中央大学博士論文

Towards Exploring Neural Basis of TILT (Translation in Language Teaching): Effectiveness of Read Aloud Instruction among Japanese Learners of English and Cortical Activations during Word Translation between Leaners at Different Learning Levels

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List of Abbreviation

CLT	Communication Language Teaching
DLPFC	dorsolateral prefrontal cortex
EFL	English as Foreign Language
ESL	English as a Second Language
fMRI	functional magnetic resonance imaging
fNIRS	functional near-infrared spectroscopy
L1	first language
L2	second language
LD	Linguistic Distance
LTM	Long-Term Memory
PET	Positron Emission Tomography
S/CRP	slash/ chunked reading practice
SIIL	strategy inventory for language learning
SLA	Second Language Acquisition
SRAWOP	simultaneous read-aloud and write out practice
STG	superior temporal gyrus
TILT	Translating in Language Teaching
RRAP	read-aloud practice
MEXT	Ministry of Education, Culture, Sports, Science and technology
ML	Mental Lexicon
WM	Working Memory

Chapter 1: General Introduction

1.1 Background

Nowadays, the world is becoming economically and culturally far more globalized than in the past. This is because there are faster and more reliable means of transportation and communication (Block & Cameron, 2002; Rodrik, 2011). In the midst of globalization, English has been regarded as an international universal language, or lingua franca, used as a means of cross-cultural communication (Crystal, 2012; Kirkpatrick, 2012; Seidlhofer, 2005; Sharifian, 2009). There are 7,079 languages in the world but approximately 60% of the languages used on the Internet is English (Simons & Fennig, 2018). In addition, 378 million people globally are native English speakers and 743 million people are non-native English speakers who use English in their daily lives. This means that the number of people using English as a second language (L2), not as a first language (L1), is approximately double that of native English speakers (Simons & Fennig, 2018). More than half of the world's population is bilingual or multilingual rather than monolingual (Marian & Shook, 2012). This means that over half of the people in the world use two or more languages in their daily lives (Tucker, 1999).

Japan is mostly a monolingual country (Hayashi, 2006; Heinrich, 2012; Watanabe, 2014). Nevertheless, many Japanese people are keen to become bilingual in Japanese and English (Hayashi, 2006). Based on growing globalization, since 1987, more than 30 years ago, the Ministry of Education, Culture, Sports, Science and technology (MEXT) has allocated native English speakers as Assistant Language Teachers (ALTs) to junior high and high schools using a program called JET (Japan Exchange and Teacher's Program). Despite such exposure to native English at school, it is said of Japanese people that their English proficiency as an international common language is low compared to other countries. This fact is evident in the scores of English tests such as the Test of English for International Communication (TOEIC; Educational Testing Service, 2020a), the International English Language Testing System (IELTS; IELTS Partners, 2020), and the Test of English as a Foreign Language TOEFL iBT (TOEFL; Educational Testing Service, 2020b). For instance, the average TOEIC score in Japan was 520 in 2018, ranking 45th out of 50 countries with more than 500 test takers in a year (Educational Testing Service, 2020). The Ministry of Foreign Affairs (2020) states that Japan had the world's third largest economy as of 2018 based on GDP (Gross Domestic Product) with an economic power that largely influences the global economy. However, Japanese people do not have a good command of English as a global lingua franca. Thus, it is worthwhile to consider the factors that make it difficult for Japanese people to acquire English.

1.2 Factors making it difficult for Japanese people to acquire English

1.2.1 Linguistic distance (LD) between Japanese and English

The LD between Japanese and English must first be taken into account. Chiswick & Miller (2005) stipulated that Japanese and English are linguistically the most distant, which contributes to Japanese people taking much more time to acquire English than people who speak a language with an LD close to English. The Japanese language is the most distant from English mainly based on morphological phonological and syntactical elements (Chiswick & Miller, 2005). The LD of other languages to English ranges from the lowest score (hardest to learn) of 1.00 for Japanese to the highest score (easiest to learn) of 3.00 for Afrikaans, Norwegian, Rumanian and Swedish. That is to say, the higher the score, the more easily people can acquire English. Needless to say, for L1 speakers to process an L2 with a large LD is not easy. Example scores are depicted in Table 1.1.

