The Haptic Effect of Writing on Vocabulary Learning
A Comparison between Handwriting and Typewriting

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Abstract

A large body of data supports the view that movement plays an important role in learning and has demonstrated that handwriting could improve vocabulary learning. However, little is known about the effect of typing on language learning. Because handwriting movements differ from typewriting movements, this change in motor conditions could affect vocabulary learning performance. To test this, a total of 78 participants were trained to memorize forty word pairs either by reading, writing or typing. Immediately after their training they took a test and the accuracy of the three groups were compared. The results showed no significant differences between the three groups.

Keywords: handwriting, typing, learning, haptics, motor-perceptual interactions

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Introduction

At work, in school or at home, nowadays almost everybody writes using a keyboard and computers seem to replace pen and paper at an ever-increasing rate. More and more of our current writing is with a digital device, whether it is a laptop, digital tablet or a mobile phone. Even very young children are increasingly being introduced to writing with computers in addition to, and even at the expense of, writing by hand (Mangen & Velay, 2010). However, in studies of writing, the role of the physically tangible writing device is rarely addressed.

The process and skill of writing is studied on several levels and in many disciplines, from neurophysiologic research on the shaping of each letter to studies on the effect of writing on learning a second language (Longcamp, Anton, Roth & Velay, 2003, 2005; James & Gathier, 2006; Vinter & Chartrel, 2008). Early research was dominated by cognitive approaches mainly focusing on the visual component of the writing process, therefore maintaining a separation between visual perception and the combination of tactile perception associated with active movements, called haptics (Mangen & Velay, 2010). However, recent studies suggest that perception and haptics are in fact closely connected and reciprocally dependent. This means writing is a complex cognitive process relying on intricate combinations of visual perception and motor action. Because for some learners it is essential to simultaneously engage their bodies and their minds in the procedure of acquiring new information (Barsalou, 1999), this switch from pen and paper to a keyboard may entail major differences in the way we cognitively learn, process and understand information being presented to us.

Previous studies on the effect of writing on language learning found that handwriting could improve vocabulary learning (Pichette, De Serres & Lafontaine, 2011; Thomas & Dieter, 1987). However, little is known about the possible effect of typing on language learning. Therefore, this study will examine if the difference in haptics between writing by hand or by keyboard has an effect in the memorizing of new words while learning a second language, to provide an answer to its research question: What is the effect of the haptics of writing on second language vocabulary learning?

1. Literature Review

1.1 Embodied Cognition

The act of writing is a complex cognitive process relying on intricate perceptual-sensorimotor combinations (Longcamp, Zerbato-Poudou & Velay, 2005a), suggesting that cognition, action and perception are strongly entwined. The idea that our movements organize our perceptions and contribute to setting up our spatial representations is not new (Lakoff & Johnson, 1980). Recently, emphasizing the importance of motor information in learning has received renewed attention as researches have become interested in theories of embodied cognition (de Koning & Tabbers, 2011). Embodied theories of cognition propose that cognition or psychological processes are influenced and shaped by the body including body morphology, sensory systems and motor systems as well as the body's interaction with the surrounding world (Barsalou 2010; Glenberg 1997; Zwaan 1999). That is, perceptual and action-related processes are tightly linked to each other as well as to more abstract and higher-order cognitive processes such a language and mathematics (Barsalou, 1999). This means that cognition is grounded in perception and action.

Because cognition, perception and action are so strongly entwined they have an effect on each other. For example, the comprehension of action sentences can involve motor resonance. Glenberg and Kaschak (2002) showed that subjects who listened to sentences such as "He opened the drawer" had to assess whether the sentence made sense or not. These sensibility judgments were made by pressing a button, which required either movement toward or movement away from their body. This revealed an action-compatibility effect, meaning that responses were faster when the physical response was in the same direction as the movement implied by the sentence. For instance, responses made toward the body were faster after "He opened the drawer" than after "He closed the drawer," and the reverse was true for responses away from the body (Glenberg & Kaschak, 2002).

The body can not only be used to understand actions, but directed actions can also guide learning. Several studies have shown that manipulating learners' actions resulted in better text comprehension (Glenberg et al, 2008) or better problem solving (Thomas and lleras, 2009). Goodwyn, Acredolo & Brown (2000) conducted a study in which infants were aided by their parents during the acquisition of language by reinforcement of symbolic gesturing linked with the verbal word for the object or action. The results illustrated a significant increase in language acquisition between infants who combined symbolic gesturing with verbal speech over infants who only verbalized. It seemed this form of kinesthetic expression of language enhances a child's language learning procedure and attributes to the idea that the acquisition of language can be stimulated via movement (Goodwyn et al., 2000).

1.2 The Haptics of Writing

Writing is a process that requires the integration of visual, proprioceptive and tactile information in order to be accomplished (Fogassi & Gallese, 2004). In other words, the acquisition of writing skills involves a perceptual component (learning the shape of the letter) and a graphomotor component (learning the trajectory producing the letter's shape) (Van Galen, 1991). Research has shown that sensory modalities involved in handwriting, for example vision and proprioception, are so intimately entwined that strong neural connections have been revealed between perceiving, reading, and writing letters in different languages and symbol/writing systems (James & Gathier, 2006; Kato et al., 1999; Longcamp et al, 2003, 2005; Matsuo, Kato, Okada, Moriya, Glover & Nakai, 2003: Vinter & Chartrel, 2008; Wolf, 2008).

The combination of tactile perception associated with active movements is called haptics (Mangen & Velay, 2010). The haptics is considered to be very important when it comes to learn how to write. We learn to associate actions with their correlated perceptions in order to build up unified, coherent representations of objects. The more input, the stronger the underlying neural connections. Once the neural network underlying a given representation has been structured, any one of the inputs that was initially present suffices to reactivate the whole network (Martin, Ungerleider & Haxby, 2000: Pulvermuller, 1999 from Longcamp et al., 2005a). The existence of these motor-perceptual links has been observed with neuroimaging techniques in humans. The visual presentation of pictures of objects to which a specific ation can be attributed, activated a premotor cortical area, even when no actual response was required (Chao & Martin, 2000). Sirigu, Duhamel & Poncet (1991) suggest that sensorimotor knowledge about the functional properties of objects is part of their representation, and can be used to recognize or name them. This means that a motor-perceptual interaction involves the association of an object, thereby potentially strengthening the neural network.

