4-25-2016

Examining the Role of Language Experience and Learning Strategies in Novel Language Learning using Eye-Tracking and ERPs

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Document Type
Thesis

Degree Name
Bachelor of Arts (BA)

Department or Program
Neuroscience

First Advisor
Naomi Wentworth

Second Advisor
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Third Advisor
Nicholas Wallin

Subject Categories
Neuroscience and Neurobiology

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Thesis Title: Examining the Role of Language Experience and Learning Strategies in Novel Language Learning using Eye-Tracking and ERPs

LAKE FOREST COLLEGE

Senior Thesis

Examining the Role of Language Experience and Learning Strategies in Novel Language Learning using Eye-Tracking and ERPs

by

Nylsa N. Mejia

April 25, 2016

The report of the investigation undertaken as a
Senior Thesis, to carry two courses of credit in
the Neuroscience Program

_____   _____
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Krebs Provost and Dean of the Faculty

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Abstract

Previous research has shown that multilinguals are more adept at learning new languages than monolinguals. Previous research also suggests that those who learn languages faster, especially when learning Chinese characters, may employ different learning strategies than slower learners. The current study examines how both factors -- language experience and learning strategies -- relate to students' success at mastering a set of Japanese kanji characters and their English translations. In contrast to previous studies, analysis of the N170 and N400 event-related brain potentials and the patterns of saccadic eye-tracking did not reveal differences between faster versus slower learners and monolinguals versus multilinguals. However, those who maintained the same learning strategy throughout the initial learning task performed better than those who did not.

Dedication

For those who came before me and those who will come ahead

Acknowledgments

I want to extend my thanks and gratitude to Professor Wentworth. Without her encouragement and support, I would not have made it this far. If not for her, I don't think I would have had the confidence to pursue what I wanted to do. Thank you for giving me the opportunity to learn and grow in ways I never thought I could.

Thanks to the members of Professor Wentworth's lab for helping me out wherever they could and for making my load a little lighter. Thanks to the rest of the members of my thesis committee – Dr. Wallin and Dr. Light – for their help.

Gracias a mi malle y a mi palle. Ustedes me han dado de todo. Gracias por su apoyo constante y todos sus sacrificios. Sin ustedes, nunca hubiera llegado a este punto en mi vida.

Last but not least, thank you to my friends and the rest of my family who encouraged and helped me drive forward whenever I felt like giving up. I might have written this, but without the constant support from everyone, none of this would have been possible.

Introduction

My study focused on how previous language experience factors into learning a new language. Despite the apparent ease with which babies acquire their first language, learning a language is actually a difficult task. Part of this difficulty comes from the multiple components that must be mastered. At a minimum, in order to be fully conversant, a person must master semantics (word meaning), articulation (pronunciation), syntax (grammar), and pragmatics (social conventions that guide speech). Given the complexity of the language-learning task, it seems reasonable to believe that the skills used to learn one language would transfer to the task of learning a second language. If so, individuals who have learned more than one language would have an advantage when it comes to learning subsequent languages. Thus, one hypothesis of this study was that individuals who are fluent in more than one language would outperform monolinguals on a task that involves learning a new language.

Although most children learn how to speak and understand at least one language, 11% of the worldwide youth population is illiterate (UNESCO Institute for Statistics, 2013), perhaps because reading adds an additional level of complexity to the language-learning task. In order to read, individuals need to map content from one system (e.g., spoken words) onto another system (i.e., the written symbols that signify the spoken words). It is possible that some individuals have more efficient strategies for learning how to accomplish this mapping. Thus, the second hypothesis was that individuals who are faster at learning how to map known words from one language onto the written words of a new language may do so by using different strategies to accomplish this task.

I will further explain the two main hypotheses of my study after I describe the elements that must be mastered in learning a language, discuss bilingualism and how

learning more than one language may affect cognitive processes, and explain two

measurement techniques (brain wave recording and saccadic eye tracking) that have been

used to study cognitive and linguistic processes.

Components of Language

In order to understand how language is processed, it is helpful to distinguish the

various aspects that make up a language. The smallest speech units that can be

perceptually distinguished are called phonemes (Weiten, 2013). It is believed that there

are as many as 47 phonemes in the English language, whereas other languages vary in

how many phonemes are used (Goldstein, 2014). In total, according to Weiten (2013),

there are thousands of phonemes that could possibly be understood but linguists say that

we can only recognize about 100 of them. No one language uses all of the possible

phonemes with the typical number used per language being between 20-80 (Weiten,

2103).

Phonemes can be combined to make another component of language called a

morpheme (Goldstein, 2014). Morphemes are the smallest units of meaning and are

basically root words and prefixes and suffixes such as dis- and -able. According to

Weiten (2013), there are about 50,000 of these morphemes in the English language.

These smaller morphemes can be combined to form bigger units (words) that give more

form to language.

In order to have a structured form of language, rules need to be in place to specify

how words are to be arranged in sentences, in other words, syntax. The set of rules and

how they operate defines the syntax of a language. Many different rules underlie how to

structure sentences and these rules can be different rules across languages. For example,

sentences in English, can be made up of one or several clauses that can be either

dependent or independent (Hacker, 2009). When attempting to classify sentence

structures on a broader level, three main categories of sentence structures arise: simple,

complex, and compound. Simple sentences consist of one independent clause and no

subordinate clauses ("The girl cried."). Complex sentences contain one independent

clause and at least one subordinate clause ("I did my homework, but my friends did

not."). A compound sentence contains two independent clauses that are usually joined

together with a comma and a coordinating conjunction ("The students went to the

museum, but they did not go to the restaurant."). A subset of the compound sentence is

the complex-compound sentence. Like a compound sentence, it must also include a

minimum of two independent clauses and at least one subordinate clause. An example of

this type of sentence would be, "Although I like to go shopping, I don't have any money,

and nothing is ever on sale". These main categories of sentence structure can be further

broken down to make sentences that are considered correct. Combining all these

structures of words and sentences, they can be used in real world situations like speaking

and comprehension.

When it comes to using languages in a real world context, semantics and

pragmatics come into place. The semantic meaning of a word is the literal meaning

without any other context. In contrast, the pragmatic meaning of a word or sentence

refers to the social context surrounding what is said or heard. In terms of pragmatics,

when addressing different people, different words or conjugations are used. Not using

them can be seen as impolite and sometimes disrespectful. For example, in some cultures

(e.g., Japanese), certain verb conjugations are used when talking to elders, which change

when referring to someone of a lower social status (Matsumoto, 1989). Matsumoto

(1989) informs that in Japanese, it is impossible to utter statements that are neutral in

social contexts. Being fluent in a language involves being able to distinguish the semantic meaning and pragmatic meaning of words, amongst other things.

Reading Languages

Part of the language learning process is learning how to read a language. Reading, however, can be a very challenging task. According to the National Assessment of Adult Literacy (NAAL), around 30 million Americans have below basic skills in prose literacy (NAAL, 2003). Many children are not able to read efficiently because of factors such as dyslexia. The reading disability in those with dyslexia is also seen at the cognitive level. For example, children and adults with dyslexia show impaired neural tuning for printed words (Eberhard & Maurer, 2015).

There are three main factors that go into learning to read an orthographic language such as English: decoding skills, visual processing, and writing (Bosse, 2015). Decoding skill, according to Bosse (2015), requires matching a grapheme (smallest unit of a writing system) to a phoneme or in other words, learning to map units of writing to units of speech. The ability to decode, according to Bosse (2015), is defined as the ease with which the orthographic form of a word can be learned. A repeated exposure to a written word in association with the spoken word establishes the connection between the written form and the spoken form. The more times this connection can be established, the better the association between the written and spoken form of a word. Jost, Eberhard-Moscicka, Frisch, Dellwo, and Maurer (2013) studied children in the 1st grade who were beginning to learn how to read. The researchers presented the children with German and English words that either matched in both the audio and visual presentation or did not. The study revealed that there were topographical brain differences in response to the matching audiovisual stimuli in comparison to the non-matching stimuli. Thus, the study

by Jost et al. provides experimental evidence for children having the ability to discern

when words matched in their audiovisual presentation and when the words did not.

Visual processing also plays a very important role in learning to read because it

involves decoding linguistic information using visual cues. Problems can arise with

visual processing for those attempting to read. For example, children with dyslexia, who

have poor visual processing abilities also have poor reading outcomes (Bosse, 2015). The

visual processing involved in reading has to process the entire word in order for the word

to be properly decoded. The third major factor in learning to read is writing. Writing

serves as a reinforcement for what is being learned during reading (Bosse, 2015). This is

most likely because writing requires the writer to process each individual letter

continually and this might be more engaging than just reading the word letter-by-letter.

These three main factors for reading (decoding skills, visual processing, and writing) are

applicable to all orthographic languages but differ slightly for logographic ones.

When it comes to reading in a logographic language, like Chinese, similar

cognitive cores for learning to read apply (McBride & Wang, 2015). One of these

cognitive cores is phonological sensitivity. Being sensitive to different levels of speech

sounds helps to indicate the ability in learning to read (McBride & Wang, 2015). Rapid

automatized naming (RAN) is another cognitive core. According to McBride and Wang

(2015), this task requires the rapid naming of written words and is a good indicator of

word recognition across languages. Skills in RAN are composed of both visual

processing of word forms and phonological access. These RAN skills can be slightly

more difficult in logographic languages like Chinese. The difficulty can arise when

assessing the kind of strokes that compose Chinese characters and rapidly naming what

the characters mean. A third cognitive core of reading Chinese is morphological

awareness. In Chinese, many words and syllables are pronounced identically so learners must be aware of the differences in the components of characters in order to disambiguate the meaning. This is done through the meaning of radicals in Chinese. Radicals inform the meaning of the character. Characters can have many radicals, some phonetic and some semantic. Readers must be aware of what kind of radicals they are seeing and be able to pull meaning and pronunciation from the character.

In summary, all of the different components of language show the big picture of what exactly makes up a language. These components must be learned to then be used in a real world setting, where languages are used. The language learning process can take time, with some later language learners unable to grasp all components that were previously discussed. The following section will cover different language milestones in children learning their first language.