Table 1.1: Index of difficulty of learning English

Language	Score	Language	Score
Afrikaans	3	Swedish	3
Norwegian	3	Rumanian	3
Dutch	2.75	French	2.5
Spanish	2.25	German	2.25
Finnish	2	Greek	1.75
Vitnamese	1.5	Arabic	1.5
Mandorin	1.5	Cantonese	1.25
Japanese	1	Korean	1

1.2.2 Environmental factors – Social factors affecting English acquisition

Apart from the LD factor, whether or not Japanese people are exposed to English in their daily lives is widely associated with English acquisition. In research of Second Language Acquisition (SLA), our daily lives or environment as they pertain to everyday English usage are differentiated between an EFL (English as a Foreign Language) environment and an ESL (English as a Second Language) environment (Matsuoka et al., 2004; Riley & Harsch, 1999). These environmental differences are said to largely affect English acquisition (Oxford & Burry-Stock, 1995). Japan is an EFL environment (Sugita & Takeuchi, 2010; Taguchi, 2008), in which English is learnt as a school subject, but is not used as a means of teaching other subjects, and English is regarded as a foreign language. Also, English is not used as a means of daily communication. Moreover, English is not used for politics, economics or law as a public language. Hence, motivation to learn English is generally low (Sugino, 2010; Xaypanya, Ismail, & Low, 2017). As a result, the Japanese and people in other countries, such as China, Korea, Turkey and Brazil (Alshahrani, 2017), living in an EFL environment take a long time to acquire English (Alizadeh, 2016; Bahramy & Araghi, 2013; Krieger, 2012). Unlike the EFL environment, in an ESL environment, English is used as a means of teaching various school subjects. English is also used for politics, economics and law as a public language. That is to say that English is used as a tool for daily communication, and it is indispensable for people living in an ESL environment. Therefore, motivation to learn English is high, contributing to faster English acquisition (Longcope, 2009; Ng & Ng, 2015). As a result, people living in an ESL environment have positive attitudes towards English acquisition in comparison to their counterparts in an EFL environment (Brecht, Davidson, & Ginsberg, 1995; Lennon, 1995; Spada, 1986). Counties with an ESL environment include India, Nigeria, the Philippines and others (Falculan & Fragata, 2016). Hence, that the Japanese language is the most distant from English in LD and that Japan is an EFL environment are two factors considered to prevent Japanese people from acquiring high English proficiency. Next, the current English education in Japan is discussed.

1.3 Current English education in Japan

English education in Japan is largely divided into two systems: the communication-oriented system and TILT (Translation in Language Teaching), which includes translating L2 into L1. These education systems will compare below.

1.3.1 English Education based on Communication Language Teaching (CLT) in Japan

The current English education in Japan, supported by MEXT, is mainly based on a communication-oriented system called communication language teaching (CLT) that started in 1989. The principle of CLT is that English should be taught in English as much as possible and communication in English must be prioritized (Berger, 2011). According to MEXT (2018), improving English as a global lingua franca is indispensable for Japan's future because understanding cross-cultural communication has become an increasingly important issue in the midst of the rapid globalization of society. English based on CLT was introduced as an obligatory subject from the third year of primary school as of the fiscal year of 2020 based on MEXT curriculum guidelines. CLT is primarily focused on communication, which means that it requires much output (speaking and writing). However, Aoki (2014) and Nae & Kim (2018) point out that there is not sufficient output (speaking and writing), which is mandatory to acquire L2, in the present English education program in Japan. The insufficient output can be explained by the results of a survey conducted by MEXT (2017). The survey was carried out in June and July of 2017 by randomly choosing 60,000 third-year junior high school students and 60,000 third-year high school students, respectively, throughout Japan. The students took an English test to comprehensively measure the four skills (reading, writing, listening and speaking) of English. The results revealed that the students from junior high and high school did not reach MEXT's target levels for the four skills. In particular, third-year high school students were rated as having a low level of output (speaking and writing) skills. In order to supplement the lack of output, activities such as reading aloud or shadowing are encouraged for L2 acquisition (Aiga, 1990; Armbruster, 2010; Murphey, 2001; Thomson, Hall, & Jones, 2010; Lee, 2014).

