects in writing for any future research and development endeavours

This theoretical model, the embodied knowledge construction model of affects in writing, must now be developed and refined further to create a pedagogical model that can account for aspects of embodied cognition in individuals.

In sum, this research has contributed to the EDR research field with multiple experiments that measured the influence of three writing modalities (handwriting, computer keyboarding and touchscreen keyboarding) on recollection among higher education students, adolescents and children. These experiments generated empirical, practical, theoretical and pedagogical knowledge, which is the ultimate objective of the EDR process (Barab & Squire, 2004; Juuti & Lavonen, 2006; McKenney & Reeves, 2018; Design-Based Research Collective, 2003).

This study has several educational, cognitive and scientific implications, but those for educational contexts are especially notable. At all levels of education, digital devices are engulfing classrooms and complicating writing modalities, thus marginalising handwriting. Concurrently, the ubiquitous digitalisation of learning environments has contributed to the substantial diversification of teaching and learning methods (Darling-Hammond & Bransford, 2007), possibly extending to writing instruction as well. In this context, changes in the writing modalities used will have continuous educational implications, some of which are not yet known. Effects will vary for different age groups and their respective education providers.

For adults in higher education, keyboarding is the most commonly used writing modality; however, their competence in keyboarding varies. Some students complete assignments and exams using only two fingers for keyboarding. Therefore, providing supplementary instruction for students in keyboarding could enhance their ability to express themselves fully, not only in their assignments but in digitalised society at large. For current adolescents in secondary school or upper secondary school, the situation is similar: some are competent in keyboarding while others are not, and the same situation applies to handwriting competence. There is therefore an urgent need for supplementary instruction in keyboarding to ensure younger generations' ability to function as active citizens in future educational endeavours, at future workplaces and in private life. The fluency to transcribe and convert language and ideas into written text (Connelly, Gee, & Walsh, 2007) affects the speed of writing and the quality of its content (Bourdin & Fayol, 1994). Adolescents taking the new matriculation examination electronically may be admitted directly to higher education should they perform well. However, these students will not have an equal opportunity for admission to higher education if they do not learn proper keyboarding. With fluency, the writing process does not constitute a heavy cognitive load for the writer, who can instead concentrate on the planning and topic of the writing (Berninger & Swanson, 1994; Klein, 1999; Ungerleider, Doyon, & Karni, 2002; Yeganeh Doost, Orban de Xivry, Bihin, & Vandermeeren, 2017). Furthermore, learning the correct way to keyboard from the beginning will also spare children from having to 'unlearn' incorrect keyboarding habits later on.

Instruction practices concerning handwriting should be developed, bearing in mind possible individual differences and the importance of motivation. Furthermore, for children in primary schools, starting from the first grade, writing practices should be balanced to ensure that they can function at their full potential using both digital and traditional devices. A variety of ICTs should become an integral part of the cultural ecology of contemporary learning environments and function as learning support tools to enable students to reach their full potential (Vahtivuori-Hänninen & Kynäslahti, 2016; Vesisenaho et al., 2017). Moreover, motivation and self-efficacy play an essential role (Cordeiro, Castro, & Limpo, 2018). Motivation has been linked with the self-perception of one's ability as a writer, influencing his or her confidence and self-efficacy beliefs and thereby reflecting on the writing performance (Limpo & Alves, 2013; Pajares, 2003; Pajares, Valiante, & Cheong, 2007).

This research has implications for cognitive and scientific contexts. Concerning cognitive implications, changes in writing habits and the shift from handwriting to keyboarding during the first years of school will affect future generations' manual dexterity, possibly extending to learning as well, but the full effects of this development remain unknown. In this research, changes in manual dexterity were evident in sub-study II, in which the participants used their thumbs for keyboarding yet managed to type faster and retain better recall than those who used all 10 fingers on a laptop

keyboard. From the scientific perspective, the embodied knowledge construction model may raise teachers' and researchers' awareness of affects in writing. The model can be used at any level of education and for any writing modality. Further, the detailed design principles, research design and test battery have been provided for future exploration purposes. Last, this research produced new scientific information about different writing modalities and the long-term and short-term recollection of written texts in different age groups. These findings provide a well-grounded starting point for a deeper empirical investigation into changing writing modalities and their effects on cognitive performance in an effort to provide educators with much-needed knowledge for their classrooms. By identifying the influence of different writing modalities on recollection, we can discuss and determine future directions for writing instruction development. Additionally, further empirical research on developmental and neural factors and the associated writing modalities is also needed to generate a more holistic understanding of the cognitive process of writing.