Although alphabetic characters are not physical objects, motor-perceptual links presumably contribute to their representation, since they are associated with highly specific writing movements. The fact that inability to write letters can be associated with reading deficits, due to an impaired ability to identify letters visually, is consistent with the existence of a tight coupling between the visual and sensorimotor perception of letter shapes (Anderson, Damasio, & Damasio, 1990). Impaired reading abilities can be improved by performing writing movements: for example, patients who were no longer able to recognize letters visually succeeded in doing so when asked to trace the outline of the letters with their fingers (Bartolomeo, Bachoud-Le´vi, Chokron, & Degos, 2002; Seki, Yajima, & Sugishita, 1995). Handwriting movements may therefore somehow activate the visual representation of letters. It seems like the writing order of the numerous strokes composing ideograms is used as a cue to retrieve them from memory (Flores d'Arcais, 1994). This suggests that the motor scheme specific to each ideogram may be an essential component of its representation, an idea that has been supported by neuroimaging studies. Matsuo et al (2001) reported that Japanese subjects showed motor activation while looking at ideograms. Similary, Longcamp et al. (2003) reported that the simple visual presentation of Roman characters activated a premotor zone in the left hemisphere in right-handed subjects, even though no motor response was required. The activation of the corresponding area in the opposite hemisphere of left-handed subjects confirmed that this visually induced activation depends on the writing hand (Longcamp et al. 2005).

1.3 Writing versus Typing

The haptics of handwriting is very important when it comes to learn and recognize new letters. Nowadays, most of our writing however is done with digital writing devices, which entails major differences in the haptics of writing. Handwriting is by essence a unimanual activity, whereas typewriting is bimanual: primarily it requires both hands. Handwriting is also a slower process than typewriting. During handwriting, the visual attention of the writer is strongly concentrated; the attentional focus of the writer is dedicated to the tip of the pen, while during typewriting the visual attention is detached from the haptic input, namely the process of hitting the keys. But the major difference between handwriting and typewriting is the way the characters are being produced. Handwriting has a graphomotor component where the writer has to produce the shape of the letter by completing the trajectory of the letter with his hand, resembling as much as possible the standard shape of the specific letter. Typewriting lacks a graphomotor component; instead the writer has to locate the specific letter on the keyboard (Mangen & Velay, 2010).

A large body of data supports the view that haptics play a crucial role in learning. Longcamp et al. (2005a) conducted a research about the role of movement in letter representation and suggest that handwriting contributes to the visual recognition of letters. Because of the difference in haptics between writing and typing, changing the motor conditions while children are learning to write by using a method based on typing instead of handwriting should affect their subsequent letter recognition performances. In order to test this hypothesis, they trained two groups of 38 children (aged 3–5 years) to copy letters of the alphabet either by hand or by typing them. After three weeks of learning, they ran two recognition tests, one week apart, to compare the letter recognition performances of the two groups. The results showed that in the older children, the handwriting training gave rise to a better letter recognition than the typing training.

Other studies have examined whether the graphic movements involved in tracing or writing may enhance the cognitive processes involved in the acquisition of reading skills. Cunningham & Stanovich (1990) compared in their study the respective advantage of learning by handwriting versus typewriting. They used a technique where children would learn the words by repeating a word spoken and written for them, writing the word while pronouncing the name of each letter, and then repeating the whole word again. In the experiments the motoric element was manipulated by letting the children write the words down by hand, by typewriter or using letter tiles. The results indicated that having first-grade children write words leads to better spelling performance than having the children type them on a computer or manipulate letter tiles to spell them. Particularly impressive was the fact that handwriting maintained its superiority under conditions strongly biased against it: the spelling of the learned words was assessed using the computer or the tiles, not by writing the words down by hand. So, the tile- and computer-training conditions were tested under conditions similar to those under which they were taught, but no words in the handwriting condition were tested in a manner similar to the writing training. However, handwriting maintained a significant superiority over the other two conditions (Cunningham & Stanovich, 1990).

1.4 Learning a Second Language

Researchers agree that in the process of acquiring a second language, the learning of vocabulary is very important (Allen, 1983; Laufer, 1986). However, for a long time researchers paid little attention to the different aspects of vocabulary learning. Issues such as the conceptualization of the process by which vocabulary acquisition occurs, the importance of context use or the extent to which a learner develops certain strategies for vocabulary acquisition were neglected (Lawson & Hogben, 1996). Therefore, Lawson and Hogben (1996) have conducted a series of experiments to gain information on these issues. In their study, 15 foreign language students were given several sentences in Italian language with one word unknown to them. The students had access to the dictionary and were asked to think about how they attempted to memorize the meaning of the word. Different techniques were used: simple rehearsal, reading of related words, cumulative rehearsal but also writing the word down. The great majority of these techniques all involved some form of repetition. This is not surprising, because to learn vocabulary the brain has to create the associations to build up a coherent representation of objects (Martin, Ungerleider & Haxby, 2000). As stated before, the more input, the stronger the underlying neural connections and the stronger the memory performance.

In the study of Lawson and Hogben (1996), one of the techniques to memorize the meaning of a word was to write it down. It is known that writing has a positive effect on integration of foreign words in memory. Thomas and Dieter (1987) conducted a study already in 1987 in which subjects had to write foreign words down using pen and paper. During the learning phase, each French word and its English equivalent appeared on a screen for 10 seconds. Each pair was shown a total of three times. As each pair was presented, subjects in the writing-practice groups were instructed to copy each French word twice. Thus, in these groups, subjects wrote each French word a total of six times. Copying the French words proved to be quite helpful in fostering written recall. Writing practice enhanced written recall of the foreign words significantly in comparison to the non-writing group.

1.5 The Involvement Load Theory

In a recent study, Pichette, De Serres and Lafontaine (2011) compared the relative effectiveness of reading and writing sentences for the incidental acquisition of new vocabulary in a second language. Subjects had to learn the meaning of an unknown word by its context in the sentence. In one condition the participants had to write the sentence down, in the second condition the participants simply had to read the sentence. Results from immediate recall showed superior recall for writing tasks over reading tasks. The researchers contribute this effect to the Involvement Load Theory: the effectiveness of a language learning task rests on the involvement load of a task, that is the amount of need, search, and evaluation it imposes (Hulstijn & Laufer, 2001). Generally, writing a text may lead to significantly higher recall than reading it if enough time is allocated for each task, writing being intrinsically longer than reading for the same amount of language (Pichette et al., 2011). More time for the brain means it can strengthen the neural connections more thoroughly, improving the memory performance.