1.3.2 English education based on TILT (Translation in Language Teaching)

As an alternative approach to CLT, the use of TILT (Translation in Language Teaching; translating L2 into L1) is encouraged to improve understanding of English. In other words, using L1 or translating L2 into L1 to understand L2 can aid L2 leaners to more effectively acquire L2 through English education (Cook, 2010; Hall & Cook, 2012; Widdowson, 1978). Interesting enough, Cook (2010), Hall & Cook (2012) and Widdowson (1978), well-known proponents of CTL, acknowledged how reasonable and effective it can be to take full advantage of translating L2 into L1 to acquire L2. They also asserted that translating L2 into L1 is a much quicker way to acquire L2. Cook (2010) stated that being able to translate is one of the major components of bilingual competence. Also, they argued that there is no scientific evidence that the activity of translating into L1 obstructs L2 acquisition. Zhao (2018) stated that building up the L2 mental lexicon (ML) can be promoted by translation activities, especially translating L2 into L1. In other words, translation activities can strengthen the links and associations of L2 to the ML (Zhao, 2018). Zhao (2018; 168) described that "translation activity may serve as a walking stick to assist learners to stand firm on the alien land of an L2 and gain strength and power in the acquisition process". Mart (2013) pointed out that the use of translation contributes to the use of L2 in an effective way and also improves L2 proficiency. Translation activity itself includes cognitive language processing and is one learning strategy (Zhao, 2018). Furthermore, Leonardi (2010) stipulated that while producing output, such as writing and speaking, translation activity is innately taking place for L2 learners. In order to consider the current English education in Japan, we must also discuss both input (reading and listening) and output (writing and speaking), which are indispensable for L2 acquisition (Ellis, 2005; Rott et al., 2002; VanPatten & Cadierno, 1993). Thus, we will review the relationships between input and output in English acquisition, and further explore its theoretical framework based on an applied linguistic viewpoint.

1.4 Theory of Second Language Acquisition (SLA)

Both input (reading and listening) and output (writing and speaking) are requisite for L2 acquisition. Without the experience of listening to or reading an unknown language or an unknow word, it is impossible to actively listen to or read the language or the word. Likewise, without the experience of writing or speaking an unknown language or an unknown word, it is impossible to actively write or speak the language or the word. L2 learners often begin their language acquisition with listening for L1 and reading for L2 (Behrens, 2006). In other words, input activity is important in the early stages of language acquisition for both L1 and L2. The importance of input in L2 acquisition is emphasized by the input hypothesis (Krashen, 1982; 1985).

1.4.1 The Comprehensible Input Hypothesis

The comprehensible input hypothesis (Krashen, 1982; 1985) puts forth that reading and listening (input) to L2 is an important key to obtaining knowledge in L2 acquisition. This hypothesis asserts that an appropriate quantity and quality of English input is essential for L2 acquisition. In particular, Krashen (1982;1985) discusses the quality of input. The "*i*" means the current level of English learners, which the first letter, *"i"*, of interlanguage. The "+1" indicates that a little bit difficult and unknown knowledge for L2 is added. That is, ideal input (reading and listening) must be a little higher level than the present L2 learners' acquisition level. When the level of L2 acquisition is lower than the present learners' level such as "*i*-1" or "*i*-2", which means the level is easier or too easy in comparison to their current level of L2, L2 learners cannot improve their English skills. Conversely, when the level of L2 acquisition is too higher ("*i*+2" or "*i*+3") than their current L2 level, this input hypothesis stipulates that L2 learners cannot understand inputted English, resulting in failure in acquiring L2.