In conclusion, the findings of this research reveal that writing modalities affect recollection, while the degree of automaticity of the given writing task also playing a role. Furthermore, knowledge construction in writing is influenced by embodied affects – the inner and outer worlds of individuals, which are shaped by not only all-pervasive action and perception sequences but also motivations, experiences and affects. This research process has revealed the immeasurable possibilities of innovative multidisciplinary research, without which this study could not have been imagined, let alone completed. In this research, quantitative and qualitative behavioural approaches were enhanced by the cognitive psychological approach, a collaboration this author thoroughly recommends. More multidisciplinary research of this kind on writing is sorely needed, as technology and writing modalities are always evolving. Writing consistently relies on a medium through which to evoke the desired message. In the modern world, possessing the skill to write messages both conventionally and digitally can empower young and old alike to become more active members of society.

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APPENDICES

Appendix A: Consent Form

Lapin yliopisto
Kasvatustieteiden tiedekunta, Mediapedagogiikkakeskus

Koehenkilötiedote ja suostumuslomake

Muistitesti käsin, näppäimistöllä ja näyttönäppäimistöllä kirjoittaen
TIEDOTE TUTKITTAVILLE JA SUOSTUMUS TUTKIMUKSEEN OSALLISTUMISESTA

Väitöskirjatutkijan yhteystiedot
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Tutkimuksen taustatiedot
Kyseessä on Lapin yliopiston väitöskirjatutkimus, jossa tutkitaan mitä mahdollisia vaikutuksia eri kirjoitusmenetelmillä on kirjoitetun asian deklaratiiviseen oppimiseen ja oppimiseen liittyviin muistitoimintoihin. Tässä osatutkimuksessa 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.

Tutkimusaineiston säilyttäminen
Tutkimuksen vastuullinen tutkija vastaa manuaalisen ja ATK:lla olevan tutkimusaineiston turvallisesta säilyttämisestä. Datanhallintasuunnitelma on tehty DMP Tuuli tutkimusaineiston hallintasuunnitelmatyökalun avulla.

Miten ja mihin tutkimustuloksia aiotaan käyttää
Tämän tutkimuksen tuloksia tullaan käyttämään opinnäytetyössä, sekä kongressi- ja seminaariesityksissä, kansallisissa ja kansainvälisissä julkaisuissa ja opetuksessa.

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 tulokset julkaistaan tutkimusraporteissa siten, ettei yksittäistä tutkittavaa voi tunnistaa. Tutkittavilla on oikeus saada lisätietoa tutkimuksesta missä vaiheessa tahansa tutkimuksen tekijältä.

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.

Päiväys		Tutkittavan allekirjoitus
Päiväys	Tarvittaessa:	Huoltajan allekirjoitus
Päiväys		Tutkijan allekirjoitus

Appendix B: Statement of the Research Ethics Committee of the University of Lapland

LAPIN YLIOPISTO
UNIVERSITY OF LAPLAND

Eettisen ennakkoarvioinnin neuvoston lausunto

Lausunnonhakija:	Satu-Maarit Frangou
Lausuntopyynnön päiväys:	6.4.2017
Tutkimuksen aihe:	Eri kirjoitustapojen vaikutukset muistitoimintoihin, oppimiseen ja kirjoitetun asian ymmärtämiseen.

Lausunto

Lapin yliopiston eettisen ennakkoarvioinnin neuvoston tehtävänä on arvioida pyynnöstä suunnitellun tutkimuksen eettistä hyväksyttävyyttä TENK:n laatimien periaatteiden mukaisesti. Eettisen ennakkoarvioinnin neuvosto on kokouksessaan 12.4.2017 käsitellyt asian toimittamanne aineiston perusteella.