The Involvement Load Theory proposes that time is an important factor when investigating the effects of writing on learning. This corresponds with the results of an earlier study from Webb (2005). He investigated the effects of receptive and productive vocabulary learning on word knowledge. Receptive learning is being defined as learning by reading or listening, for instance looking up words in a dictionary, matching words with their meanings or definitions or learning word pairs (Webb, 2005). Productive activities are for example cloze exercises or writing tasks. In two experiments, Japanese students studying English as a foreign language learned target words by either a receptive or a productive activity. The first experiment showed that, when the same amount of time was spent on both tasks, the reading task was superior. The second experiment showed that, when the allotted time on tasks depends on the amount of time needed for completion, with the writing task requiring more time, the writing task was more effective. The researcher concludes that the second experiment represents a more authentic learning, so a stronger argument could be made to use productive vocabulary learning tasks over receptive tasks.

Where the studies from Webb (2005) and Pichette et al. (2011) contribute the observed effects to the Involvement Load Theory, Thomas and Dieter (1987), Cunningham & Stanovich (1990) and Longcamp et al., (2005a) contribute their observed effects to the haptics of writing. The difference in results between these studies could be explained by the difference in experimental design. There is a difference if a student has to write down a complete sentence (Webb, 2005; Pichette et al., 2011) or only the target word itself (Thomas and Dieter, 1987). Creating a sentence with a target word and write that entire sentence down (Webb, 2005) or understand the meaning of the word out of the context of the entire sentence and duplicate that sentence (Pichette et al., 2011), asks for a different attentional focus and processing of the brain than when the brain can purely focus on the target word itself by handwriting only the target word (Thomas and Dieter,1987; Cunningham & Stanovich ,1990; Longcamp et al., 2005a). Secondly, Webb (2005) found that during experiment 1, both groups were given the same amount of time to complete their tasks, but although some learners struggled to finish the writing task on time, learners form the receptive group had ample time to finish the reading task. This means that time is an import issue to take into consideration when designing an experiment

1.6 Hypotheses

Based on the studies discussed, when learning new vocabulary of a second language, writing the words seems to be a better way of learning compared to only reading them due to the combination of the visual component with the haptics. Because nowadays often digital devices are used to write, it is interesting to investigate if the difference of haptics between the pen and paper and the keyboard and screen will result in a difference in recall when learning new words. Therefore, this study will aim to give an answer to this research question: What is the effect of the haptics of writing on second language vocabulary learning?

Previous studies to the effect of writing on language learning found that handwriting practice enhanced recall of new words significantly in comparison to reading practice (Pichette et al., 2011; Thomas & Dieter, 1987). Therefore, the first hypothesis can be formulated:

H1. Vocabulary learning using handwriting gives a higher recall than learning vocabulary by reading.

To learn vocabulary, the brain has to create associations to build up a coherent representation of objects (Martin, Ungerleider & Haxby, 2000). The more input, the stronger the underlying neural connections and the stronger the memory performance. When typing a word, not only the visual component from reading the word is activated but also the motor action part. This means a broader input and therefore creating possibly stronger cognitive neural connections when learning. Being confronted with a learned word afterwards could possibly activate the premotor zone again in the brain, similar to studies on handwriting handwriting where subjects showed motor activation while looking at ideograms or Roman characters (Matsuo et al, 2001; Longcamp et al., 2003). The activation of the motor part would function as an extra cue to retrieve the learned information from memory and enhance the recall. Therefore, the second hypothesis would be:

H2. Vocabulary learning using typewriting gives a higher recall than learning vocabulary by reading.

Cunningham & Stanovich (1990) proved that handwriting words leads to better spelling performances than having children type them on a computer. Longcamp et al. (2005a) showed that handwriting training gave rise to a better letter recognition than the typing training. This suggests that handwriting creates stronger neural connection and visual representation of a word compared to typing. The third hypothesis is therefore:

H3. Learning new words using handwriting gives a higher recall than learning new words by typewriting.

2. Method

2.1 Participants

Seventy-eight Dutch students from Tilburg University (21 male and 57 female) took part in this study. The mean age of the students was 21.27 years (SD = 2.28) and the ages ranged from 18 to 27 years old. They all were gathered using the ‘pool of subjects’ from Tilburg University, a mandatory group in which students receive credit for taking part in studies.

2.2 Experimental design

The experiment had a between group design with three conditions: a control condition and two experimental conditions that both involved a type of motor activity (writing or typing). In every condition, participants had to learn forty word pairs. Every word pair consisted of a Dutch word paired with a made-up word. The participants had to memorize these word pairs from the screen. In the control condition, the reading condition, the participants had to read the word pairs and learn them from the screen. In the writing condition they had to write the made-up word using pen and paper. In the typing condition, they had to type the word using a laptop. After the experiment, participants received a test to check how many words they remembered which resulted in an accuracy score for every participant: the number of correct answers divided by the total test items. The elements of reading, writing and typing are the independent variables. The accuracy is the dependent variable.

2.3 Experimental Material

Forty Dutch target words were used in this experiment: 24 nouns and 16 verbs. This ratio was used because nouns and verbs are the most common parts of speech found in natural text; the 6:4 ration approximates their proportional frequency of occurrence (Kucera & Francis, 1967). All of the target words were taken from the book ‘A frequency Dictionary of Dutch’. This dictionary lists the 5000 most frequently used words in Dutch drawn from a corpus of more than 100 million words. The corpus includes written and spoken material from a wide range of sources. Throughout the dictionary, the language is contemporary, spanning the past forty years and concentrating on the last twenty years. These words were used assuming that every participant in the experiment would know the Dutch word. The words have been chosen randomly but carefully, to ensure they did not resemble each other.

The target words were paired with forty made-up words to ensure that the learners had no prior knowledge of these words or recognized words from existing languages (Appendix A). The made-up words were created with the website wordoid.com. According to this website, a wordoid is a word that is made-up but sounds right. It follows the rules of phonetics and therefore sounds and looks like a real word (“wordoid”, n.d.). The word generator has three parameters: language, quality and length. Firstly, the website allows to generate made-up words constructed according to the rules of an existing language,either English, Spanish, French, Italian or German. Because the participants were Dutch students, the language parameter was set for Spanish because this is the language most likely unknown for them. The quality parameter defined how the made-up words would look, sound and feel. This was set for the highest quality so they would resemble the most natural words. The lenght parameter permits the user to put a limit on the number of letters of the word. In a recent study from Emelianova (2013), subjects had to learn twenty word pairs, consisting of English words paired with made-up words. She had generated made-up words limited to two or three syllables, for the purpose of not overcomplicating the task of memorizing. However, after analysing the results of the study she concluded that these made-up words used in her experiment could be more complicated and longer, since a significant number of participants managed to memorize the maximum number of words. Therefore, to make the task of memorizing more complicated for this study, words were generated with a maximum of ten letters, creating words with three to four syllables.