1.4.2 The Comprehensible Output Hypothesis

Just after the comprehensible input hypothesis supported by Krashen (1982;1985), Swain (1985) and Swain & Lapkin (1995) asserted the comprehensible output hypothesis, which indicates that both writing and speaking (output) are also significant to acquire English as L2 learners. Based on the comprehensible output hypothesis, Swain (1985) and Swain & Lapkin (1995) suggested that L2 learners should realize and notice their limitations by using their own interlanguage of English effortfully. Swain (1985) and De Bot (1996) stipulated that this cognitive language processing can play four significant roles as described below. First, L2 learners can notice the gap between 'what they want to say to someone' and 'what they can say to someone' through their output, namely, speaking and writing. The ability to notice the gap (Schmidt, 1990) is said to be concerned with L2 learners' proficiency (Doughty & Williams, 1998). When L2 learners are unable to say something to someone, they can realize the weakness of their own L2 proficiency. The weakness is divided into two aspects: A. There are some limitations due to which L2 learners cannot express what they want to say in English (L2). B. There are some gaps between their accurate remarks and their inaccurate remarks (Doughty & Williams, 1998). Second, through output (speaking and writing), L2 learners can verify their own interlanguage proficiency. Then they can establish a hypothesis for how they can make someone understand utilizing their own vocabulary, syntax and phonological knowledge. In order to test this hypothesis, they try speaking to someone to observe whether or not what they want to say is comprehensible. Third, outputting can promote syntactic processing in L2 learners. Swain (1985) argued that L2 learners cannot improve syntactic processing with comprehensible input (Krashen, 1982;1985) because the input is based mainly on semantic processing. In other words, outputting can allow L2 learners to consciously reflect on their own grammatical knowledge. Finally, continuous output by an L2 learner can allow them to automatize their own L2 language processing based on the comprehensible output hypothesis (De Bot, 1996; Swain, 1985). This indicates that outputting can transfer declarative memory to procedural memory. That is to say, there is a huge dichotomy between what they know in their mind and what they can do practically. Repeated output of their L2 knowledge is mandatory for them so as to automatize their knowledge (De Bot, 1996). In particular, in order for L2 learners to acquire English, they are required to produce as much output as possible (Swain, 1985 and Swain & Lapkin, 1995). As described above, it can be said that the input hypothesis alone cannot elucidate the principles of L2 acquisition, but that the inclusion of the comprehensible output hypothesis can clarify L2 acquisition and can establish a more in-depth L2 acquisition theory.

1.5 The purpose of this dissertation and its study outline

As described above, the much lower English proficiency among Japanese leaners of English compared to other countries might be associated with linguistic and environmental factors. That is, the Japanese language is the most distant from English in terms of linguistic distance (LD). Moreover, Japan is in an EFL (English as a foreign language) environment, resulting in insufficient output in terms of the use of English. This further leads to insufficient output in English education. Considering these conditions, the purpose of this doctoral dissertation is to investigate the second language acquisition mechanisms of Japanese learners of English. To achieve this purpose, two studies were conducted. One focused on the effectiveness of English learning methods expected to be cognitively effective. The other explored the cognitive neuroscience perspective of a word translation activity, which is the most basic tool for second language acquisition. In Chapter 2, the details of study 1, which examined the effectiveness of an English learning method called the “read-aloud instruction package" (Shinozuka, Mizusawa, & Shibata, 2017), will be described. The "read-aloud instruction package" consists of four parts: slash reading, reading aloud, cloze test and simultaneous read-aloud and writing out. This method is expected to compensate for the lack of output in the current English education system in Japan (Aoki, 2014; Nae & Kim, 2018). In study 1, this method was intensively applied to Japanese university students with an elementary level of English to assess whether or not it was effective for improving their English skills. The effects of this method on their motivation and learning strategies were also examined. In "the read-aloud package instruction”, word translation, which is the most basic process in second language acquisition, was the essential activity. As described in Chapter 3, study 2 was conducted to examine cortical activation patterns during word translation with a neuroimaging approach in order to clarify cognitive processing during word translation. There are various levels of Japanese learners of English. Because the level of English acquisition may affect the cortical activation patterns during translation, both advanced Japanese learners of English who might easily translate Japanese into English and vice versa and elementary learners who might not easily do the same thing were compared. In study 2, the effects of word translation direction (Japanese-into-English/English-into-Japanese) and word familiarity were also examined.