Learning a New Language

The process of learning a first language typically follows a systematic sequence with predictable milestones. According to Weiten (2013), at first babies learn to distinguish between various phonemes which, as previously mentioned, are the smallest units of speech that can be perceived. The ability to distinguish between different phonemes throughout development follows a use-it-or-lose-it concept. That is, 3-month olds can distinguish phonemes from many different world languages, but when children reach the age of approximately one year, they can only perceive the phonemes used in the language they are learning to speak (Goldstein, 2014; Weiten, 2013). The ability to perceive phonemes used in the child's native language persists into their adulthood. A different developmental timeline is seen when it comes to the production of speech sounds.

According to Weiten (2013), during the first 6 months of age, children just cry, coo, and laugh. Then, from 6-18 months, they begin to babble and then proceed to do repetitive consonant vowel combinations ("lalalalala"). From 10-13 months, children start to utter sounds that resemble words. Across languages, children's first words are very similar in terms of their phonetic sound ("da"/"ba"). This is because they resemble syllables babies often babble spontaneously and those syllables happen to mean dad and mom in these languages, i.e., "da-da" being heard as "dad" in English.

As development continues, children start to remember words and produce some of them. According to Weiten (2013), children can produce about 30-50 words by the time they are 18 months old. However, they have a larger receptive vocabulary than a productive one. In other words, they understand more words than they can actually produce. The words that they do understand tend to refer to objects more than to social actions like, for example, knowing the word "toy" versus the word "hello". Children also learn nouns before verbs presumably because nouns are more concrete in meaning. At around 18 months, there is a vocabulary explosion or naming explosion once babies realize everything has a name. This is due to fast mapping, which allows children to learn around 20 words a week. According to Weiten (2013), fast mapping is when a word is learned and remembered after just one exposure event. The development in the ability to fast map might be due to articulation skills, understanding of syntax, or a combination of both says Weiten (2013). According to him, by 1st grade, children will have a vocabulary of 10,000 words and by 5th grade they know about 50,000 words (Weiten, 2013). Gaining this new vocabulary can come as a result of many influences, with one including children being read to by adults (Evans & Saint-Aubin, 2013). An eye movement study found that children who were read stories with images and low-frequency words were

able to make modest vocabulary gains, even though the children tended to focus on the

images a lot more than the print.

Although children make extraordinary progress in learning the very complicated

rules that govern language, their understanding is not always perfect. According to

Weiten (2013), children tend to make a lot of overextensions and underextensions. They

will use a word, like ball, to refer to round objects in general (overextension) or they will

use a word, like doll, to refer only to their favorite doll (underextension). When it comes

to combining words they know, children are able to do this by the end of their 2nd year.

They, however, do not do this perfectly. Children will use telegraphic speech where they

will omit nonessential words like articles and prepositions.

According to Weiten (2013), by the end of their 3rd year, children can express

complex ideas like plurals and past tense but they overregularize a lot. This means that

they incorrectly generalize grammatical rules to irregular cases where they do not apply.

This happens across different languages so it shows that they are attempting to master the

rules of their language. All of these stages of language development only pertain to the

mastering of a single language at childhood. Many children also learn another language

simultaneously or around the time they enter school. Depending at what age a new

language is learned, different processes will take place in order to attempt to master it.

Bilingualism

According to Weiten (2013), the definition of bilingualism is an acquisition of

two languages that use different speech sounds, vocabulary, and grammatical rules.

Because of this additional set of language rules that those who speak more than one

language possess, it would be logical to conclude that there would perhaps be differences

among those who can speak more than one language and those who cannot. Early studies

looked at bilingualism in children to see if knowing more than one language affected

their cognitive abilities (Weiten, 2013). Although these studies found that knowing a

second language negatively impacted language development, they were faulty because

bilingual children from their samples tended to come from impoverished homes

compared to the monolingual children, and the researchers made the bilingual children

take their IQ test in their 2nd language (Weiten, 2013). A more accurate picture portrays

both advantages and disadvantages of being bilingual (Weiten, 2013).

The disadvantage of knowing two languages is that bilinguals are slightly slower

at raw language processing speed and verbal fluency. This is because when they hear or

read in one language, there is cross-cultural interference since both L1 (native language)

and L2 (second language) processes are active. There is evidence that bilinguals, when

reading in their second language, have an increased difficulty in sentence wrap-up

compared to their monolinguals counterparts (Weber & Lavric, 2008). Some studies have

shown that bilinguals have a smaller vocabulary in each language when compared to

monolinguals but their total words are about the same or slightly better (Oller & Pearson,

2002).

According to a meta-analysis, some advantages of being bilingual are increased

attentional control, working memory capacity, metalinguistic awareness, and abstract

reasoning (Adesope, Lavin, Thompson, & Ungerleider, 2010). The increase of attentional

control in bilinguals might have something to do with the simultaneous activation of L1

and L2. Because of the higher amount of activation, the individual would need to

maximize control of their attention to avoid intrusions and distractions when producing

and understanding a language (Kuipers & Thierry, 2010). This increased attentional

control also keeps going into adulthood and may even protect against age-related

cognitive decline (Bialystok, Craik & Freedman, 2007).

A task used to study attentional control differences in bilinguals and monolinguals

is the language switch task (Verhoef, Roelofs, & Chwilla, 2010). This task involves

switching reading or speech production from one language to another. It might seem like

a fast process, especially to the individuals doing the language switch, but research has

shown that there is a time cost (Chauncey, Grainger, & Holcomb, 2010; Christoffels,

Ganushchak, & Koester, 2013; Jackson, Swainson, Mullin, Cunnington, & Jackson,

2004; Misra, Guo, Bobb, & Kroll, 2012, Verhoef et al., 2010). The time cost, or slower

performance, is a reflection of the switch in attention from one language to another.

Studies that measure language switch give pre-cues to signal to the participant what

language they should switch to. Giving pre-cues as signals to a stimulus was previously

developed to show how attention can be manipulated (Posner, 1980). Despite the

differences between language switching and spatial pre-cueing tasks, Verhoef et al.,

(2010) found that there are similar brain regions activated during both the language

switch task in bilinguals and those doing the spatial cueing task which is uninvolved in

language (Verhoef et al., 2010).

Although language switching might seem like a process that is equally time

consuming regardless of the direction of the switch (i.e., L1 to L2 or L2 to L1), a study

by Christoffels and colleagues (2013) suggests otherwise. A previously postulated theory,

the language asymmetry hypothesis, stated that switching from the L1 to the L2 is slower

when compared to L2 to L1 translation switching. Christoffels et al. (2013) used event-

related potentials, a derivative of the electroencephalogram to test the theory. Participants

with Dutch as their L1 and English as their L2 were given the task to switch in naming

the translation from Dutch to English and vice versa. Some of the words shown to the

participants, however, were interlingual homographs (i.e., words that are written the same

but have different meanings in different languages). The study revealed that the

interlingual homographs were translated at a slower rate than words written differently

and with different meaning in both languages and participants were prone to make more

errors in translation. The results of the study also did not provide support for the language

asymmetry hypothesis. Christofells et al. (2013) note that further interpretation of the

data supports the conclusion that the brain is able to distinguish early on (200 ms after the

target stimulus) what translation to go in and activate the meaning of the word shortly

thereafter (around 300 ms).

Not all bilinguals are created equal. Some have an earlier age of acquisition

(AoA), in other words, an earlier age that individuals begin to learn a language, while

others do not acquire a second language until they enter school (Hernandez, 2013).

Unfortunately, many studies that look into differences between bilinguals and

monolinguals do not take into account what *type* of bilinguals are recruited into the

samples. This lack of account could possibly introduce an unexpected confound to the

results acquired by these studies. Evidence of the importance of such confounds comes

from an ERP study that looked at how proficiency in a second language can affect

learning of new words (Elgort et al., 2014). Elgort et al. (2014) found that those with a

higher language proficiency in English L2 were better at contextual learning of rare

English words than those with lower language proficiency.

As previously discussed, being bilingual presents both advantages and

disadvantages to the speaker. Just as there are differences between bilinguals in terms of

how exposed they are to their L1 and L2, differences arise between bilinguals and

monolinguals, specifically in novel language learning (Abu-Rabia & Sanitsky, 2010; Kaushanskaya & Marian, 2009; Klein, 1995; Reder, et al., 2013). One study looked at students in junior high school who were learning English and knew either one language or multiple languages (Klein, 1995). The participants were tested on both their lexical learning and syntactic learning. The results revealed that those who were acquiring English as their third or fourth language outperformed participants who were acquiring English as their second language. This study, however, presented some tricky confounds since the participants, especially those in the multilingual groups, varied in what kind of languages they knew.

Another study took the hypothesis (i.e. individuals who have more language experience are better language learners) a step further by testing more aspects of language and controlling for what languages the participants already knew. Abu-Rabia and Sanitsky (2010) investigated the role of novel language learning in Hebrew monolinguals learning English and Russian/Hebrew bilinguals learning English. Both groups had been learning English for three years in school. In order to assess the students' proficiency in English and their respective languages, they were given tests that assessed their reading strategies, syntactic judgment, orthographic choice, orthographic knowledge, and phonological awareness, vocabulary, word reading, spelling, and reading comprehension. This study revealed that students who were bilingual in Russian and Hebrew were more proficient in English than their Hebrew monolingual counterparts.

Another study by Kaushanskaya and Marian (2009) also found similar results to the two previously mentioned. Participants in this study were either English monolinguals or English-Spanish bilinguals. Both groups were taught novel words that were similar to English orthographically but not phonologically. This study uncovered that bilinguals

outperformed the monolingual group in learning the artificial novel words. The studies by

Abu-Rabia et al. (2010), Kaushanskaya et al. (2009), and Klein (1995) looked at how

multilinguals were able to obtain a new language when compared to monolinguals but

differences between these two groups also arise when looking at language processing of

their L1. One such study looked at French monolinguals and French/German second

language learners and how they performed in different French language tasks (Reder et

al., 2013). The investigators defined their multilingual participants as second-language

learners (SLLs) instead of bilinguals because the participants began to learn German in

school instead of alongside their native language of French. All participants were in first

grade at the time of the study. Both groups completed phonological, morphological, and

syntactic awareness tasks. The results revealed that the SLLs outperformed monolinguals,

specifically on the language aspects of French that differed from German. This evidence

supports the claim that those who are bilingual have a better metalinguistic awareness,

i.e, are better aware of language as a code that can be dissected.

Two types of measures have been particularly informative about the cognitive

processes that underlie language processing: brain wave recording and eye movement

tracking. In the following sections, I will discuss how both of these measures can inform

about language processes.