Neuvosto toteaa, että hakijan esittämässä suunnitelmassa on seikkoja, jotka edellyttävät huolellista tutkimuseettistä pohdintaa. Hakijaa pyydetään kiinnittämään erityistä huomiota lupakäytäntöihin oppilaan, koulun ja vanhempien suostumusten osalta. Toimittamanne materiaalin perusteella tutkimuseettiset näkökohdat on käsitelty suunnitelmassa muutoin asianmukaisesti ja kattavasti, eikä neuvosto näe estettä tutkimuksen toteuttamiselle esitetyllä tavalla. Neuvosto puoltaa tutkimuksen käynnistämistä suunnitelman mukaan.

Rovaniemellä 12.4.2017

[nimi poistettu / name removed]

[nimi poistettu / name removed]

Appendix C: Permission to Conduct Research in Primary Schools by the Municipality

Rovaniemen kaupunki **Viranhaltijapäätös** 1 (3)
Palvelualuepäällikkö Koulutuspalvelut 25.04.2017 **§ 8**
Tutkimuslupapäätös

ROIDno-2017-626
Tutkimuslupa Frangou Satu-Maarit

Lapin yliopiston väitöskirjatutkija Satu-Maarit Frangou (pääaineena mediakasvatus) hakee tutkimuslupaa väitöskirjatutkimustaan varten. Tutkimuksen tekijällä on Lapin yliopiston Eettisen ennakkoarvioinnin neuvoston puoltava lausunto tutkimukselleen.
Tutkimuksen työnimi on "Eri kirjoitustapojen vaikutukset muistitoimintoihin, oppimiseen ja kirjoitetun asian ymmärtämiseen". Tutkimuksessa vertailtavina kirjoitusmetodeina ovat käsin kirjoittaminen ja tietokoneen näppäimistöllä kirjoittaminen, sekä tablettitietokoneen virtuaalisella näppäimistöllä kirjoittaminen. Vertailtavina tutkimushenkilöinä ovat aikuiset, jotka ovat oppineet koulussa kaunokirjoituksen (tämä osa tutkimuksesta on jo tehty) ja lapset, jotka oppivat tänä päivänä tekstauksen ja kymmensormijärjestelmän. Tutkimus rajautuu Rovaniemen alakouluihin ja tutkija sopii kaikki käytännön järjestelyt koulujen kanssa. Tutkimuksessa käytetään Wechslerin muistitestiä, joka on kansainvälisesti tunnettu muistitesti. Tutkimuksen tekoon menee noin 45 minuuttia yhteensä, ja viikon päästä tapahtuvaan muistitehtävään noin 10 minuuttia. Kysymyksessä on kertaluonteinen tutkimus. Tutkimustuloksista kirjoitetaan tieteellinen artikkeli, josta tutkimushenkilöt eivät ole tunnistettavissa. Tutkimukseen osallistuminen on vapaaehtoista ja tutkimushenkilöille kerrotaan ennen tutkimusta mistä tutkimuksessa on kyse ja mihin saatua aineistoa tullaan käyttämään. Tutkija sitoutuu käyttämään saamiaan tietoja hyvien eettisten periaatteiden mukaisesti.

Väitöskirjaohjaaja toimii professori Heli Ruokamo.

Päätös
Satu-Maarit Frangoulle myönnetään em, tutkimuslupa.

Tiedoksi
Satu-Maarit Frangou, Rovaniemen alakoulujen koulunjohtajat/rehtorit

Allekirjoitus

palvelualuepäällikkö [nimi poistettu / name removed]

Oikaisuvaatimus
§ 8

Oikaisuvaatimusohje
OIKAISUVAATIMUSOHJE

Oikaisuvaatimusoikeus
Päätökseen tyytymätön voi tehdä kirjallisen oikaisuvaatimuksen. Oikaisuvaatimuksen saa kuntalain 92 §:n mukaan tehdä se, johon päätös on kohdistettu tai jonka oikeuteen, velvollisuuteen tai etuun päätös välittömästi vaikuttaa (asianosainen) sekä kunnan jäsen. Oikaisuvaatimuksen voi tehdä tarkoituksenmukaisuus- tai laillisuusperusteella.