Chapter 2:

Effectiveness of Read-aloud Instruction on Motivation and Learning Strategy Among Japanese College EFL Students (Study1)

2.1 Introduction

English is considered the most important international lingua franca in the world and many efforts have been made in the past decades to improve EFL students' English proficiency in various aspects (e.g., professional training, teaching strategy, curriculum development, and creating better instructional materials). More recently, in order to improve overall English skills in Japan, given this age of globalization, English instruction has been implemented from the third year of primary school (Ministry of Education, Culture, Sports, Science and Technology in Japan, 2013). However, despite these efforts, the English language proficiency of Japanese college students is still not satisfactory. The English Proficiency Index (EPI) indicated that Japanese adults have not improved their English in the past six years, while other Asian countries, most notably Indonesia and Vietnam, have made a significant progress (Japan Today, 2014). The EPI also indicated that Japan ranked 26th out of 65 countries in global English proficiency in spite of being a far wealthier and more developed country. "Japan is struggling to teach English for use in a competitive global economy" (Japan Today, 2014). Educational Testing Service (ETS, 2010) also revealed that the average score of Japanese college students measured on the TOFEL iBT® (internet-based test) in 2010 was considerably low, and was ranked 27th out of 30 Asian countries. International English Language Testing System (IELTS, 2015) also showed that the Japanese academic module candidates' mean band score in 2012 ranked 14th among 15 Asian countries.

Poor performance in English among Japanese college EFL students has often been attributed to pedagogical issues in teaching methods which are still considered teacher-centered (Diaz-Maggioli, 2004), or focused on grammar-translation method (Smith, 1981). In addition, poor English proficiency of Japanese students has been associated with linguistic distance (LD) influencing in the considerably low results in TOEFL and IELTS. This suggestion is supported by Chiswick & Miller (2005) who analyzed that LD between English and Japanese languages is farther compared to distance between English and Afrikaans Norwegian, Rumanian and Swedish.

Seeking more effective teaching methods has been one of the main goals in the field of TESOL/ESL in Japan, which motivated Shinozuka, Mizusawa, and Shibata (2014) to design the "read-aloud instruction package." This series of instructional methods emphasizes repeated read-aloud practices which are combined with other classroom activities such as slash/chunked-reading, cloze-test, and simultaneous read-aloud and write-out practice. In their study, Shinozuka et al. (2014) found that their instruction package improved students' EFL proficiency after three months of instruction. However, there was still a need to investigate the effectiveness of these instruction practices with a different participant group in order to determine further support for the findings of Shinozuka et al. (2014). This study also explored the influence of these instructional methods, if any, on student motivation and learning strategies, two significant factors for successful language learning.

2.2 Literature Review

2.2.1 Read-aloud instruction package

To improve students' EFL proficiency, Shinozuka et al. (2014) designed the "read-aloud instruction package" for Japanese college EFL students whose English proficiency was at the elementary level, based on TOEIC IP (Institutional Program) scores as a placement test conducted by the college of the participants (Shinozuka et al, 2014, 116). Rationales for effectiveness of each of the four components of instruction are discussed below.