ERP Research in Language

Electroencephalography (EEG) is a method used to measure brain wave potentials

(Teplan, 2002). EEG consists of placing electrodes on the scalp with a conducting gel and

these electrodes measure cortical potentials. These cortical brain potentials occur when

groups of neurons fire and the electrical potential of this firing carries all the way to the

scalp. Recording those electrical potentials can inform what kind of neural processes are

occurring. This method has been used for different types of research including sleep,

memory, and language. Recording brain potentials allows for good temporal resolution

because of the general quick property of conducting electricity. This can be advantageous

in studies where examining a rapid brain response requires a method that can measure

potentials at nearly the same time that a stimulus is being presented.

Studies have been done that show how EEG measurements can have good

temporal resolution. A study using EEG recordings examined the presence of brain wave

components in 3-month old babies using an oddball auditory paradigm that is also used

with adults (Basirat et al., 2014). They tested for a possible homologue of adult brain

wave potentials present during the oddball paradigm in babies, which would point to

hierarchical processing in infants. This study revealed that the recordings of the children

did show the homologue present. Because of the good temporal resolution of EEG

measurements, potentials that happen in small time frames like in the Basirat et al. (2014)

study can be examined. However, because only scalp readings are being taken, the spatial

resolution is poor, especially when compared to measurements like functional magnetic

resonance imaging (fMRI) or positron emission tomography (PET) scans.

Using EEG analysis, event-related potentials (ERPs) can be examined. ERPs are

time locked events that allow for an examination of a brain potential dependent on the

onset of a stimulus (Teplan, 2002). These time-locked brain potentials peak at different

areas of the scalp and shed light on different mental processes that are invoked when a

participant is presented with a stimulus. The names of these potentials usually inform

both whether the waveform is positive or negative and around what time the waveform

peaks.

Two specific potentials are of interest in this thesis because of what they can tell us about language processing. The first brain potential is the N170 waveform. The N170 has an occipito-temporal negative and fronto-centrally positive topography with a maximum negative peak occurring at occipital leads around 150 and 200 ms after stimulus onset (Maurer et al., 2005). The waveform has been found when participants look at faces or when looking at objects of expertise (e.g., bird watchers looking at pictures of birds) and tends to either be bilateral or lateralized to the right (Maurer et al., 2008). According to Maurer and colleagues (2005), there is also an increased left-lateralization observed when visual words are seen in comparison to symbols. Maurer et al., (2008) examined ERPs in English speakers and native Japanese speakers with an English L2, i.e. second language. The researchers showed the participants both Japanese hiragana and kanji along with English words and symbol strings. The study revealed that the N170 waveform was strongly left-lateralized when Japanese speakers viewed kanji and hiragana when compared to their English speaking counterparts who showed a bilateral N170. The N170 waveform was also left-lateralized in both groups when they viewed the English words and symbol strings. These findings suggest that left lateralization of the N170 depends on reading expertise and is seen across languages. Another study by Yum et al. (2014) looked at the N170 waveform, but in the context of Chinese characters. The investigators attempted to teach English monolingual speakers Chinese characters in a laboratory setting over the course of ten sessions. The participants were taught 200 characters and their English translations over these sessions. The study revealed that there were fast and slow learners in their participant pool. The fast learners showed an increased left lateralization of the N170 when compared to slow learners.

The second ERP component of interest is the N400 waveform. Yum et al. (2014) also found an increased N400 waveform in the faster learners. The N400 brain potential had previously been shown to reflect lexical search and semantic integration (Batterink & Neville, 2014; Brouwer et al., 2012; Yum et al., 2014). For example, Yum et al. (2014) showed that participants who were faster at learning the English translations of Chinese characters had an increased N400 as the lab sessions progressed, whereas those who were slower learners had an N400 wave that became more positive as the sessions progressed. Another study confirmed the findings of Yum et al. (2014) and showed that the N400 waveform reflected language comprehension (Batterink & Neville, 2014). In Batterink and Neville's study, English monolingual participants were taught French sentences that were paired with pictures in order to illustrate the sentence's meaning. One group was given a grammatical list of rules and told they were going to be tested after the language training (explicit group), while the other group was not given the list and not told they were going to be tested (implicit group). The study revealed that the N400 was correlated with the L2 comprehension of the participants, which supports the findings of Yum et al. (2014). Another theory has proposed, however, that the N400 reflects memory retrieval (Brouwer et al., 2012). The N400 has been seen as more prevalent in the L2 of participants, which would support semantic integration and/or memory retrieval. In summary, research has shown that the N400 is a good indicator of language comprehension.

Although both the N170 and the N400 waveform can tell us a lot about possible learning processes, especially when it comes to learning a new language, looking at brain potentials is not the only way to examine cognitive processes. Eye movements can also say a lot about what is going on in the brain without directly examining the brain.

Eye Movements and Language

Eye movements can be measured using eye-tracking cameras. Eye-tracking has been used for different research fields and has also been suggested as a possible way of diagnosing certain mental illnesses like attentional deficit hyperactivity disorder (ADHD) and schizophrenia (Luna et al., 2008). This is because different eye movement patterns have been correlated with certain cognitive processes. For example, it has been shown that people who have been diagnosed with schizophrenia cannot smoothly pursue a moving object as well as their healthy counterparts (Luna et al., 2008). Other findings of studies using eye-tracking methods have demonstrated how people, especially children, scan faces. Oakes and Ellis (2013) examined how children scanned upright and inverted faces. They looked at children of different ages: 4.5, 6.5, 8, and 12.5 months. They found that when it came to inverted faces, all of the children looked at the eye region more. The real difference was seen when the infants looked at upright faces. The 4.5 and 6.5 month olds scanned the eye region, but the 8 and 12.5 month olds looked at the face more broadly. Hu et al. (2014) examined the Other-Race effect, which proposes that individuals process the faces of their race differently from other races. They found that in both Chinese children and Chinese adults there were more fixations made to the eye region of Caucasian faces and more fixations to the nasal region of Chinese faces. Eye movement research can also assess differences in language reading (e.g., Apel et al., 2012).

There are a number of things that eye movements can tell us when it comes to language (Blythe, 2014). Concerning reading language, Blythe mentions that eye movements must be made in order for words to fall on the fovea, the area in the retina that allows for detailed vision. The exact brain mechanisms needed for the eye

movements that occur when reading, such as when and where to perform the eye

movements, are not well known but the patterns of the movements themselves can tell a

lot about what is going on.

One eye movement characteristic that is observed during reading is perceptual

span. This is the area in which the most visual information can be processed (Apel et al.,

2012; Whitford & Titone, 2011). When reading left to right, there is a rightward

asymmetry in terms of how many words fall into foveal view. This extends to three to

four characters on the left and around 14 and 15 on the right of the viewing point (Rayner

& Clifton, 2009). When it comes to languages that are read from right to left, a leftward

asymmetry is seen. Apel et al. (2012) have found that perhaps the asymmetry of

perceptual span does not have to do with the reading direction of the language itself but

rather with the intended direction of a following saccade. Knowing more than one

language, however, can affect the perceptual span along with the fixations and saccadic

movements made by the eye. Whitford and Titone (2014) revealed that higher exposure

to an L2 led to an increased ease in L2 reading processing, however, there was decreased

L1 reading processing.

Another study looked at saccadic size and perceptual span in the context of

processing information (Phillips & Edelman, 2008). The participants in this study had to

do a linear search task in which they had to look top to bottom for visual information.

The researchers found a correlation between the speed of search and the number of items

scanned per fixation. They also found that an increased saccadic perceptual span led to

increased performance over the tasks. The results of most of the previously mentioned

studies, however, mainly focus on phonographic writing or writing based on syllables.

Other studies have also looked at logographic writing systems like Chinese and Japanese.

Chinese, along with Japanese, Korean, and others, qualifies as a logographic language. It uses a square unit of space in which the characters are formed by strokes. These strokes form groups called radicals, which inform the meaning of the character. Characters can have many radicals, some phonetic (informing the pronunciation of the word) and some semantic (providing meaning of the character). Being able to read these characters requires high acuity visual encoding through both foveal and parafoveal vision (Yan et al., 2011). Strokes are written in specific order so those that are written first are called early, whereas the later written strokes are called late strokes. A study by Yan et al. (2011) found that there were longer reading times when 50% of strokes were removed. They also found that there were also longer reading times when early strokes were removed along with more fixations and regressions.

In order to understand what my study attempted to teach the participants, a basic understanding of the Japanese writing system will be detailed. Japanese, as previously mentioned, qualifies as a logographic language. Unlike Chinese, Japanese has three different writing systems (Jincho et al., 2014). The first, katakana, is used for foreign words like coffee (コーヒー, ko-hi-) and onomonopias. Speech-wise, katakana represents individual syllables that, unlike English, have only one pronunciation. The second writing system is called hiragana. This system is used to represent auxiliary verbs, particles, and inflections of content words. Hiragana also represents individual syllables. Both of these systems represent the same syllables with the differences arising in how they are written and when they are used. The third writing system, which stands more apart when compared to the other two, is kanji. They are very similar to Chinese characters, with many kanji being borrowed from the Chinese writing system. Kanji is used to represent stems of contents words, e.g., adjectives, nouns, and verbs. Unlike the

hiragana and katakana writing systems, kanji gives both phonetic and semantic

information about the character and can represent one or multiple syllables.

Seeing how complex the Japanese writing system can be dictates that it is

valuable to examine how Japanese readers scan text. Jincho et al. (2014) looked at eye

movements of Japanese readers of different ages. The participants included native

Japanese speakers in third grade, fifth grade, or undergraduates. The investigators found

that the third and fifth graders had more refixations for kanji words than for hiragana

words along with longer fixation times. They also found that the third and fifth graders

employed a kanji targeting strategy, i.e, focused on the kanji more, that is also used by

adults. Although logographic and orthographic languages differ in their writing system,

the method used to recognize words are similar.

One commonality between orthographic and logographic writing systems is that

they have an optimal viewing point (OVP). This OVP is the viewing point in which a

word can most quickly be recognized. In shorter words of an orthographic language, the

OVP is near the center while in longer words it is located slightly to the left (Liu & Li,

2013). Sometimes, however, the initial viewing point (IVP) is not always in the OVP

area. When this occurs, eye fixations are made towards the OVP. When the IVP is closer

to the OVP, there are less refixations towards the OVP. A study looking at Chinese

characters and their OVP revealed that the OVP for single characters was slightly to the

left, on the first character in a two -character word, and a U-shaped OVP for 3-4

characters (Liu & Li, 2013).