Oikaisuvaatimusaika ja sen alkaminen
Oikaisuvaatimus on tehtävä 14 päivän kuluessa päätöksen tiedoksisaannista. Kunnan jäsenen katsotaan saaneen päätöksestä tiedon, kun pöytäkirja on asetettu yleisesti nähtäväksi. Asianosaisen katsotaan saaneen päätöksestä tiedon, jollei muuta näytetä, seitsemän (7) päivän kuluessa kirjeen lähettämisestä. Käytettäessä tavallista sähköistä tiedoksiantoa asianosaisen katsotaan saaneen tiedon päätöksestä kolmantena (3) päivänä viestin lähettämisestä. Oikaisuvaatimusaikaa laskettaessa tiedoksisaantipäivää/ nähtäväksi asettamispäivää ei lueta määräaikaan.

Oikaisuvaatimuksen muoto ja toimittaminen
Oikaisuvaatimus on tehtävä kirjallisesti. Oikaisuvaatimus on tekijän, laillisen edustajan tai asiamiehen allekirjoitettava. Siinä tulee mainita tekijän, ja jos hän ei ole allekirjoittaja, myös allekirjoittajan nimi, osoite, asuinkunta sekä puhelinnumero, johon asiaa koskevat ilmoitukset voidaan toimittaa. Jos oikaisuvaatimuspäätös voidaan antaa tiedoksi sähköisenä viestinä, yhteystietona pyydetään ilmoittamaan myös sähköpostiosoite.

Oikaisuvaatimuksessa on mainittava päätös, jota vaaditaan oikaistavaksi sekä vaatimuksen sisältö ja perusteet. Oikaisuvaatimukseen on liitettävä asiakirjat, joihin tekijä vetoaa vaatimuksensa tueksi, jollei niitä ole aikaisemmin toimitettu viranomaiselle.

Oikaisuvaatimus on toimitettava oikaisuvaatimusviranomaiselle ennen oikaisuvaatimusajan päättymistä. Jos määräajan viimeinen päivä on pyhäpäivä, itsenäisyyspäivä, vapunpäivä, joulu- tai juhannusaatto tai arkilauantai, oikaisuvaatimuksen saa tehdä ensimmäisenä arkipäivänä tämän jälkeen. Muutoshakemus on tehtävä viimeistään määräajan viimeisenä päivänä ennen viraston aukioloajan päättymistä. Mikäli oikaisuvaatimus lähetetään postitse, on se jätettävä postiin niin ajoissa, että se ehtii perille viraston aukioloaikana ennen oikaisuvaatimusajan päättymistä. Sähköisen asiakirjan (telekopio tai sähköposti) tulee olla määräaikana viranomaisen käytettävissä vastaanottolaitteessa tai tietojärjestelmässä siten, että viestiä voidaan käsitellä.

Oikaisuvaatimuksen voi toimittaa myös faksina tai sähköpostitse. Sähköistä asiakirjaa ei tarvitse täydentää allekirjoituksella, jos asiakirjassa on tiedot lähettäjästä eikä asiakirjan alkuperäisyyttä tai eheyttä ei ole syytä epäillä. Oikaisuvaatimuksia, jotka sisältävät arkaluonteisia henkilö- tai salassa pidettäviä tietoja, ei suositella lähetettäväksi sähköpostitse tai sen liitteenä.

Oikaisuvaatimus lähetetään aina lähettäjän omalla vastuulla.

Oikaisuvaatimuksen maksu
Oikaisuvaatimuskäsittely on maksutonta.