2.2.1.1 Slash/chunked reading practice (S/CRP)

Read-aloud practice involves "*chunking,*" which involves taking a large text passage or individual words and breaking them into smaller chunks. Much previous research has found that S/CRP increases reading speed (Ellis, 2003; Newell, 1990; Nishida, 2009; Ohtagaki & Ohmori, 1991; Tan & Nicholson, 1997), and improves reading fluency and comprehension of struggling students in reading (Jones, 2012; Kadota, 1982; Kiroglu & Demirel, 2012; Kowal, O'Cannel, O'Brien, & Bryant, 1975). Struggling readers, on the other hand, often do not understand where a meaningful phrase ends, and they do not understand the whole sentence (Ransinki et al., 2005), whereas advanced readers are able to read a text by chunking it into meaningful phrase units effortlessly because they understand the sentence structure. They are not only able to process reading materials on a surface basis but comprehend the deeper meanings of the materials. In other words, successful readers can skim and scan reading materials, at the same time they can read them in a more in-depth way (Ransiki et al., 2005). S/CRP helps the readers comprehend syntactical sentence structure (Foder, Bever, & Garrett, 1974; Schreiber & Read, 1980). Casteel (1988) investigated if S/CRP would be beneficial for improving the reading skills of high school students with learning disability. In comparing the experimental and the control groups, he found that the chunked reading group significantly improved their reading skills. Furthermore, the effectiveness of S/CRP is also explained from a neuroscientific perspective (i.e., the working memory) system in the brain (e.g., Gilbert, Boucher, & Jemel, 2014; Just & Carpenter, 1987). Hook and Jones (2002) stated that S/CRP might be used for students with dyslexia. Because of these positive findings from previous studies, S/CRP was included as a teaching method in the "read-aloud instruction package" in this study.

2.2.1.2 Repeated read-aloud practice (RRAP)

Developing fluency and automaticity in word and syntactic processing are indispensable elements (Grabe & Stroller, 2002). Similarly, Stoddard, Valcante, Sindelar, and Algozzine (1993) state that repeated oral reading practice may contribute to increasing both fluency and automaticity in reading. In support of this, Schwanenflugel, Harnishleger, and Stowe (1998) found that oral reading practice could lead to improving decoding speed and developing prosody in reading, as well as reading comprehension skills. Chang (2012) examined the effects of repeated oral reading on 35 college students in Taiwan, and found that it can be beneficial to increasing reading comprehension skills. In addition, Fuchs, Fuchs, and Hosp (2001) found that the correlations between oral reading fluency and comprehension were very high (r =.81 to .90), which concurred with other studies (see, for example, Miyasako, 2008).

2.2.1.3 Cloze tests

Cloze tests are similar to fill-in-the-blank tests, and have a relatively long history established by Taylor (1953) for various purposes. Since the validity and reliability of the test were supported by numerous researchers (e.g., Darnell, 1968; Jongsma, 1971; Oller, 1972), the tests have been used as a major measurement of overall language proficiency since the 1970s (see Jongsma, 1971; Oller, 1976; Robinson, 1972). There are some opponents who are skeptical of the effects of cloze tests, claiming that the tests only measure the ability to make localized connections in the texts (Alderson, 1980;

Porter, 1983; Bachman, 1982 and 1985). However, Alderson (1979) and Readance, Balwin, Bean, and Dishner (1980) state that the cloze tests are a particularly valid measure of reading comprehension as well as text readability for native speakers of English, and are one of the most useful tools for assessing reading comprehension level, learning process, and accurate grammatical knowledge of EFL learners. For nonnative English speakers, it is considered as a reliable measure of comprehensive L2 language proficiency (Bialystok & Howard, 1979; Aitken, 1977; Oller, 1976).

2.2.1.4 Simultaneous read-aloud and write-out practice (SRAWOP)

Since Kunihiro (1970) introduced this method for Japanese EFL learners in the early 1970s, it has become one of the important teaching methods of English in Japan. This resembles transcription, but EFL students are required to read the passage verbally themselves instead of a third person. While reading aloud has been a common practice in L2 language classrooms in Japan, simultaneous read-aloud and write-out practice is not, and little research has been conducted which sheds light on this method.