Current Study

The topic of this thesis - and the subsequent study - was to examine both eye

movements and ERPs and how they relate to both language experience and language

learning strategies. Previous research has shown that those who are multilingual tend to be better language learners, and slightly better at attention control tasks, than those who can only speak one language (e.g., Adescope et al., 2010; Kaushanskaya et al., 2010). In the present study, multilinguals and monolinguals were taught Japanese kanji and based on previous studies, it was hypothesized that multilinguals would be better learners of the kanji than monolinguals.

Yum et al. (2014) found that there were slow and fast learners in their participant pool. The faster learners performed better in the behavioral tasks and had higher and left-lateralized N170 along with a higher and more anterior N400 brain potential. The researchers speculated that these differences in learning speed arose because of how the participants attempted to memorize the kanji. They believed that faster learners used structural representations to learn the kanji, whereas slow learners used a more holistic approach. In other words, fast learners attempted to break down the structures of a character for easier recognition while slow learners attempted to learn the character as a whole. A second goal of the present study was to further test this speculation of learning strategies.

To that end, the Yum et al. (2014) study was closely replicated to test the validity of their speculation. The behavioral tests they used were recreated, along with their ERP analysis of the N170 and N400 wave potentials. In addition, examination of eye movements during one of the tasks was added to determine if the learning strategies of fast and slow learners could be uncovered. With this study, I hoped to uncover whether language experience and learning strategies affect the success of a student's ability to learn the English translations of Japanese kanji characters.

Method

Participants

Six English monolingual speakers and 13 multilingual speakers participated in the study. All participants were between the ages of 18-25 and attended Lake Forest College at the time of their participation. The study was approved by the Human Subjects Review Committee of Lake Forest College. All participants gave written consent prior to participating. Those who were recruited from psychology classes and language classes were compensated with extra-credit while those not recruited from those classes were not compensated. In order for a participant to be categorized as an English monolingual, certain criteria had to be met: they could not have studied a language (other than English) in an academic setting for more than four years and they could not consider themselves fluent in any language other than English. In order for a participant to be classified as a multilingual speaker, they needed to consider themselves fluent in one or more languages other than English. The language experience of the participants was assessed with a language experience questionnaire (as seen in Appendix). In order to participate, participants could not have been previously exposed to Japanese kanji or any other languages with similar logographic characteristics of Japanese kanji, such as Chinese and Korean.

Apparatus

Eye Movements

For eye movement recordings, participants sat in a comfortable chair with their chin resting on a chin rest. This was done to stabilize the head while the eye tracker was recording their eye movements. The stimuli were presented as black kanji characters/letters on a white background on a computer monitor. Eye movements were

recorded using an ISCAN eye tracker. A 5-point calibration screen was used to calibrate

the eye tracker with the eye movements of the participants.

ERP Recordings

A 7-channel EEG was recorded using Ag-AgCl disk electrodes with a right

mastoid reference and forehead ground. The electrodes were placed at 7 scalp locations

(F_z, C_z, P_z, O_1, O_2, T_5, T_6) using the 10-20 International system of electrode placement

and 4 locations for electrooculography (outer canthi of both eyes and above and below

the right eye) (Jasper, 1958). Before taking EEG measurements, participant's heads were

measured for location of electrode placement. Locations where electrodes were placed

were abraded lightly and cleaned with rubbing alcohol to remove dead skin cells.

Participants sat in a comfortable chair in a dimly-lit room while performing the semantic

categorization task. The stimuli were presented as white characters/letters on a black

background on a computer monitor. Averages for ERP analysis were only obtained for

non-artifact-rejected trials (i.e. no eye movements and no trials where participants were

told to respond).

Research Design

The predictors in this study were language experience and language performance,

which were both of nominal scaling. Language experience had two levels: monolinguals

and multilinguals. Language performance also had two levels: low performance and high

performance. The performance levels were determined by the scores in the backwards

translation task. The dependent variables were scores on the translation recognition task,

scores on the backwards translation task, number of eye fixations, area of the N170

waveform, and area of the N400 waveform. All dependent variables were of ratio scaling.

The scores for the translation recognition task were determined by how many correct

matching or non-matching translations were recognized by the participants. The scores

for the backwards translation task were determined by how many correct English

translations were given by the participant when presented with the kanji. The eye

fixations were measured using the eye-tracking video recorded during the word-word

association task. The areas of both brain wave potentials (N170 and N400) were

measured using the EEG recordings taken during the semantic categorization task. The

design of the study was a 2 (language experience) x 2 between-subjects factorial design.

Data Analysis

For analysis of eye movements, the number of eye fixations were counted for

each area of each character. Each kanji was composed of either 2 or 3 areas. These areas

were defined by radical composition. The method of numbering the areas depended on

where the areas were in relation to each other. If the areas were stacked on top of each

other, numbering went from top-to-bottom (竜, top=area 1, bottom=area 2). If the areas

were positioned side-by-side, numbering went from left-to-right (湖, left=area 1,

middle=area 2, right=area 3). If areas were placed in a combination of being side-by-side

and on top of each other, numbering went from left-to-right in a clockwise fashion (指,

left=area 1, top right=area 2, bottom right=area 3). The division of the kanji into areas

allowed for the analysis of fixations in a systematic way. Because the sequence of the

word-word association task showed the kanji-to-be-learned a total of three times, the

mean fixation for each block of 2 and 3 area characters were analyzed. Two other

members of Dr. Wentworth's lab independently analyzed 37% of the eye movement

videos where they counted the number of fixations for each of the 20 characters.

Comparisons across coders yielded an inter-rater reliability of 85%.

Two eye movement strategies were determined: focused and distributed. Focused strategy meant that fixations were primarily made in one area of the kanji. The distributed strategy meant that fixations occurred in all areas of the kanji. For assessing the strategies, only the first block of kanji characters was analyzed. The mean number of fixations for the 2- and 3-area kanji was calculated separately for each block. To do this, the number of fixations for each area for all of the 2-area kanji shown in that block (N=8) and the 3-area kanji (N=12) were determined and then divided by the number of 2- or 3-area kanji, respectively (i.e., 8 or 12). This is the reason why almost all areas were comprised of decimal point fixations (e.g., 0.50 fixations).

Because participants examined 2- and 3-area kanji, different criteria had to be met in order to classify the participant's eye movement strategy as either a focused or distributed strategy for the 2- and 3-area kanji. All of these criteria were determined by examining the distributions of the number of fixations for 2- and 2-area kanji of all participants. For 2-area characters, in order for a participant to be classified as having a focused strategy, one area had to have below 0.45 fixations while the other area had to have above 0.45 fixations. The reasoning behind these criteria was that if the mean fixations of an area (over the 8, 2-area kanji) were less than 0.45, the participant fixated on this area very little. For a distributed strategy in the 2-area kanji characters, the participant had to have above 0.45 fixations on both areas. The 3-area kanji characters had slightly different classifications. Because one of the three areas had less than 0.30 fixations (fixated on the area very little), only 2 areas that had higher than 0.40 fixations were examined. For the 3-area kanji characters, in order for a participant to be classified as having a focused strategy, the two areas that had more than 0.30 fixations had to have a fixation difference of 0.35 fixations or higher. In order for the participant to have a

distributed strategy, the two areas that had more than 0.30 fixations had to have a fixation

difference that was less than 0.35 fixations.

The N170 waveform was analyzed for all electrodes between the 160-210 ms time

window after the onset of the stimuli. Specifically, the average amplitudes for the left

electrodes (O_1 and T_5) and right electrodes (O_2 and T_6) for the N170 were analyzed. A

repeated measures ANOVA was run comparing the within-subjects factor of the area of

the leads (left vs right) and the between-subjects factor of language experience. The same

repeated measures ANOVA was run to compare the leads and the between-subjects factor

of language performance.

The N400 waveform was also analyzed for all electrodes between the 300-500 ms

time window. In order to determine the anterior-posterior amplitude for the N400, the F_z

and P_z leads were examined. A repeated measures ANOVA was run comparing the

within-subjects factor of the area of the leads (anterior vs. posterior) and the between-

subjects factor of language experience. The same repeated measures ANOVA was run to

compare the leads and the between-subjects factor of language performance.

Stimuli

A total of 20 Japanese kanji were selected so that some had similar structures and

consisted of only nouns with the help of Professor Ichinose from Lake Forest College.

Along with those 20 kanji, 10 additional kanji were selected for inclusion in the N-back

task. An additional 10 kanji were shown to participants before the semantic

categorization task so that baseline readings of brain wave potentials could be attained

when a participant did not recognize a kanji. These 10 kanji shown to the participants

were not analyzed for this study.

Procedure

Day 1

On the first day of data collection, participants were asked to come to Room 004 in Hotchkiss Hall. Three different tasks were employed on this day.

Task 1: Go/no-go N-back Task: The first task was a go/no-go N-back word task. The N-back task required the participant to match a presented stimulus to a stimulus before it, matching it back either 1 or 2 stimuli before it. During this task, the 20 kanji-to-be-learned throughout the study were shown one at a time interspersed with 10 kanji presented as distractor stimuli. The participant was asked to click the mouse provided to them if the kanji they previously saw matched the one currently presented. An N-back of 1 and 2 were shown to the participants. This task was done to familiarize the participants with the 20 kanji they had to learn. This task took approximately 4 minutes and the sequence of the task was as follows: 500 ms L2 word (kanji) on, 1,500 ms intertrial interval (ITI). During the ITI, participants clicked the mouse if they detected a repeat item. Before the task commenced, they were given training trials with nature scenes to familiarize them with how the task worked due to the complex nature of the task.

Task 2: Word-Word Association Task: After a short break, the participants proceeded onto the second task where eye tracking took place. They were instructed to move their head as little as possible during this task and to be as attentive as possible. After the eye tracker had been calibrated, the task commenced. The task itself was a word-word association task. The 20 kanji-to-be-learned were presented along with their English translations. The English translations were presented first followed by another screen that presented the corresponding kanji. The trial sequences were 500 ms of the English translation, 1,000 ms of the kanji, and 2,500 ms ITI. A total of 60 association

trials were conducted so that the participant was exposed to each kanji character and its

English translation three times. Once this task was done, the participant had a short break.