Oikaisuvaatimusviranomainen ja yhteystiedot
Oikaisuvaatimusviranomainen: Rovaniemen kaupunki, Koulutuslautakunta
Postiosoite: PL 8216, 96101 Rovaniemi
Käyntiosoite: Hallituskatu 7, Rovaniemi
Sähköpostiosoite: kirjaamo(at)rovaniemi.fi
Telefax: (016) 322 6450
Puhelin: (016) 3221
Virka-aika kello 8.00 – 16.00

Appendix D: Permission to Conduct Research in Secondary Schools by the Municipality

Rovaniemen kaupunki | **Viranhaltijapäätös** | 1 (3)
Palvelualuepäällikkö Koulutuspalvelut | 28.04.2017 | **§ 11**
Tutkimuslupapäätös

ROIDno-2017-626
Tutkimuslupa II Frangou Satu-Maarit

Lapin yliopiston väitöskirjatutkija Satu-Maarit Frangoulle (pääaineena mediakasvatus) on myönnetty viranhaltijapäätöksellä 25.04.2017§8 väitöskirjatutkimusta koskeva tutkimuslupa Rovaniemen alakouluja varten. Tutkimuksen vertailuaineiston laajentamiseksi Satu-Maarit Frangou hakee tutkimuslupaa myös [redacted] peruskoulun yläluokkia varten. Tutkimuksen tekijällä on Lapin yliopiston Eettisen ennakkoarvioinnin neuvoston puoltava lausunto tutkimukselleen.
Tutkimuksen työnimi on "Eri kirjoitustapojen vaikutukset muistitoimintoihin, oppimiseen ja kirjoitetun asian ymmärtämiseen". Tutkimuksessa vertailtavina kirjoitusmetodeina ovat käsin kirjoittaminen ja tietokoneen näppäimistöllä kirjoittaminen, sekä tablettitietokoneen virtuaalisella näppäimistöllä kirjoittaminen. Vertailtavina tutkimushenkilöinä ovat aikuiset, jotka ovat oppineet koulussa kaunokirjoituksen (tämä osa tutkimuksesta on jo tehty) ja lapset, jotka oppivat tänä päivänä tekstauksen ja kymmensormijärjestelmän. Tutkimus rajautuu [redacted] peruskoulun yläluokkien oppilaisiin ja tutkija sopii kaikki käytännön järjestelyt koulujen kanssa. Tutkimuksessa käytetään Wechslerin muistitestiä, joka on kansainvälisesti tunnettu muistitesti. Tutkimuksen tekoon menee noin 45 minuuttia yhteensä, ja viikon päästä tapahtuvaan muistitehtävään noin 10 minuuttia. Kysymyksessä on kertaluonteinen tutkimus. Tutkimustuloksista kirjoitetaan tieteellinen artikkeli, josta tutkimushenkilöt eivät ole tunnistettavissa. Tutkimukseen osallistuminen on vapaaehtoista ja tutkimushenkilöille kerrotaan ennen tutkimusta mistä tutkimuksessa on kyse ja mihin saatua aineistoa tullaan käyttämään.
Tutkija sitoutuu käyttämään saamiaan tietoja hyvien eettisten periaatteiden mukaisesti.

Väitöskirjaohjaajana toimii professori Heli Ruokamo.

Päätös
Satu-Maarit Frangoulle myönnetään em. tutkimuslupa.

Tiedoksi
Satu-Maarit Frangou, [nimi poistettu / name removed]

Allekirjoitus

palvelualuepäällikkö [nimi poistettu / name removed]

Oikaisuvaatimus
§ 11

Oikaisuvaatimusohje
OIKAISUVAATIMUSOHJE

Oikaisuvaatimusoikeus
Päätökseen tyytymätön voi tehdä kirjallisen oikaisuvaatimuksen. Oikaisuvaatimuksen saa kuntalain 92 §:n mukaan tehdä se, johon päätös on kohdistettu tai jonka oikeuteen, velvollisuuteen tai etuun päätös välittömästi vaikuttaa (asianosainen) sekä kunnan jäsen. Oikaisuvaatimuksen voi tehdä tarkoituksenmukaisuus- tai laillisuusperusteella.