The word pairs were showed to the subjects by a PowerPoint presentation. This offered the possibility to create a fully automatic process of showing the words to the subject, ensuring every subject saw every word pair the same amount of time. To prevent a possible effect on the learning of words caused by the order of the words, three wordlists were created containing the same word pairs but in a different order. This way every participant could randomly receive one out of the three wordlists.

2.4 Pre-test

Although the created made-up words do not exist and have never been seen before by the subjects, it might be possible that these words still evoke certain associations with the reader. The existence of these possible associations could influence the procedure of learning words during the experiment. To ensure that these forty made-up words would not evoke any associations with the Dutch counterpart words ten participants, who did not partake in the final experiment, were asked to write down their associations with the forty words. The made-up words did not create any consistent associations with the counterpart words in Dutch.

Next, a pilot of the experiment was carried out with five subjects, who did not partake in the word-association test as mentioned above nor in the actual experiment. In this pilot twenty-five word pairs were used, based on the amount of word pairs used in similar vocabulary learning studies such as Emelianova (2013) and Thomas and Dieter (1987), and the amount of time each word was shown to the subject was set on ten seconds. The pilot showed however that these ten seconds were too short. Thirteen seconds was the appropriate time needed to handwrite a word two times. Also, the subjects found the amount of twenty-five word pairs pretty easy. Therefore, all forty word pairs were used for the actual experiment. Finally, the pilot revealed that the visualization of the test needed to change. The questions and answer possibilities were all provided on one webpage. Some subjects were comparing questions and answer possibilities while making the test, therefore being able to rule out certain answers on questions they did not know.

2.5 Procedure

Every participant was given a seat behind a computer screen. They filled in the consent form (Appendix B) after which they could start reading the instructions of the experiment on the screen (Appendix C). Depending on the condition the participants were assigned to, there was also pen and paper or a laptop in front of the computer screen for them to either write or type along. In all conditions, the participants were instructed to learn the word pairs shown on the computer screen. In the two writing conditions, the instruction was added that the made-up word had to be written down twice when a word pair was showed. In the writing condition, the participant received the instruction to write down the words two times and then flipped the notebook to the next page so they faced a blank page again. In the typing condition, the participants had the instruction to type the words two times on the laptop and then push on the button ‘enter’ so that the laptop screen became blank again. If there were no questions from the participant after reading the instructions the experimenter started the showing of the word pairs.

A total of forty word pairs were shown two times with an interval in between. Each word pair appeared on the screen for thirteen seconds, preceded by a blank screen for two seconds. After all forty word pairs were shown a blank screen appeared for thirty seconds. After that, the forty word pairs were shown again, in the same way and order as the first cycle. The showing of the word pairs was fully automatic and took exactly 20 minutes.

Immediately after the learning phase, the experimenter took away the pen and paper or laptop and the participant received the online test on the computer screen to check how many words they remembered. To measure the recall of the memorized word pairs, a multiple-choice test was constructed using the website www.classmarker.com. In this test the subjects needed to choose the meaning of the Dutch word from four made-up words. The website offered the possibility to randomize the order of the questions and possible answers. This ensured that every subject received a different test with regard to the order of the questions and answers. The subjects could only answer one question at a time. When answered, the question disappeared and a new one appeared. There was no option to go back to a previous question. Offering one question at a time ensured that subjects did not start to compare questions and answers, therefore possibly being able to rule out certain answers. After completing the test the experiment was finished and the participants were being thanked for their participation.

3. Results

The test made by the subjects after the experiment resulted in a test score for every participant. This test score is defined as the number of correct answers on the test. For every condition, a mean accuracy was calculated based on the test score dividing the number of correct answers by the total test items, in this case forty. The dependent variable accuracy is used to test the three hypotheses. The first hypothesis tested was: “Learning new words using handwriting gives a higher recall than learning new words by reading.” The accuracy of the handwriting condition was compared with the accuracy of the reading condition and statistically tested for a significant difference. For the second hypothesis: “Learning new words using typewriting gives a higher recall than learning new words by reading”, the accuracy of the typewriting condition was compared with the accuracy of the reading condition and statistically tested for a significant difference. For the third hypothesis: “Learning new words using handwriting gives a higher recall than learning new words by typewriting”, the accuracy of the handwriting condition was compared with the accuracy of the typewriting condition and statistically tested for a significant difference.

Before being able to compare the accuracy between the three conditions, the characteristics of the data had to be inspected. As a first step, the data was checked for possible outliers. Generating a boxplot revealed there were no significant outliers in the data, as seen in figure 1.

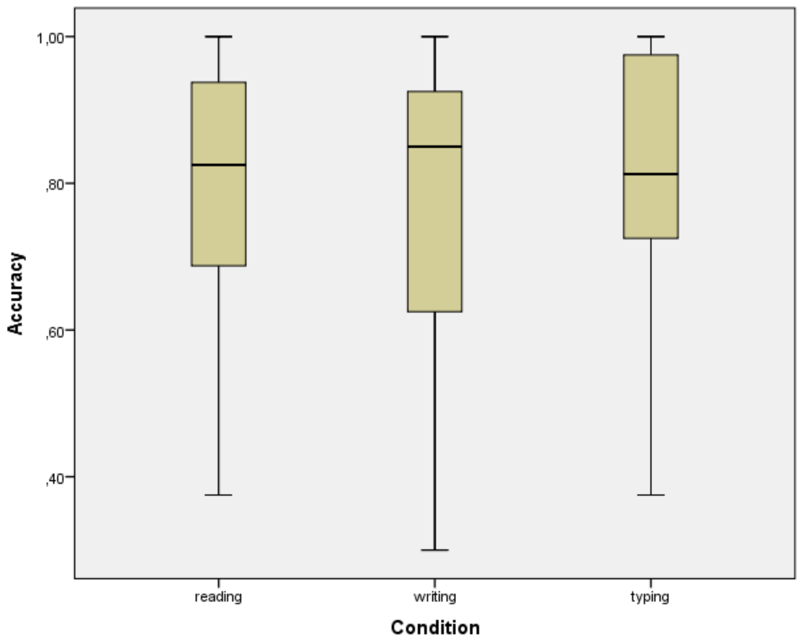

Figure 1: A box plot of the Accuracy in the three conditions

To check the homogeneity of variance, the Levene's test showed that the variances are not significantly different and the homogenetiy of variances assumption is tenable ($F(1,75) = .82$, $p = .45$). To assess the normality of the data, the accuracy for every condition was plotted in a histogram. Figure 2 shows for every condition how the accuracy is distributed.