Task 3: Translation Recognition Task: After the break, the participant moved on to

the third task. This task was the translation recognition task. It consisted of two different

blocks. The first block first presented the Japanese kanji followed by an English

translation, which either matched with the kanji or not. During the response phase, the

participant verbally indicated if the translation matched the character. Feedback was

given after every translation trial (800 ms kanji, 500 ms blank, 800 ms translation, wait

for response, 800 ms feedback, and 2,500 ms ITI). The second block followed the same

procedure except the English matching or not-matching translation was presented first.

Participant's responses were written on a response recording sheet for later analysis of

language performance. Once all these tasks were done, participants were debriefed on the

tasks that they had just completed and given a debriefing form to contact the investigators

if they had any questions, comments, or concerns.

Day 2:

On the second and last day of data collection, participants were asked to come to

Room 306 in Hotchkiss Hall. Two different tasks were employed on this day. The first

task served as further training in the Japanese kanji stimuli and the second task served as

a task to assess the learning of the stimuli with EEG recordings being simultaneously

taken.

Task 1: Japanese-to-English Backward Translation Task: The first task was a

Japanese-to-English backward translation task. Participants were shown a Japanese kanji

and asked to verbally give its English translation. Feedback was given after every trial.

Their responses were written on a response recording sheet for later analysis of language

performance.

Task 2: Semantic Categorization Task: The second task was a semantic

categorization task during which EEG was recorded. Before the task began, electrodes

were placed on the participant's head at 7 scalp locations (F_z, C_z, P_z, O_1, O_2, T_5, T_6) and 4

locations for electrooculography (outer canthi of both eyes and above and below the right

eye). A reference electrode was attached over the right mastoid bone and a forehead

ground electrode was applied. Participants were asked to try to keep their head and eyes

as still as possible. Initially, participants were presented 10 novel kanji that they were not

shown in any of the previous trials to provide a baseline reading for EEG analysis.

During the task, Japanese kanji were presented and participants were asked to categorize

some of the kanji. Three different categories (body part, food and drinks, and nature)

were presented to the participants before the set of 20 kanji. Brain waves that were

generated while participants looked at the kanji that they were not asked to categorize

were analyzed. Once this task was completed, the electrodes were removed and

participants were debriefed and given a debriefing form.

Results

Language Learning Performance

In order to examine individual differences in language learning performance, both

the translation recognition task and backwards translation task were examined. The mean

score for the translation recognition task was 36.42 out of 40 possible points (91%)

(*SD*=2.714) and the mean score for the backwards translation task was 7.68 out of 20

possible points (38%) (*SD* = 3.698). To determine if both performance distributions were

normal, Kolmogorov-Smirnov tests were run (Table 1). The test revealed that the mean

translation recognition scores deviated from normal ($Z = 0.216$, $p = 0.020$) whereas the

backwards translation scores did not ($Z = 0.152$, $p = 0.200$). Because the backwards

translation task scores were normally distributed, this task was used to assess language

learning performance.

Participants' scores on the backwards translation task were used to classify them

as fast or slow learners. The median of the score was found to be 7 and then a median

split was used to classify participants who scored less than 7 as slow learners (n = 9)

whereas participants who scored 7 or above were classified as fast learners (n = 10).

The backwards translation scores were also analyzed as a function of language

experience. Figure 1 shows the mean backwards translation scores for the mono- and

multi- language experience groups. Contrary to expectations, those who were in the low

language experience group (monolinguals) had a higher mean score of 9 ($SD = 3.90$)

while those in the high language experience group (multilinguals) had a lower mean

score of 7.08 ($SD = 3.59$). An independent samples t-test was done to see if this

difference in group scores was significant. As Table 2 shows, there was no significant

differences in the backward translation scores for the low and high level language

experience groups; $t(17) = 1.06$, $p = 0.305$. Thus, multilingual participants did not get

significantly higher scores on the backwards translation task.

Eye-Movement Learning Strategies

As previously mentioned, eye fixations during the word-word association task

were analyzed for 2 and 3 area kanji over three blocks. Descriptive statistics for the mean

number of fixations of all areas and all blocks are shown in Table 3. As can be seen in the

table, an interesting pattern emerged when looking at the fixation means. Participants

tended to make more fixations towards the second area of the kanji for the 2-area type,

regardless of block. A similar pattern was observed for the 3-area kanji. Independent of

block, the fewest fixations were made in the first area and the most number of fixations

were made to the third area (Area 1 < Area 2 < Area 3). To analyze whether there was a

significant difference in mean fixations for the different areas, specifically for the 2-area

kanji, and trial block, a 2 x 3 analysis of variance (*ANOVA*) was conducted, as seen in

Table 4. There was a highly significant main effect for area, $F(1, 18) = 26.45$, $p = .000$.

However, there was no significant main effect for trial block, $F(2, 36) = 0.655$, $p = .53$.

There was also no significant interaction between area and trial block, $F(2, 36) = 0.595$, p

$= .56$. To test whether there was a significant difference between the mean number of

fixations of the two areas averaged over all three blocks, a paired samples t-test was

conducted, as seen in Table 5. According to the t-test, there was a significant difference

in the mean number of fixations for Area A ($M = 0.46$, $SD = 0.26$) and Area B ($M = 0.94$,

$SD = 0.20$), $t(18) = -5.14$, $p < .001$. In order to test whether there was a significant

difference between the areas of 3-area kanji and trial block, a 3x3 *ANOVA* was run, as

seen in Table 6. According to the test, there was a highly significant main effect for area,

$F(2, .153) = 36.12$, $p < .001$. There was also a significant main effect for block, $F(1.91,$

$34.30) = 0.312$, $p = 0.001$. However, there was no significant interaction between area

and trial block, $F(3.21, 57.80) = 0.028$, $p = .685$.

       In order to analyze whether there was a relationship between learning strategy in

2- and 3- area kanji and language performance, 2 two-way chi-square (χ^2) tests were

conducted. The first chi-square test, shown in Table 7, looked at possible significance in

the relationship between learning strategy (focused, distributed) in the 2-area character

area and language performance (low, high). There was no significant relationship

between the type of learning strategy employed for the 2-area kanji and language

performance, χ^2 (1, N = 19) = 0.059, p = .81). The second chi-square test, shown in Table

8, looked at a possible relationship between learning strategy (focused, distributed) in the

3-area kanji area and language performance (low, high). Again, there was no significant

relationship between the type of learning strategy employed for the 3-area kanji and

language performance, χ^2 (1, N = 19) = 0.038, p = .85).

As previously mentioned, participants were classified as having two learning

strategies, one for 2-area and one for 3-area kanji. Some participants had the same

strategies for both types of characters (focused-focused, distributed-distributed) while

others had different strategies (focused-distributed, distributed-focused). To determine

whether there was a relationship between having the same strategy for both 2- and 3-area

kanji characters and language performance, a two-way chi-square test was conducted,

which can be seen in Table 9. According to the test, there was a significant relationship

between learning strategy and language performance such that people with consistent

strategies were higher language performers, χ^2 (1, N = 19) = 9.98, p = .002).

ERP Analysis

Descriptive statistics for all seven leads at the 160-210 ms timeframe (N170) are

shown in Table 10. The bar graph in Figure 2, displays the mean areas for the N170

waveforms of the left and right leads for both language performance groups. It can be

seen that, as hypothesized, there was a greater difference between the left and right leads

of the high performance when compared to the low performance group. Descriptive

statistics on which the analysis of variance (ANOVA) was based on can be seen for the

left and right leads in both language performance groups in Table 11. In order to test for

possible significance, a 2 x 2 mixed factor *ANOVA* was conducted with lead (left vs.

right) as a within-subjects measure and performance group (low vs. high) as a between-

subjects measure. As seen in Table 11, the mean left lead area was 0.00236 V ($SD =$

0.00063) whereas the mean right lead area was 0.00210 V ($SD = 0.00063$) but as seen in

Table 12, the *ANOVA* revealed that there was no significant main effect for lead, $F(1, 17)$

$= 3.33$, $p = .085$. The mean area of both leads for the low performance group was 0.002 V

($SD = 0.00$) whereas the mean area of both leads for the high performance group was

0.002 V ($SD = 0.00$) and there was no significant main effect for performance group, $F(1,$

$17) = 2.82$, $p = 0.111$. Contrary to what was hypothesized, the interaction between lead

and performance group was not significant, $F(1, 17) = 0.273$, $p = .608$.

Descriptive statistics for all seven leads at the 300-500 ms timeframe (N400) are

shown in Table 13. The bar graph in Figure 3, displays the mean areas for the N400

waveforms of the anterior (F_z) and posterior (P_z) leads for both language performance

groups. From Figure 3, it can be seen that there is a greater mean area for the anterior

lead in the low performance group than the high performance group. It can also be seen

that the mean areas for the anterior leads of both performance group were very similar.

Descriptive statistics on which the analysis of variance (ANOVA) was based on can be

seen for the anterior and posterior leads in both language performance groups in Table

14. In order to test for possible significance, a 2 x 2 mixed factor *ANOVA* was conducted

with lead (anterior vs posterior) as a within-subjects measure and performance group

(low vs high) as a between-subjects measure. As seen in Table 14, the mean anterior lead

area was 0.01588 V ($SD = 0.00378$) whereas the mean posterior lead area was 0.01688 V

($SD = 0.00495$) but as seen in Table 15, the *ANOVA* revealed that there was no significant

main effect for lead, $F(1, 17) = 4.09$, $p = 0.059$. The mean area for all leads of the low

performance group was .017 V ($SD = 0.001$) whereas the mean area for all leads of the

high performance group was .016 V ($SD = 0.001$) but there was no significant main effect

for performance group, $F(1, 17) = 0.862$, $p = 0.366$. Contrary to what was hypothesized,

the interaction between lead and performance group was not significant, $F(1, 17) = 1.94$,

$p = 0.181$.

Discussion

Previous studies have found that multilinguals are better language learners than

monolinguals. To test whether these findings were replicated, this study attempted to

teach multilinguals and monolinguals Japanese kanji. Because a previous study (Yum et

al., 2014) postulated that better language learners have differing learning strategies than

slower learners, eye movements were examined to see if these learning strategy

differences could be discerned while participants attempted to learn the kanji. Yum et al.

(2014) also found differences in both the N170 and N400 waveforms for fast language

learners (for Chinese characters) and slow language learners. To replicate these results

with Japanese kanji, EEG measurements were recorded and ERPs were measured for

those two waveforms. Thus, this study aimed to replicate the results of the Yum et al.

(2014) study, along with identifying the learning strategy differences in the language

performance groups. The following discussion will focus on the different findings and

what they mean for language and future studies.