Oikaisuvaatimusaika ja sen alkaminen
Oikaisuvaatimus on tehtävä 14 päivän kuluessa päätöksen tiedoksisaannista. Kunnan jäsenen katsotaan saaneen päätöksestä tiedon, kun pöytäkirja on asetettu yleisesti nähtäväksi. Asianosaisen katsotaan saaneen päätöksestä tiedon, jollei muuta näytetä, seitsemän (7) päivän kuluessa kirjeen lähettämisestä. Käytettäessä tavallista sähköistä tiedoksiantoa asianosaisen katsotaan saaneen tiedon päätöksestä kolmantena (3) päivänä viestin lähettämisestä. Oikaisuvaatimusaikaa laskettaessa tiedoksisaantipäivää/ nähtäväksi asettamispäivää ei lueta määräaikaan.

Oikaisuvaatimuksen muoto ja toimittaminen
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Oikaisuvaatimuksessa on mainittava päätös, jota vaaditaan oikaistavaksi sekä vaatimuksen sisältö ja perusteet. Oikaisuvaatimukseen on liitettävä asiakirjat, joihin tekijä vetoaa vaatimuksensa tueksi, jollei niitä ole aikaisemmin toimitettu viranomaiselle.

Oikaisuvaatimus on toimitettava oikaisuvaatimusviranomaiselle ennen oikaisuvaatimusajan päättymistä. Jos määräajan viimeinen päivä on pyhäpäivä, itsenäisyyspäivä, vapunpäivä, joulu- tai juhannusaatto tai arkilauantai, oikaisuvaatimuksen saa tehdä ensimmäisenä arkipäivänä tämän jälkeen. Muutoshakemus on tehtävä viimeistään määräajan viimeisenä päivänä ennen viraston aukioloajan päättymistä. Mikäli oikaisuvaatimus lähetetään postitse, on se jätettävä postiin niin ajoissa, että se ehtii perille viraston aukioloaikana ennen oikaisuvaatimusajan päättymistä. Sähköisen asiakirjan (telekopio tai sähköposti) tulee olla määräaikana viranomaisen käytettävissä vastaanottolaitteessa tai tietojärjestelmässä siten, että viestiä voidaan käsitellä.

Oikaisuvaatimuksen voi toimittaa myös faksina tai sähköpostitse. Sähköistä asiakirjaa ei tarvitse täydentää allekirjoituksella, jos asiakirjassa on tiedot lähettäjästä eikä asiakirjan alkuperäisyyttä tai eheyttä ei ole syytä epäillä. Oikaisuvaatimuksia, jotka sisältävät arkaluonteisia henkilö- tai salassa pidettäviä tietoja, ei suositella lähetettäväksi sähköpostitse tai sen liitteenä.

Oikaisuvaatimus lähetetään aina lähettäjän omalla vastuulla.

Oikaisuvaatimuksen maksu
Oikaisuvaatimuskäsittely on maksutonta.

Oikaisuvaatimusviranomainen ja yhteystiedot
Oikaisuvaatimusviranomainen: Rovaniemen kaupunki, Koulutuslautakunta
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Käyntiosoite: Hallituskatu 7, Rovaniemi
Sähköpostiosoite: kirjaamo(at)rovaniemi.fi
Telefax: (016) 322 6450
Puhelin: (016) 3221
Virka-aika kello 8.00 – 16.00

Appendix E: Information Sent to Minor Participants' Legal Guardians

Informaatiokirje vanhemmille/huoltajalle
Eri kirjoitustapojen vaikutukset muistitoimintoihin, oppimiseen ja kirjoitetun asian ymmärtämiseen –tutkimus

Hyvä isä, äiti tai muu huoltaja!

Lapsenne osallistuu koulupäivän aikana tutkimukseeni eri kirjoitustavoista ja niiden vaikutuksista oppimiseen ja muistitoimintoihin. Tutkimus on osa väitöskirjatutkimustani Lapin yliopistossa. Vertailtavina kirjoitusmetodeina ovat käsin kirjoittaminen ja tietokoneen näppäimistöllä kirjoittaminen, sekä tablettitietokoneen virtuaalisella näppäimistöllä kirjoittaminen. Vertailtavina tutkimushenkilöinä ovat aikuiset, jotka ovat oppineet koulussa kaunokirjoituksen (tämän tutkimuksen olen jo tehnyt) ja lapset, jotka oppivat tänä päivänä tekstauksen ja kymmensormijärjestelmän.