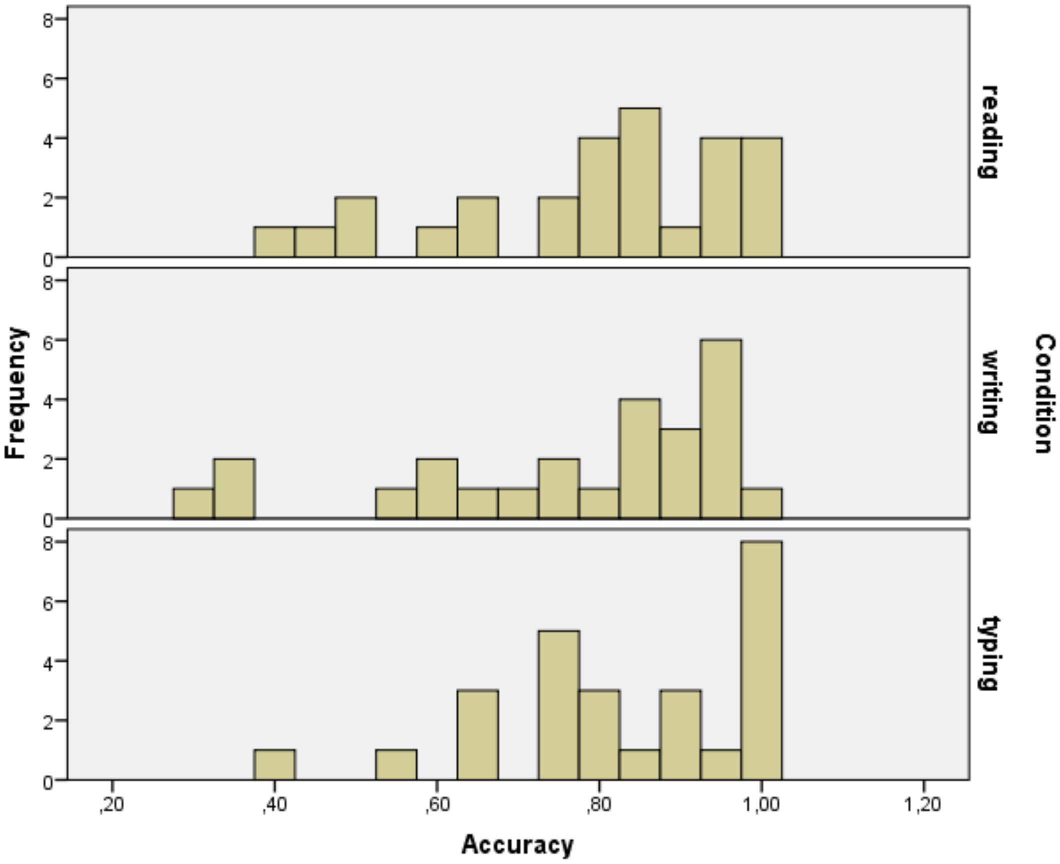

Figure 2: Distribution of the test scores in the three conditions

A visual inspection of figure 2 gives the impression that the data in all three conditions were not normally distributed. The Shapiro-Wilk test revealed that the data indeed was not normally distributed because all three conditions, reading ($p = .02$), writing ($p = .00$) and typing ($p = .03$), significantly deviated from a normal data distribution. This means the assumption of normal data is violated and a non-parametic test had to be chosen to analyse the data.

Table 1 shows the results of the test made by the subjects. It displays the mean test scores, representing the number of correct answers on the test, and mean accuracy per condition. The accuracy is defined here as the number of correct answers divided by the total test items, in this case forty. The results are displayed per group and per sex.

Table 1

Test Score and Accuracy per Group and per Sex

			Test Score		Accuracy	
Group	Sex	N	Mean	SD	Mean	SD
Reading	Man	13	31.23	8.00	.78	.20
	Woman	14	31.43	6.98	.79	.17
	Total	27	31.33	7.34	.78	.18
Writing	Man	7	27.14	10.40	.68	.26
	Woman	18	31.72	7.21	.79	.18
	Total	25	30.44	8.26	.76	.21
Typing	Man	1	29.00	-	.73	-
	Woman	26	32.80	6.57	.82	.16
	Total	27	32.65	6.48	.82	.16

Note: the test score is on a scale from 0 to 40, 0 being the minimum and 40 being the maximum score. The accuracy is on a scale from 0 to 1, 0 being minimum and 1 being maximum accurate.

In order to compare the accuracy of the three conditions with each other to test the hypotheses, the nonparametric Kruskal-Wallis test was used to statistically analyse the data. It showed that there was not a statistically significant difference in accuracy among the three conditions, $\chi^2(2) = .798$, $p = .671$, with a mean rank test score of 39.06 for reading, 36.88 for writing and 42.48 for typing. This means that for the variable accuracy neither between handwriting and reading, typewriting and reading or handwriting and typewriting a statistically significant difference was found. Because there was no statistically significant difference found among the three conditions, it was not possible in SPSS to create a post-hoc analysis to make a pairwise comparison between the three conditions and calculate the *p*-value for every comparison. This is also not really necessary, because the Kruska-Wallis test revealed that there is no significant difference in accuracy among the three conditions whatsoever. This means the three hypotheses have to be rejected.

4. Discussion

Previous studies on language learning in relation to writing and typing found that sensorimotor activation plays a big role in learning. For instance, Longcamp et al. (2005a) showed that handwriting training by older children gave rise to a better letter recognition. Cunningham & Stanovich (1990) proved that handwriting words leads to better spelling performances than having children type them on a computer. Pichette et al. (2011) found that writing sentences to learn the meaning of unknown words had a superior recall over reading tasks. Thomas and Dieter (1987) proved that writing practice enhanced written recall of the foreign words significantly in comparison to the non-writing group. They all indicate that the combination of tactile perception associated with active movements, called haptics, can be an important factor in language learning. However, although most of our writing is done nowadays with digital writing devices which entail major differences in haptics compared to handwriting, little is known about the possible effect of typing on language learning.