The first hypothesis of this study was that those with higher language experience

would perform better in the Japanese language tasks than those with lower language

experience. When testing for differences in language performance for those with low and

high language experience, just the opposite was found for those in the low level group

had higher backwards translation scores. Although an independent samples t-test revealed

that these mean differences were not significant. As previously mentioned, this lack of

significance could easily be due to the low number of participants. However, another

possible reason could be that, due to the logographic structure of the kanji, any possible

advantage that multilinguals had in learning other non-logographic languages was

eliminated. In the current procedure, the elimination of a language exposure advantage

could be due to the nature of the task that participants were given in the present study.

That is, the actual Japanese words were not taught to the participants, only the English

translations of the kanji were. This is a procedural problem because previous language

studies that found the multilingual advantage in learning a new language tested

participants on their ability to learn actual grammar and syntax while this study did not.

The method for the present study was modeled after a study by Yum et al. (2014),

which only taught Chinese characters and did find differences in fast and slow learners.

However, their sample only included monolingual participants. Just like the participants

in the Yum et al. (2014) study, none of the groups in the present study were previously

exposed to logographic characters, and their ability to learn might have had more to do

with how they mapped the English word to the kanji. Since the monolinguals were only

fluent in English, they could have been better at mapping the English words when

compared to multilinguals. Although it was known that all participants were fluent in

English, the degree to which multilinguals were fluent was unknown. A difference in

English fluency might have presented some difficulty to the multilingual group in

mapping the English word to the kanji. In any case, the present results did not support the

hypothesis of higher language experience dictating higher performance on learning the

kanji translations.

Next, the hypothesis of the relationship between eye movement strategies and

language performance was tested. It was hypothesized that those who were in the high

performance group would have more focused eye movement strategies while those in the

low performance group would have more distributed eye movements. In the chi-square

tests to test this hypothesis, there was no significant relationship between 2-area kanji

learning strategy and performance group or in the 3-area kanji learning strategy and

performance group. These results did not support the hypothesis concerning eye

movement learning strategies and language performance groups.

A second analysis was done to see if there could possibly be a significant

relationship between having the same or different learning strategies for the two types of

kanji and language performance. Because participants received two scores for eye

movement strategies (one for 2-area kanji and one for 3-area kanji), it was possible to test

whether the participant employed different or similar strategies across both types of kanji

in the word-word association task. This chi-square test conducted to address this question

revealed a significant correlation between maintaining the same learning strategy and

performance.

Although there were no significant differences in language performance and

learning strategy, for all participants, certain trial blocks had more fixations than others.

A 2 x 3 ANOVA test (for 2-area kanji) and a 3 x 3 *ANOVA* test (for 3-area kanji)

revealed that there were significant differences in the areas of all trial blocks. In other

words, participants fixated more on certain areas of both 2-area and 3-area kanji.

Other than not having enough participants in the study, there are other possible

explanations for why no significant differences were found in learning strategies and

language performance. One of those factors could have been that the quality of the

fixation mattered more than just making the fixation. If a participant looked around in an

area, rather than staying fixated on one spot of the area, different visual information

would have been stored for either scenario. Differences between performance groups in

learning strategies were not significant; in fact, all participants fixated on the kanji in

similar ways. A possible reason for this is because the area participants fixated on most

was closer to the center of the kanji compared to the area the participants fixated on the

least. As previously mentioned, the optimal viewing point (OVP) for orthographic words

is in the center (Liu & Li, 2013). Because none of the participants had been exposed to

logographic languages, then there is the possibility that they were using the same OVP

for the kanji. This indicates another possible reason for participant's fixations focusing on

certain areas, which might be that all of the participants believed that the area (which they

fixated the most) provided them with the most visual information that would allow them

to distinguish characters from each other. For this study, characteristics of the eye

fixations like how long those fixations lasted and how many saccadic eye movements

were made inside the area, were not taken into account. This deeper examination of eye

movement characteristics could have found differences between the performance groups.

The third hypothesis tested concerned language performance and both the N170

and N400 waveforms. It was hypothesized that for the N170 waveform, those in the high

performance group would have a left lateralized N170 while those in the low

performance group would have either a right lateralized or bilateral N170. When looking

at the visual representation of the mean areas for the groups, it appeared that the area for

the N170 was lateralized more to the left for the high performers when compared to the

low performance group's means. However, no significant effect for lead and group was

found along with no significant interaction between the two. Similar to all the previous

statistical tests conducted, this could have been due to not having enough participants in

each group.

Another possible reason for not finding significant results between language groups and N170 mean area was because of electrode placement. In norms of EEG and ERP studies, the signal-to-noise ratio must be kept optimal so external noise can be excluded. When the impedance of an electrode is too high, the distortions that it can cause in the EEG measurements can make it difficult to separate the distortions from the signal (Teplan, 2002). According to Teplan (2002), the optimal impedance levels for electrodes is below 5 kΩ. When the impedance levels are too high and cannot be corrected, those channels are excluded. In the current study, one of the electrodes (O_1) had an impedance that was higher than the optimal level. This channel, however, was not excluded from the N170 ERP data when the impedance was too high. Using the channel for data analysis could have affected the results of the N170 waveform between language performance groups. Based on the tests conducted, the hypothesis about the type of lateralization for both language performance groups in terms of the N170 waveform was not supported.

The second half of the third hypothesis was that there would be differences in the N400 waveform for both language performance group. Specifically, those in the high performance group would have a more anterior N400 when compared to the low performance group while the low group would have a more posterior N400. To see if this hypothesis was supported, the F_z (anterior) and P_z (posterior) leads were examined for both groups. When looking at the bar graph of the mean average areas of these leads, it appeared that there was a greater area for the anterior lead in the low performance group, which was not expected. For the posterior leads, the low group had a slightly higher mean area than the high group, which was expected. However, the mixed factor *ANOVA* on the results showed that there was no significant effect for lead and group, along with no

significant interaction between the two. So, although the anterior area values were opposite of what was expected for both groups and the values for the posterior area were expected values for both groups, these values were shown to not be significant. Again, this lack of significance could have been due to the low number of participants. These results do not align with previous studies that have found that the N400 is a possible reflection of language comprehension (Batterink et al., 2014; Yum et al., 2014).

Almost all EEG and ERP studies, including the ones referenced in this thesis, only included right-handed individuals in their sample (e.g., Batterink et al., 2014; Maurer et al., 2013; Yum et al., 2014). The exclusion of left handed individuals comes from those who are left or right handed having different brain processing or flipped processing (i.e., right handed individuals having left-lateralized processing for stimuli while left handed individuals have right-lateralized processing). In order to prevent the confound of not finding a process because the direction is flipped, which could easily be prevented by sampling from a more representative sample of the population, left-handed individuals are excluded. In the current study, the handedness of participants was not taken into consideration and was not an excluding factor for participation. The handedness of the participants could have possible affected the ERP measurements analyzed for both the N170 and N400.

In contrast to previous novel language studies, no significant differences were found in almost all of the tests conducted. One main reason for not finding significance in many of the tests could have been the low number of participants in both language experience groups (n = 19), particularly in the low language experience group (n = 6). Unless the effect of language experience were extremely high, the ability to find significance with such a small number of participants was highly unlikely. The low

number of participants almost precluded the possibility of being able to factor out

individual differences among participants. Because of this, any differences in mean

scores and brain potentials could possibly be due to the general ability to memorize items

rather than the language experience of the individual.

Recruiting the number of participants needed to find possible significance in

many of the tests was very difficult. It was particularly hard to recruit participants who

were monolingual. Because Lake Forest College has such a diverse student body, many

students are fluent in at least two different languages. Perhaps if there had been more

time available to recruit participants, the initial goal of recruiting 20 participants for each

language group could have been reached.

As previously mentioned, this study aimed to replicate the study by Yum et al.

(2014), with the addition of the examination of learning strategies and previous language

experience. The replication of their study was successful to a degree with the starkest

difference being the amount of time participants spent in the study. The difference in

learning time between their study and my study could be a possible factor in why many

of my hypotheses were unsupported. In Yum et al.'s (2014) study, participants went

through 10 sessions where they learned 200 Chinese characters with 4 different EEG

measurements recorded per participant. The researchers were able to examine how

language performance differed across each session and how the N170/N400 changed

over the progression of the study. In contrast, the participants in the present study went

through 2 sessions and EEG measurements were recorded once. If the current study had

been extended to ten sessions, perhaps the differences between multilinguals and

monolinguals could have been seen during later sessions.

Future studies could go further into the investigation of the role of language experience and novel language learning. (this sentence is a bit awkward and vague). If the design and tasks were to be replicated, more careful measures of eye movements should be analyzed. This could possibly reveal more subsets of the two learning strategies examined in this study that are both more qualitative and quantitative, e.g., meaningful focused scanning or meaningful distributed scanning. Although no significant relationships between learning strategy and language performance were found, there was a significant difference in where participants fixated their eye movements. This difference points to eye movements as being a significant variable to study in language learning. Another thing that could be improved upon would be teaching more kanji characters and examining the relationship in the number of strokes in the character and how many kanji are memorized by the participants. This addition could possibly make participant's learning strategies become more apparent because of the difficulty in learning many complicated kanji characters.

In conclusion, this thesis combined insights from the eye movement and ERP literature to test whether multilinguals are better language learners than monolinguals. The multilinguals in the current study presented an opportunity to study those who were fluent in languages that were very different in their writing and language structure, e.g., English, Farsi, Spanish. However, the ability to recruit monolinguals, and participants in general, was greatly diminished so any differences between these two language groups were not found.

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Table 1

One-Sample Kolmogorov-Smirnov Tests for Normal Distribution

One-Sample Kolmogorov-Smirnov Test

		Translation Recognition Score	Backwards Translation Score
N		19	19
Normal Parameters[a,b]	Mean	36.4211	7.6842
	Std. Deviation	2.71448	3.69764
Most Extreme Differences	Absolute	.216	.152
	Positive	.100	.152
	Negative	-.216	-.107
Test Statistic		.216	.152
Asymp. Sig. (2-tailed)		.020[c]	.200[c,d]

a. Test distribution is Normal.

b. Calculated from data.

c. Lilliefors Significance Correction.

d. This is a lower bound of the true significance.

Note. The above table is a One-Sample KS test to test if the distributions for the translation recognition scores and backwards translation scores were normal. According to the test, the distribution for the translation score was not normally distributed ($p < .05$) while the distribution for the backwards translation score was normally distributed ($p > .05$).