This method has two concepts: the EFL students are supposed to read aloud, and then write down meaningful English sentences and vocalize them simultaneously. The method uses three major sensory motor elements simultaneously, i.e., visual (visual input of the reading materials), kinetic (read-aloud, verbal output), auditory (listen to one's own reading through bone conduction[1]), and kinetic again (handwriting/writing out). It is suggested that using various cognitive sensory motor elements simultaneously promotes better memorization and conservation in long-term memory (LTM), as well as better access to LTM (i.e., recall/retrieve necessary information easily) (e.g., Baddeley, 1986, 1998, 1999; Pontart et al., 2013). Kunihiro (1970) also claims that kinetic exercise, similarly to playing sports, helps to automatize learning. He also states that for elementary level EFL learners, after the critical period (Lenneberg, 1967), repeated reading aloud and writing out are both mandatory in order to acquire L2.

Figure 2.1 illustrates a simultaneous read-aloud and write-out practice. As the figure indicates, this practice includes the four skills of language (i.e., reading, listening, writing and speaking) with visual and auditory input and oral/ kinetic output.

[1] Bone conduction is defined as the conduction sensor of sound to the inner ear via the bones of the skull (Carhart, 1950).

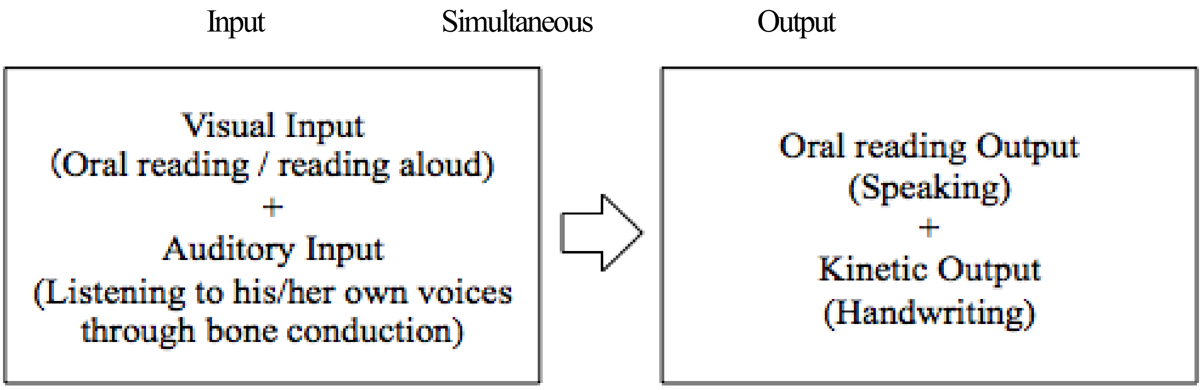

Figure 2.1. Model of simultaneous reading-aloud and writing-out practice

2.2.2 Motivation of EFL Learners

Learner motivation has been a popular topic for many ESL/EFL researchers since it is claimed to play an important role in developing a second or foreign language. Gardner and Lambert (1972) were the first scholars who classified motivation to learn a foreign language as instrumental and integrative (see also Gardner, 1985a, 1985b). They found that integrative motivation was positively related to higher proficiency than instrumental motivation. However, there are a number of studies that found instrumental motivation was related to higher proficiency rather than integrative motivation (e.g., Au, 1988; Oller, Hudson & Liu, 1977). Even though these two categories persist in being the essential components, recent scholars have explored alternative motivation models to explain and accommodate learners' social and cultural backgrounds, and to investigate the relationship between learners' English proficiency and their motivation (Dörnyei, 1994; Oxford & Shearin, 1994). Ely (1986) found three distinct motivation clusters by using a factor analysis, e.g., integrative, instrumental, and the foreign language requirement. In the Japanese university EFL context, Ayabe, Kano and Ito (1995) identified factors which are not directly related to the purpose of learning a foreign/second language, such as to obtain a good grade and to respond to the expectation from parents and/or others. Yoshida (2009) mentioned that responding to the expectation from parents and/or others is a uniquely important concept in Japanese culture, where traditionally "family" precedes "individual" and children have been required to meet parents' expectations. Brown (2004) identified four factors using factor analysis, i.e., personal development, job-related factors, intrinsic interest, and pop-culture related factors. Miyahara et al (1997) compared motivation to learn English among university students in China, Korea, and Japan, and found that integrative motivation of Japanese learners differed from the other two Asian countries.