The aim of this study was to determine whether the difference in haptics between writing by hand or by keyboard had an effect in the memorizing of words, a vital element in learning a second language. Based on previous research three hypotheses were formulated. The first hypothesis was that vocabulary learning using handwriting would give a higher recall than learning vocabulary by reading. The second hypothesis was that vocabulary learning using typewriting would give a higher recall than learning vocabulary by reading. The third hypothesis was that the use of handwriting would give a higher recall when used to learn new words in comparison to typewriting. However, no significant differences were found. This can be explained by several causes.

Firstly, in this study, only the immediate recall is measured. It is possible that measuring the long-term recall generate different results. In a study from Longcamp, Boucard, Gilhodes and Velay (2006) adult participants were trained to write new characters either by handwriting them or by typing them on a keyboard. After a training period, tests were ran requiring visual recognition of the correct character. Results showed that when the characters had been learned by handwriting, they were more frequently correctly identified then when they had been learned by typing. This handwriting advantage however did not appear immediately, but mostly three weeks after the end of the training (Longcamp et al., 2006). This suggests that the difference in haptic is responsible for a different level of processing. With sufficient practice, the internal model of a new motor skill gradually becomes less fragile and this consolidation is accompanied by changes in the neural representation of motor memory (Penhune & Doyon, 2002; Shadmehr & Holcomb, 1997; from Longcamp et al, 2006). Once it has been thoroughly learned and stabilized, motor memory can last for very long periods of time without any further practice (Shadmehr & Brashers-Krug, 1997). Considering that the subjects in this study immediately after the training period of twenty minutes were tested it is safe to say that the motor memory was presumably not yet consolidated, and memorizing relied mainly on the visual memory created by reading instead of writing or typing.

The findings of Thomas and Dieter (1987) that handwriting practice enhanced written recall of the foreign words significantly in comparison to the non-writing group, is a result not replicated in this study. A possible explanation for this is the fact that, similar to other studies (Cunningham & Stanovich, 1990; Pichette et al., 2011; Webb, 2005) they tested the subjects using handwritten tests instead of a multiple-choice test. This means that the subjects had to write the answer instead of choosing it out of four answer possibilities. Writing an answer using pencil and paper involves motor action retrieved from motor memory. Because the words were learned using pen and paper, the motor memory was trained as well. So in this case, writing the answers might have given an advantage because motor memory was involved. A multiple-choice test lacks this advantage, because choosing out of four given possibilities probably requires more of the visual memory than the motor memory. It could be objected that the training of motor memory requires some time to become fully consolidated. This effect could have been increased due to the fact that Thomas & Dieter (1987) presented target words both visually and orally. As such, word writing may have enabled participants to attend to sound-to-sound spelling correspondences in a manner that was more beneficial to encoding the new forms (Barcroft, 2006).

It is possible that the design of the experiment was not sufficient or too limited to measure the effect. For example, the experiment might not have been complicated enough, since the test scores were very high. Nine participants managed to memorize the maximum of forty words, four participants memorized thirty-nine words and seven participants memorized thirty-eight words. This means that 25% of the participants managed to memorize almost every word. Adapting the experiment using longer words or more words could increase the difficulty to memorize the words, thereby increasing the possible effect of writing and typing on the learning ability. The complexity of the experiment can also be increased by altering the mechanics of the execution of the experiment. For example, the number of training cycles can be limited to one instead of two. However, this means that the participants perform less motoric action, potentially harming the effect that is investigated.

The amount of time that a word was visible to the subject could also be a factor that made it difficult to study the effect of haptic on learning. Although the pre-test showed that thirteen seconds was the limited time needed to handwrite a word two times, this time might have overshadowed the possible effect of the haptic. To read a word takes less time than to write or type a word. The Involvement Load Theory states that the effectiveness of a language learning task rests on the involvement load of a task. In comparison to reading, the task of writing and typing has a much higher involvement load demanding more involvement and effort of the subject. This means that normally a subject might spend less time learning a word by reading it instead of also typing or writing it, because reading demands less effort (Webb, 2005). Because the subject in this experiment cannot decide how long he is exposed to a word, the subject will read the word more times than normally necessary, thereby exceeding the involvement load creating an overcompensating effect of reading which glozes over the haptic effect of writing and typing. It becomes very difficult to attribute a found result to either the difference of haptics, or simply because there was relatively more time available for reading.

Finally, the characteristics of the participants impede the generalizability of this study's findings as well. For instance, all subjects were university students. This means that they are well educated and, in general, fast and easy learners. They all were students of Communication and Information sciences, a study which also focus on subjects like text design, comprehension and understanding. Therefore, it is possible that the participants used in this study, due to their high level of education and possibly affiliation with text and language, are better in word learning than generally be assumed.

5. Conclusion

The underlying research question of this study was: What is the effect of the haptics of writing on second language vocabulary learning? This has been investigated by experimenting if the difference in haptics between handwriting and typing had a significant effect on the memorizing of word pairs. The expectation was that writing, both handwriting and typing, would improve the learning process when compared to reading. However, the present results show no significant differences in accuracy between the conditions of reading, writing and typing, indicating that writing or typing does not have any effect on memorizing word pairs. This means that, when it comes to memorizing word pairs in a given amount of time, it apparently does not matter for the result if the word pairs are learned by reading or also with the help of handwriting or typing. Therefore, the answer on the research question seems to be: The haptics of writing has no effect on second language vocabulary learning.

The answer as formulated above however, only applies if certain conditions are met. As Cunningham and Stanovich (1990) states, the unique strength of an experiment is its isolation of a variable for study and removal of the confounding complexities of the natural environment. This however, can also be a limitation. The present results of this study indicates no effect from writing on learning, but only when it comes to memorizing word pairs, in a given amount of time, measuring the immediate recall. The results contradict with earlier research (Thomas & Dieter, 1987; Pichette et al., 2011) therefore providing new possibilities to explore for future research. For instance, the haptics of handwriting and typing may have an effect on learning over a longer period of time. Another possibility is to explore if the difference in haptics could have an effect on learning for subjects who find it difficult to learn a language. Either way, it is imperative that future research will increase their focus on the role of the physically tangible writing device. Because the technology growing at an ever-increasing rate, the ways of writing is changing as well. Further research is necessary to become aware and understand the implications of this change in haptics on our way of learning.

References

Anderson, S. W., Damasio, A. R., & Damasio, H. (1990). Troubled letters but not numbers: Domain specific cognitive impairments following focal damage in frontal cortex. Brain, 113, 749–766.

Allen, V.F. (1983). Techniques in teaching vocabulary. New York: *Oxford University Press.*

Barcroft, J. (2006). Can writing a new word detract from learning it? More negative effects of forced output during vocabulary learning. *Second Language Research*, *22*(4), 487-497.