Table 2

Independent Samples T-test for Backwards Translation Scores and Language Experience

Independent Samples Test

		t-test for Equality of Means		
		t	df	Sig. (2-tailed)
Backwards Translation Score	Equal variances assumed	1.057	17	.305
	Equal variances not assumed	1.024	9.105	.332

Note. Table 2 shows an independent samples t-test for significance between backwards translation scores and language experience. No significance between these two variables was found ($p > .05$).

Table 3

Mean Number of Fixations in Areas as a Function of Trial Blocks

2-area

Block	Area	
	A	B
1	.45	.93
2	.51	.94
3	.43	.93

3-area

Block	Area		
	A	B	C
1	.27	.68	.86
2	.23	.70	.89
3	.18	.60	.76

Note. The preceding table shows the mean number of fixations of each area of the 2- and 3-area kanji for each block.

Table 4

Summary Table for ANOVA Test of Trial Blocks and 2-Area Kanji

Source	Type III Sum of Squares	df	F	Sig.
Area	6.456	1	26.452	.000
Error (area)	4.393	18		
Block	.038	2	.655	.525
Error (block)	1.045	36		
Area*Block	.027	2	.595	.557
Error (Area*Block)	.806	36		

Note. Table 4 shows the summary results of the *ANOVA* test run to check for significance in different areas for the 2-area kanji and blocks. There was a significant main effect for area ($p < .000$) and but no significant main effect for block ($p > .05$). There was also no significant interaction between the two ($p > .05$).

Table 5

Paired Samples T-test for Mean Number of Fixations in Area A and B in all Trial Blocks

Paired Samples Test

		t	df	Sig. (2-tailed)
Pair 1	Mean Area A - All Blocks - Mean Area B - All Blocks	-5.143	18	.000

Note. Table 5 shows the paired-samples t-test conducted for the mean number of fixations of Area A and Area B for all blocks. There was a significant difference between the number of fixations in both areas ($p < .05$).

Table 6

Summary Table for ANOVA Test of Trial Blocks and 3-area Kanji

Source	Type III Sum of Squares	df	F	Sig.
Area	11.042	2	36.120	.000
Error (area)	5.503	.153		
Block	.320	1.905	.313	.001
Error (block)	.701	34.298		
Area*Block	.038	3.211	.028	.685
Error (Area*Block)	1.312	57.799		

Note. The preceding table shows the summary results of the *ANOVA* test run to check for significance in different areas for the 3-area kanji and blocks. There was a significant main effect for area ($p < .000$) and block ($p < .05$) but no significant interaction between the two ($p > .05$).

Table 7

Chi-Square Test for Learning Strategy in 2-area Kanji and Language Performance

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.059[a]	1	.809		
Continuity Correction[b]	.000	1	1.000		
Likelihood Ratio	.059	1	.809		
Fisher's Exact Test				1.000	.586
Linear-by-Linear Association	.056	1	.814		
N of Valid Cases	19				

a. 3 cells (75.0%) have expected count less than 5. The minimum expected count is 4.26.

b. Computed only for a 2x2 table

Note. The proceeding table shows a Chi-Square test to examine for a possible correlation between learning strategy for 2-area kanji and language performance. No significant correlation was found between both of these variables ($p > .05$).

Table 8

Chi-Square Test for Learning Strategy in 3-area Kanji and Language Performance

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.038[a]	1	.845		
Continuity Correction[b]	.000	1	1.000		
Likelihood Ratio	.038	1	.845		
Fisher's Exact Test				1.000	.605
Linear-by-Linear Association	.036	1	.849		
N of Valid Cases	19				

a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is 3.79.

b. Computed only for a 2x2 table

Note. The proceeding table shows a Chi-Square test to examine for a possible correlation between learning strategy for 3-area kanji and language performance. No significant correlation was found between both of these variables ($p > .05$).

Table 9

Chi-Square Test for Similar Learning Strategies across 2- and 3-area Kanji and Language Performance

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	9.975[a]	1	.002		
Continuity Correction[b]	7.193	1	.007		
Likelihood Ratio	12.791	1	.000		
Fisher's Exact Test				.003	.002
Linear-by-Linear Association	9.450	1	.002		
N of Valid Cases	19				

a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is 3.32.

b. Computed only for a 2x2 table

Note. The proceeding table shows a Chi-Square test to examine for a possible correlation between having similar learning strategies for 2- and 3-area kanji and language performance. A significant correlation was found between both of these variables ($p <$ .05).

Table 10

Descriptive Statistics for Lead Average Areas (N170)

Statistics

		Fz - N170 Average Area	Cz - N170 Average Area	Pz - N170 Average Area	T5 - N170 Average Area	T6 - N170 Average Area	O1 - N170 Average Area	O2 - N170 Average Area
N	Valid	19	19	19	19	19	19	19
	Missing	0	0	0	0	0	0	0
Mean		.00243862	.00245150	.00243895	.00217462	.00212043	.00254834	.00207737
Std. Error of Mean		.0001605	.0001588	.0001630	.0001498	.0001967	.0001887	.0001494
Median		.00217968	.00222531	.00237968	.00196886	.00203032	.00258800	.00214567
Mode		.001406[a]	.001479[a]	.001325[a]	.001282[a]	.000951[a]	.001217[a]	.001149[a]
Std. Deviation		.0006995	.0006923	.0007106	.0006529	.0008573	.0008227	.0006511
Variance		.000	.000	.000	.000	.000	.000	.000
Skewness		.287	.643	.646	.409	1.044	.844	.125
Std. Error of ...		.524	.524	.524	.524	.524	.524	.524
Kurtosis		-1.300	-.858	.365	-1.197	1.611	1.752	-1.157
Std. Error of Kurtosis		1.014	1.014	1.014	1.014	1.014	1.014	1.014
Range		.002265	.002279	.002611	.001944	.003487	.003551	.002023

a. Multiple modes exist. The smallest value is shown

Note. The proceeding table shows descriptive statistics for the average area of the leads at the N170 time region.

Table 11

Descriptive Statistics for N170 Leads and Language Performance

Descriptive Statistics

	Performance Level	Mean	Std. Deviation	N
Left Leads Average Areas	Low Performance	.00253750	.000494476	9
	High Performance	.00220306	.000727440	10
	Total	.00236148	.000634577	19
Right Leads Average Areas	Low Performance	.00235284	.000594850	9
	High Performance	.00187036	.000596561	10
	Total	.00209890	.000629658	19

Note. The proceeding table shows descriptive statistics for the left (O_1, T_5) and right (O_2, T_6) N170 time-frame leads and language performance.

Table 12

Summary of Mixed-Factor ANOVA for N170 potential and Performance Groups

Source of Variance	Type III Sum of Squares	df	Mean Square	F	Sig.
Lead	6.339E-7	1	6.339E-7	3.335	.085
Performance Group	1.581E-6	1	1.581E-6	2.822	.111
Lead*Performance Group	5.191E-8	1	5.191E-8	.273	.608
Error	3.231E-6	17	1.901E-7		

Note. Table 12 shows the summary results of the Mixed-Factor *ANOVA* conducted to test for significance of lead (left vs right) and performance group (low vs high). No significant effects or interaction was found.

Table 13

Descriptive Statistics for Lead Average Areas (N400)

Statistics

		Fz - N400 Average Area	Cz - N400 Average Area	Pz - N400 Average Area	T5 - N400 Average Area	T6 - N400 Average Area	O1 - N400 Average Area	O2 - N400 Average Area
N	Valid	19	19	19	19	19	19	19
	Missing	0	0	0	0	0	0	0
Mean		.01588347	.01694924	.01687704	.01458292	.01274103	.01606919	.01354323
Std. Error of Mean		.0008674	.0011120	.0011367	.0011708	.0007493	.0009965	.0008269
Median		.01525393	.01687040	.01657969	.01449083	.01230469	.01545906	.01255882
Mode		.010410[a]	.010420[a]	.009363[a]	.008653[a]	.007292[a]	.010192[a]	.008690[a]
Std. Deviation		.0037808	.0048472	.0049549	.0051035	.0032659	.0043434	.0036042
Variance		.000	.000	.000	.000	.000	.000	.000
Skewness		1.047	1.355	1.146	2.001	1.017	.539	.859
Std. Error of ...		.524	.524	.524	.524	.524	.524	.524
Kurtosis		2.072	3.095	2.076	5.654	2.029	-.844	.082
Std. Error of Kurtosis		1.014	1.014	1.014	1.014	1.014	1.014	1.014
Range		.015969	.020859	.021043	.022501	.014406	.013505	.012356

a. Multiple modes exist. The smallest value is shown

Note. Table 13 shows descriptive statistics for the average area of the leads at the N400 time region.

Table 14

Descriptive Statistics for N400 Leads and Language Performance

Descriptive Statistics

	Performance Level	Mean	Std. Deviation	N
Fz - N400 Average Area	Low Performance	.01719564	.004306391	9
	High Performance	.01470252	.002971982	10
	Total	.01588347	.003780774	19
Pz - N400 Average Area	Low Performance	.01749326	.005475165	9
	High Performance	.01632244	.004662030	10
	Total	.01687704	.004954928	19

Note. The table shows descriptive statistics for the anterior (F_z) and posterior (P_z) N400 time-frame leads and language performance.