Tutkimukseen osallistuminen on lapselle vapaaehtoista, ja lapsi antaa kirjallisen suostumuksen tutkimusmateriaalin käytöstä tutkimus– ja opetustarkoituksiin. Tutkimuksessani käytän Wechslerin muistitestiä, joka on kansainvälisesti tunnettu muistitesti. Tutkimuksen tekoon menee noin 45 minuuttia yhteensä, ja viikon päästä tapahtuvaan muistitehtävään noin 10 minuuttia. Tutkimustuloksista kirjoitetaan tieteellinen artikkeli, ja tutkimushenkilöille taataan nimettömyys ja tunnistamattomuus kaikissa tutkimusprosessin ja raportoinnin vaiheissa.

Vastaan mielelläni kaikenlaisiin tutkimukseen liittyviin kysymyksiin.

Satu-Maarit Frangou
Väitöskirjatutkija
Lapin yliopisto
044-0350146
sfrangou@ulapland.fi

Appendix F, Story C, Sub-study I, II (Pilot Experiment and Experiment 2), Sub-study III

Story C, Adults and adolescents (translation).
Large beasts of prey are **familiar** to the **border guards** of the **eastern division**. Border guard **Jacob Smith** has seen a **bear three times** during his **career**. The **previous case** happened **two years ago** when he was **patrolling** with his **dog** one **July morning**. They passed a **valley** when they **heard a sound**. A bear had **touched** the **barbed wire** and **came across the border**. The man decided to **whistle**, and the bear **turned right back**. The border guards of the **Lake District**, for example, meet bears about **five times a year**.

Each of these items earn one point if recalled:
Large beasts of prey, familiar, border guards, eastern division, Jacob, Smith, bear, three times, career, previous case, two years ago, patrolling, dog, July morning, valley, heard a sound, touched, barbed, came across, border, whistle, turned back, Lake District, five times, a year.

Kertomus C
Suurpedot / ovat tuttuja **itärajaa** / **valvoville** / **rajamiehille**./ Rajamies **Jaakko** / **Nieminen** / on nähnyt karhun **kolme kertaa** / **uransa aikana**. / **Edellinen tapaus** / sattui **kaksi vuotta sitten**,/ kun hän oli **partioimassa** / **koiran kanssa**/ **heinäkuisena** / **aamuna.** / He kulkivat **vastatuuleen** / **solassa**, / kun jostain kuului ääni./ Karhu kosketti **piikkilankaa** / ja tuli **Suomen puolelle**. / Mies **vihelsi** /ja samassa karhu **kääntyi takaisin.**/ Esimerkiksi **Tohmajärven** / **rajavartioaseman** / rajamiehet kohtaavat suurpedon **vuosittain** / **noin viisi kertaa**./

Jokaisesta muistetusta asiasta saa yhden pisteen:
Suurpedot, itärajaa, valvoville, rajamiehille, Jaakko, Nieminen, kolme kertaa, uransa aikana, edellinen tapaus, kaksi vuotta sitten, partioimassa, koiran kanssa, heinäkuisena, aamuna, vastatuuleen, solassa, ääni, piikkilankaa, Suomen puolelle, vihelsi, kääntyi takaisin, Tohmajärven, rajavartioaseman, vuosittain, noin viisi kertaa.

Appendix G: Story A, Sub-study II (Experiment 1)

Story A translation, Experiment 2
A **student** called **Leevi** from **Ranua** found a **small** and strange **animal yesterday on the way to school.** He drove with a **moped** to take it to a **zoo** where the **vet recognized** the animal to be a **rare reptile.** The **beautiful** reptile had certainly **escaped** from a **pet shop** because it would not survive in the **northern nature.** Here it needs a **terrarium** and a **heat lamp.**

Each of these items earn one point if recalled:
Student, Leevi, Ranua, small, animal, yesterday, on the way to school, moped, zoo, vet, recognized, rare, reptile, beautiful, escaped, pet shop, northern nature, terrarium, heat lamp.