Bartolomeo, P., Bachoud-Le ́vi, A.-C., Chokron, S., & Degos, J.-D. (2002). Visually- and motor-based knowledge of letters: Evidence from a pure alexic patient. Neuropsychologia, 40, 1363–1371.

Barsalou, L. W. (1999). Perceptual symbol systems. The Behavioral and Brain Sciences, 22, 577–660.

Barsalou, L. W. (2010). Grounded cognition: Past, present, and future. Topics in Cognitive Science, 2, 716–724.

Chao, L. L., & Martin, A. (2000). Representation of manipulable man-made objects in the dorsal stream. NeuroImage, 12, 478–484.

Cunningham, A. E., & Stanovich, K. E. (1990). Early spelling acquisition: Writing beats the computer. Journal of Educational Psychology, 82, 159–162.

de Koning, B. B., & Tabbers, H. K. (2011). Facilitating understanding of movements in dynamic visualizations: An embodied perspective. *Educational Psychology Review*, *23*(4), 501-521.

Emelianova, M. (2013). *The effect of kinaesthetic stimuli on the learning words in the second language.* (Master's thesis, Tilburg University, The Netherlands). Retrieved from http://arno.uvt.nl/show.cgi?fid=130886.

Fischer, M. H., & Zwaan, R. A. (2008). Embodied language: a review of the role of the motor system in language comprehension. *The Quarterly Journal of Experimental Psychology*, *61*(6), 825-850.

Flores d'Arcais, G. B. (1994). Order of strokes writing as a cue for retrieval in reading Chinese characters. European Journal of Cognitive Psychology, 6, 337–355.

Fogassi, L., & Gallese, V. (2004). Action as a binding key to multisensory integration. *The handboock of multisensory processes. MIT Press, Cambridge*, 425-441.

Glenberg, A. M. (1997). What memory is for. The Behavioral and Brain Sciences, 2, 1–55.

Glenberg, A. M., & Kaschak, M. P. (2002). Grounding language in action. Psychonomic Bulletin and Review, 9, 558–565.

Glenberg, A. M., Sato, M., Cattaneo, L., Riggio, L., Palumbo, D., & Buccino, G. (2008). Processing abstract language modulates motor system activity. Quarterly Journal of Experimental Psychology, 61, 905–919.

Goodwyn, S. W., Acredolo, L. P., & Brown, C. A. (2000). Impact of symbolic gesturing on early language development. *Journal of Nonverbal behavior*, *24*(2), 81-103.

Hulstijn, J. H., & Laufer, B. (2001). Some empirical evidence for the involvement load hypothesis in vocabulary acquisition. *Language learning*, *51*(3), 539-558

James, K. H., & Gauthier, I. (2006). Letter processing automatically recruits a sensory–motor brain network. *Neuropsychologia*, *44*(14), 2937-2949.

Kato, C., Isoda, H., Takehara, Y., Matsuo, K., Moriya, T., & Nakai, T. (1999). Involvement of motor cortices in retrieval of kanji studied by functional MRI. *Neuroreport*, *10*(6), 1335-1339.

Kucera, H+, & Francis, W. N. (1967) *A computational analysis of present-day American English.* Providence, RI: Brown University Press.

Lakoff, G., & Johnson, M. (2008). *Metaphors we live by*. University of Chicago press.

Laufer, B. (1986). Possible changes in attitude towards vocabulary acquisition research. *IRAL. International review of applied linguistics in language teaching*, *24*(1), 69-75.

Lawson, M. J., & Hogben, D. (1996). The vocabulary learning strategies of foreign language students. *Language learning*, *46*(1), 101-135.

Longcamp, M., Anton, J. L., Roth, M., & Velay, J. L. (2003). Visual presentation of single letters activates a premotor area involved in writing. *Neuroimage*, *19*(4), 1492-1500.

Longcamp, M., Anton, J. L., Roth, M., & Velay, J. L. (2005). Premotor activations in response to visually presented single letters depend on the hand used to write: a study on left-handers. *Neuropsychologia*, *43*(12), 1801-1809.

Longcamp, M., Zerbato-Poudou, M. T., & Velay, J. L. (2005a). The influence of writing practice on letter recognition in preschool children: A comparison between handwriting and typing. *Acta psychologica*, *119*(1), 67-79.

Longcamp, M., Boucard, C., Gilhodes, J. C., & Velay, J. L. (2006). Remembering the orientation of newly learned characters depends on the associated writing knowledge: A comparison between handwriting and typing. *Human Movement Science*, *25*(4), 646-656.

Mangen, A., & Velay, J. L. (2010). Digitizing literacy: reflections on the haptics of writing. Zadeh MH (Ed.), *Advances in Haptics*, 385-401

Martin, A., Ungerleider, L. G., & Haxby, J. V. (2000). Category specificity and the brain: The sensory/motor model of semantic representations of objects. *The new cognitive neurosciences*, *2*, 1023-1036.

Matsuo, K., Kato, C., Okada, T., Moriya, T., Glover, G. H., & Nakai, T. (2003). Finger movements lighten neural loads in the recognition of ideographic characters. *Cognitive Brain Research*, *17*(2), 263-272.

Mueller, P. A., & Oppenheimer, D. M. (2014). The Pen Is Mightier Than the Keyboard Advantages of Longhand Over Laptop Note Taking. *Psychological science*, 0956797614524581.

Penhune, V. B., & Doyon, J. (2002). Dynamic cortical and subcortical networks in learning and delayed recall of timed motor sequences. Journal of Neuroscience, 22, 1397–1406.

Pichette, F., de Serres, L., & Lafontaine, M. (2011). Sentence reading and writing for second language vocabulary acquisition. *Applied Linguistics*, amr037.

Pulvermüller, F. (1999). Words in the brain's language. *Behavioral and brain sciences*, *22*(02), 253-279.

Seki, K., Yajima, M., & Sugishita, M. (1995). The efficacy of kinesthetic reading treatment for pure alexia. Neuropsychologia, 33, 595–609.

Shadmehr, R., & Brashers-Krug, T. (1997). Functional stages in the formation of human long-term motor memory. The Journal of Neuroscience, 17, 409–419.

Shadmehr, R., & Holcomb, H. H. (1997). Neural correlates of motor memory consolidation. Science, 277, 821–825.

Sirigu, A., Duhamel, J. R., & Poncet, M. (1991). The role of sensorimotor experience in object recognition: A case of multimodal agnosia. Brain, 114, 2555–2573.