Table 15

Summary of Mixed-Factor ANOVA for N400 potential and Performance Groups

Source of Variance	Type III Sum of Squares	df	Mean Square	F	Sig.
Lead	8.709E-6	1	8.709E-6	4.087	.059
Performance Group	3.179E-5	1	3.179E-5	.862	.366
Lead*Performance Group	4.141E-6	1	4.141E-6	1.943	.181
Error	3.623E-5	17	2.131E-6		

Note. Table 15 shows the summary results of the Mixed-Factor *ANOVA* conducted to test for significance of lead (anterior vs posterior) and performance group (low vs high). No significant effects or interaction was found.
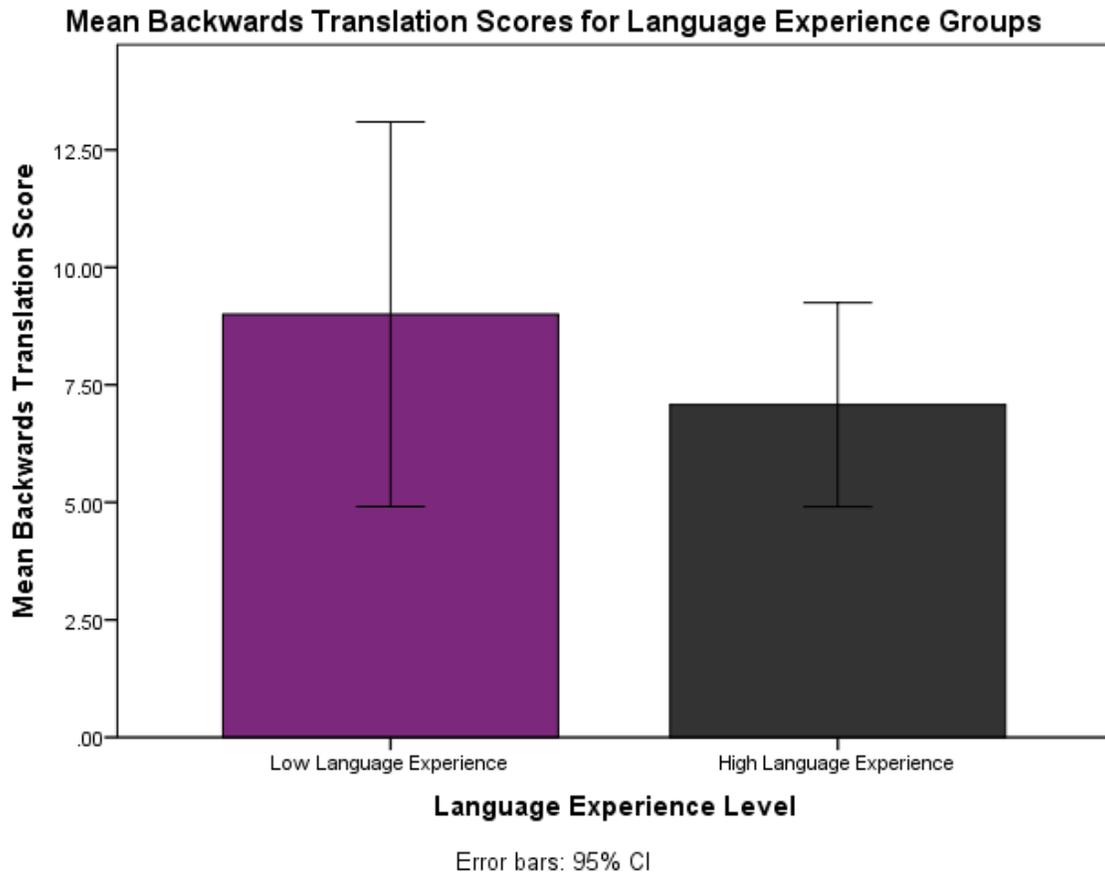
Figure 1. This bar graph shows the mean backwards translation scores for the low and high language experience groups. It can be seen that the mean score for the low language experience is higher than the mean score for the high language experience group.
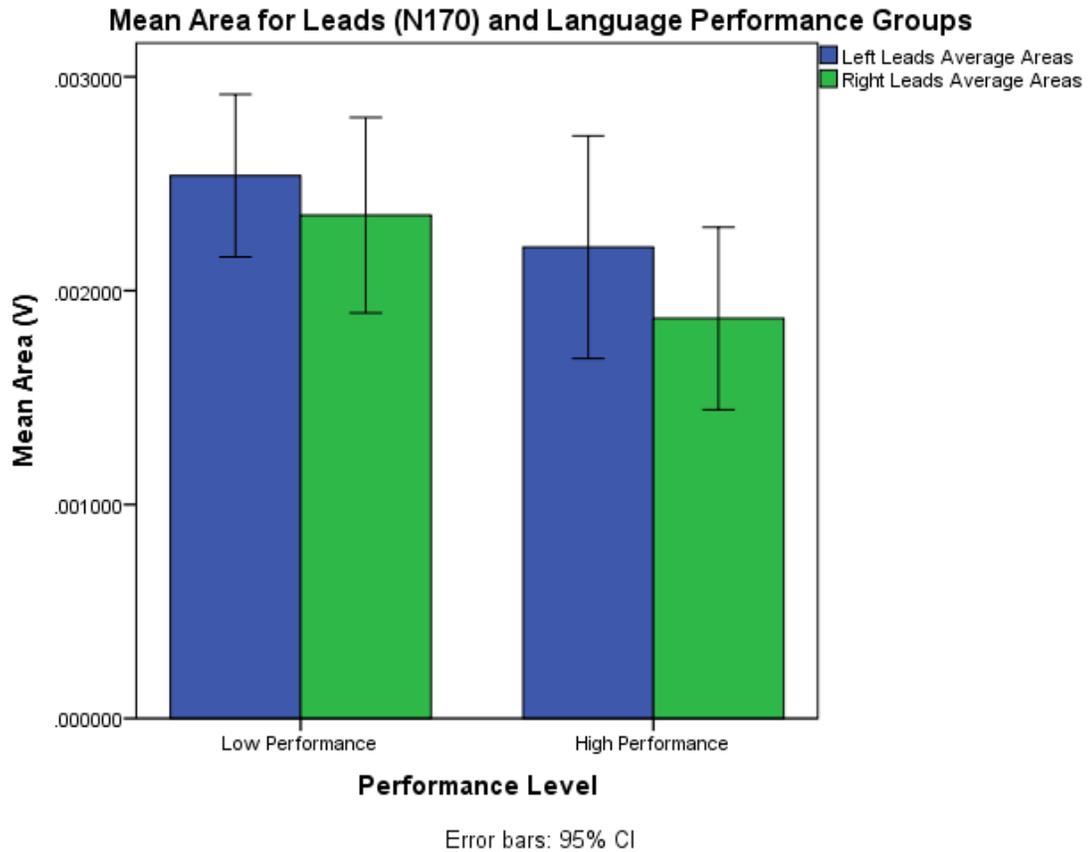
Figure 2. The preceding bar graph shows the mean area (V) for both left (O$_1$, T$_5$) and right (O$_2$, T$_6$) leads and language groups. It can be seen that there is a greater mean area difference in the high language performance group when compared to the low language performance group.
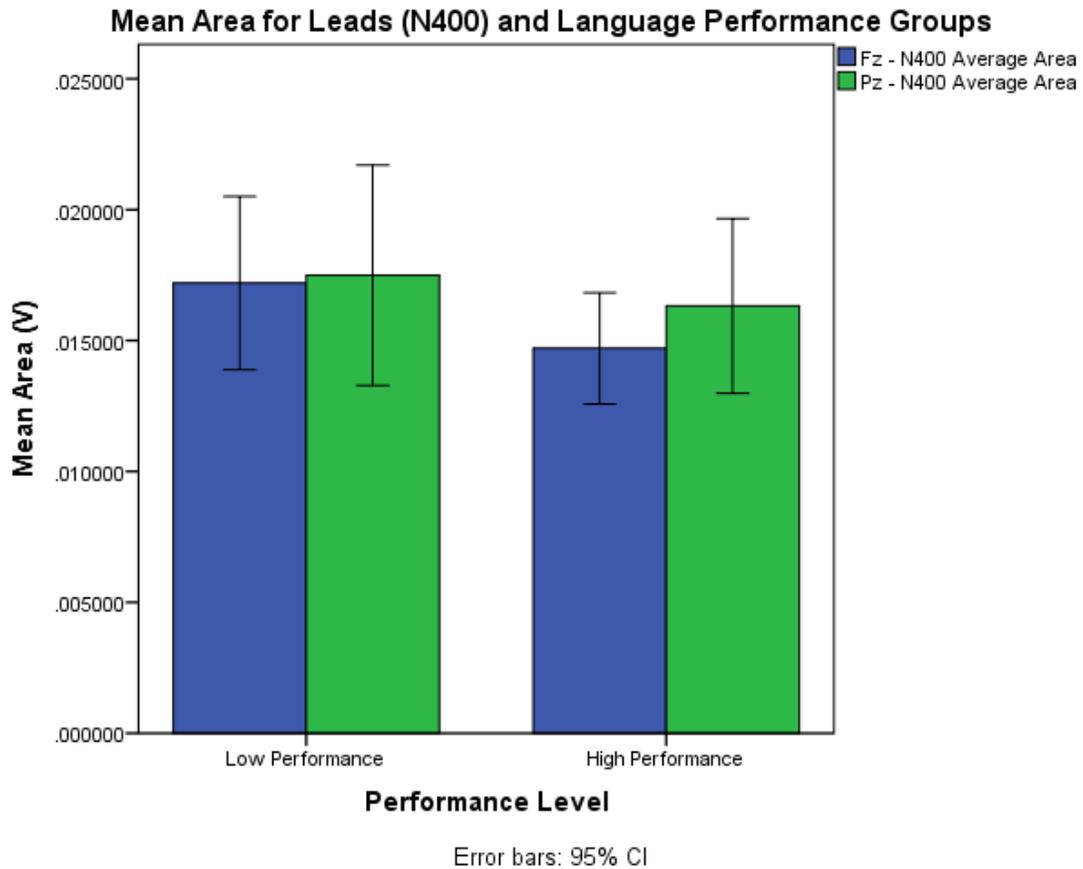
Figure 3. The preceding bar graph shows the mean area (V) for both anterior (F_z) and posterior (P_z) leads and language groups. It can be seen that there is a greater mean area for the low performance group's anterior and posterior leads when compared to the high performance group's leads.

Appendix

Language Experience Questionnaire

Are you between the ages of 18 to 25 (Check One)?   Yes_____   No_____

Please list any languages you consider yourself fluent in:

_____

_____

_____

_____

_____

_____

Other than English, please list the languages you are fluent in:	For each language, on a scale of 1-3 (1-moderately proficient, 2-proficient, 3-truly fluent), rate your:		
	Reading Level	Speaking Level	Writing Level

Have you ever lived or studied abroad for 3 or more months in a country whose main language is not English? (Circle One):

Yes or **No**

Please list any languages you know but do **NOT** consider yourself fluent in:

_____

_____

_____

_____

_____

_____

Other than English, please list the languages you know but are **NOT** fluent in:	For each language, on a scale of 1-3 (1-not proficient, 2-slightly proficient, 3-moderately proficient), rate your:		
	Reading Level	Speaking Level	Writing Level

Do you know, or are fluent in, any Asian languages i.e Chinese, Japanese, Korean? (Circle one):

Yes or **No**