TEKSTI A, 3.-4.lk
Ranualainen / opiskelija / Leevi / löysi **eilen** / **koulutieltä** / **pienen** / oudon **eläimen**. / Hän lähti **mopolla** / viemään sitä **/ eläintarhaan**, jossa **eläinlääkäri / tunnisti** olion **harvinaiseksi / matelijaksi.** / **Kaunis** olio oli varmasti **karannut eläinkaupasta**, sillä se ei pärjäisi **pohjoisen luonnossa**, vaan tarvitsee elääkseen täällä **terraarion** ja lämpölampun. **(40 sanaa, 20 yksityiskohtaa)**

Jokaisesta muistetusta asiasta saa yhden pisteen:
Ranualainen , opiskelija/poika, Leevi, eilen, koulutie/koulumatka, pieni, eläin, mopo, eläintarha, eläinlääkäri, tunnisti, harvinainen, matelija, kaunis, karannut, eläinkaupasta, pohjoinen, luonto/metsä, terraario, lämpölamppu

Appendix H: Story B, Sub-study II (Experiment 1)

Story B translation, Experiment 2
During the **weekend, four men** went to **Norway** on a **fishing trip.** They did not stay in a **cottage,** but in a **caravan.** On **Sunday,** the **sun** was shining and the **fish bite well.** Then the **boat's cap disappeared** and it was **filled** with water**.** The nearby **Japanese tourists** came to **help** and the men started their **trip home wet.**

Each of these items earn one point if recalled:
Weekend, four, men, Norway, fishing trip, cottage, caravan, Sunday, sun, fish, bite well, boat's, cap/cork, disappeared, filled, Japanese, tourists, help, trip home, wet.

TEKSTI B, 3.-4.lk
Neljä / miestä / lähti **/ viikonloppuna / kalastamaan / Norjaan**. / Heillä ei ollut **mökkiä**, / vaan he asuivat **/ asuntovaunussa. / Sunnuntaina** / **aurinko** paistoi ja **kala söi** hyvin**.** Sitten **veneen tappi** / **katosi** ja se / **täyttyi** vedellä. / Lähistöllä olleet **japanilaiset turistit** / tulivat **auttamaan** ja / miehet lähtivät **märkinä kotimatkalle**. / 40 sanaa, 20 yksityiskohtaa

Jokaisesta muistetusta asiasta saa yhden pisteen:
Neljä, miestä, viikonloppuna, kalastamaan, Norjaan, mökki, asuntovaunu, sunnuntai, aurinko, kala, söi, vene, tappi/korkki, katosi, täyttyi, japanilaiset, turistit, auttaa, märkinä, kotimatka.

Appendix I: Story C, Sub-study II (Experiment 1)

Story C translation, Experiment 2
Bears are familiar to **old Emma** that **lives in the woods**. **Last summer** Emma saw a bear **three times**. **Last time** it happened when she went to **pick berries** with the **dog**. They walked on a **forest path** when a **sound** was heard. The bear was **stealing honey**. The bear was **startled** by the **barking** of the dog and **slowly walked away**.

Each of these items earn one point if recalled:
Bears, old, Emma, lives, in the woods, last (one year ago), summer, three, times, last time, pick berries, dog, forest, path, sound, stealing honey, startled, barking, slowly walked, away.

TEKSTI C, 3.-4. lk
Karhut / ovat tuttuja **metsässä asuvalle vanhalle Emmalle**. / **Viime kesänä** Emma / näki karhun **kolme kertaa**. / **Viimeisellä** kerralla / hän oli **marjastamassa / koiran** kanssa. / He kulkivat **/ metsäisellä polulla**, / kun jostain kuului ääni./ Karhu oli **hunajavarkaissa**. / Karhu **säpsähti** koiran **haukkuessa,** ja löntysti hitaasti **pois./** 40 sanaa, 20 yksityiskohtaa

Jokaisesta muistetusta asiasta saa yhden pisteen:
Karhu, metsä, asua, vanha, Emma, viime, kesä, kolme, kertaa, viimeksi/edellisellä, kerralla, marjastaa, koira, metsäinen/tiheä, polku, ääni, hunaja/hunajavaras, säpsähti, haukkumista, löntysti/lähti pois.