Thomas, M. H., & Dieter, J. N. (1987). The positive effects of writing practice on integration of foreign words in memory. *Journal of Educational Psychology*, *79*(3), 249.

Thomas, L. E., & Lleras, A. (2009). Swinging into thought: Directed movement guides insight in problem solving. Psychonomic Bulletin & Review, 16, 719–723.

Van Galen, G. P. (1991). Handwriting: Issues for a psychomotor theory. *Human movement science*, *10*(2), 165-191.

Vinter, A., & Chartrel, E. (2008). Visual and proprioceptive recognition of cursive letters in young children. *Acta psychologica*, *129*(1), 147-156.

Webb, S. (2005). Receptive and productive vocabulary learning: The effects of reading and writing on word knowledge. *Studies in Second Language Acquisition*, *27*(01), 33-52.

Wordoid. (n.d.) Retrieved from http://www.wordoid.com

Wolf, M. (2008). *Proust and the squid: The story and science of the reading brain*. New York: HarperCollins

Zwaan, R. A. (1999). Embodied cognition, perceptual symbols, and situation models. Discourse Processes, 28, 81–88.

Appendix A: List of words

nr.	Dutch word	Made-up word	noun or verb	English word
1	hebben	armamente	verb	to have
2	jaar	mirasos	noun	year
3	liggen	santidades	verb	to lie
4	denken	sudamente	verb	to think
5	stad	estampocos	noun	city
6	kans	porcentral	noun	chance
7	verliezen	secuente	verb	to lose
8	persoon	indicos	noun	person
9	deur	canaron	noun	door
10	programma	bretarial	noun	program
11	vertrekken	ediciencia	verb	to leave
12	antwoord	tramon	noun	answer
13	schouder	coltaron	noun	shoulder
14	raam	colocal	noun	window
15	stoel	brujano	noun	chair
16	fluisteren	perdieras	verb	to whisper
17	wedstrijd	aquetes	noun	contest
18	minister	ageskog	noun	minister
19	paard	tambia	noun	horse
20	school	podiante	noun	school
21	vergeten	noviembres	verb	to forget
22	praten	combiando	verb	to talk
23	begrijpen	encruente	verb	to understand
24	leven	paquit	verb	to live
25	huis	pizar	noun	house
26	deksel	mozla	noun	lid
27	prikkelen	bucarabes	verb	to stimulate
28	zeep	rogeno	noun	soap
29	juichen	ciertener	verb	to cheer
30	blaffen	embajando	verb	to bark
31	maaltijd	hervencia	noun	dinner
32	vork	sorprensa	noun	fork
33	pistool	vallazgo	noun	pistol
34	worstelen	insitores	verb	to struggle
35	aanvoelen	mantia	verb	to feel
36	fluit	paraliados	noun	flute
37	duif	interos	noun	pigeon
38	asfalt	coronauta	noun	asphalt
39	masker	zapatizo	noun	mask
40	schommelen	poderan	verb	to swing

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Appendix B: Informed consent form

Informatie & Consentverklaring

Code: 30-11-2014
Titel: Woorden leren

Doel onderzoek: In dit onderzoek willen we weten hoe mensen woorden leren. Het onderzoek doorloopt verschillende fases. Je gaat eerst een opdracht uit te voeren waarin je een aantal woorden dient te leren. Vervolgens dient er een vragenlijst te worden ingevuld.

Duur onderzoek: Het onderzoek duurt ongeveer 30 minuten en je kunt er 0.5 proefpersoonuur mee verdienen.

Vertrouwelijkheid: Alle data die worden verzameld zullen hoogst vertrouwelijk behandeld worden. Jouw naam zal in geen enkel geval verbonden worden aan de resultaten.

Vrijwillige deelname: Je bent niet verplicht om aan dit onderzoek deel te nemen. Als je toestemt in deelname, kun je op elk moment je deelname aan het onderzoek opzeggen. Je bent niet verplicht om vragen te beantwoorden die je niet wilt beantwoorden.

Contact: Mocht je na afloop van dit onderzoek nog vragen hebben, dan kun je contact opnemen met Koen Luttels. Voor meer informatie over de richtlijnen waaraan onderzoeken dienen te voldoen, zie het proefpersonenreglement en de ethische richtlijnen onder Course Information van de Proefpersonenpool op Blackboard.

Toestemming

Ik heb de gelegenheid gehad deze Informatie & Consentverklaring te lezen en het onderzoek is aan mij uitgelegd. Ik heb de mogelijkheid gehad om vragen te stellen over het onderzoek en mijn vragen zijn beantwoord. Ik ben bereid om te participeren in het huidige onderzoek. Ik krijg een kopie van deze verklaring na ondertekening.

Ik verklaar daarnaast kennis genomen te hebben van het feit dat er geen informatie over de aard of het doel van het onderzoek verstrekt mag worden aan derden. Door ondertekening van dit document stem ik in met de geheimhoudingsplicht.

____________________________ Handtekening proefpersoon

______________________ Datum

____________________________ Naam proefpersoon

____________________________ Handtekening proefleider

______________________ Datum

Appendix C: Instruction example

(Example of written instruction, in this case the reading condition)

Welkom!

Fijn dat je mee wil doen aan dit experiment. Het experiment bestaat uit twee delen.

Als eerste krijg je zometeen twee keer 40 slides te zien. Op elke slide staat een woordpaar: een Nederlands woord met daarachter in het cursief de buitenlandse vertaling. Elke slide is zichtbaar voor 13 seconden. Hierna volgt 2 seconden rust, gevolgd door de volgende slide. Wanneer de 40 woordparen zijn getoond, volgt 30 seconden rust. Hierna volgen dezelfde 40 woordparen nog een keer op dezelfde manier.

De bedoeling is om de buitenlandse vertaling van het Nederlandse woord te leren. In het tweede deel krijg je namelijk een test: het Nederlandse woord wordt gegeven waarna jij de juiste buitenlandse vertaling moet kiezen.

Nu volgt eerst een voorbeeld hoe de slide met woordparen eruit ziet.

Wanneer het eerste woord verschijnt zullen de woorden elkaar automatisch opvolgen. Het is dus niet nodig om zelf te klikken. Tussen elke slide verschijnt gedurende 2 seconden een blank scherm zodat je je kan voorbereiden op het nieuwe woord.

Als je nog vragen hebt kun je deze nu stellen aan de experimentleider.

Als de test begint volgen eerst twee seconden een leeg scherm. Daarna zal het eerste woord verschijnen.
Succes!