They concluded that Japanese students did not have a strong desire to learn English for the purpose of integrating into English-speaking communities, but have a general positive interest in traveling and communicating with native English speakers. In Yashima's study (2000), it was reported that learners who were both instrumentally and integratively motivated earned higher proficiency.

Motivation is an important factor in learner success as mentioned earlier, and teaching skills to teachers to motivate learners in the classroom is an important part of teaching effectiveness. Dörnyei and Csizer (1998) identified that the environment for learning is one of the components that affects a learner's motivation, and proposed ten specific teaching strategies to motivate language learners based on the survey results of two hundred Hungarian teachers of English. In a study by Hiromori and Tanaka (2006), it was found that five weeks of task-based group presentation activity enhanced the Japanese university EFL learners' intrinsic motivation. Kato (2012) also reported three classroom activities, i.e., reproduction, group work, and shadowing practice, increased the learners' self-autonomy after 14 weeks. Nevertheless, these previous studies used a motivation survey only after the instruction. The current study, therefore, conducted pre and post survey after the instruction to assess whether the instruction (read-aloud instruction package) enhanced student motivation.

2.2.3 Learning strategy and language proficiency

Language learning strategies are generally defined as the EFL learner's consciously chosen tools for active, self-regulated improvement of language learning. There are a number of ways to categorize types of learning strategies (e.g., Purpura, 1997; Gan, Humphreys, & Hamp-Lyon, 2004; O'Malley, Chamot, Stewner-Manzanares, Kupper, & Russo, 1985), but "Oxford's (1990) work lays out the most exhaustive hierarchy of learning strategies to date." (Rivera-Mills & Plonsky, 2007, p. 535).

Oxford (1990) divided the strategies into two major classes: direct and indirect, and then subdivided them into a total of six subgroups. "Indirect" strategies are those that support or manage language learning without directly involving the target language (Oxford, 1990, p. 135). The six subgroups of learning strategies are: (1) Memory strategies for storing and retrieving information, (2) Cognitive strategies for understanding and producing the language, (3) Compensation strategies for overcoming limitations in language learning, (4) Metacognitive strategies for planning and monitoring learning, (5) Affective strategies for controlling emotions, motivation, and (6) Social strategies for cooperating with others in language learning. Memory, Cognitive, and Compensation strategies are under the "direct" strategies category, and Metacognitive, Affective, and Social strategies are under the "indirect."

Many studies have been conducted to establish the relationship between ESL/EFL learning strategies, and the wide range of variables found in learners such as age or school year (e.g., Griffiths, 2003; Oxford & Ehrman, 1995; Riazi, 2007; Srisupha, 2012), English proficiency (e.g., Baker & Boonkit, 2004; Ghafournia, 2014; Murray, 2010), cultural background (e.g., Alhaisoni, 2012; Lengkanawati, 2004), motivation (e.g., Oxford & Nyikos, 1989), and personality traits (e.g., Kaufman et al., 2008; Moldasheva & Mahmood, 2014). Previous studies also found that more successful ESL/EFL learners tend to make more frequent use of learning strategies overall (e.g., Ghani, Mahfuz, Saad, & Yusoff, 2014; Akbari, 2003, Green & Oxford, 1995; Murray, 2010; Wharton, 2000). Some studies also examined the learners' cultural backgrounds. For example, Iranian students used metacognitive strategies the most frequently, followed by cognitive and social, with affective being the least (Pishghadam, 2009). Khamkhien (2010a, 2010b) found that Thai and Vietnamese EFL students used compensation the most, followed by cognitive and metacognitive strategies, while Baker and Boonkit (2004) reported metacognitive, cognitive and compensation were the strategies that more successful Thai students used the most. Murray (2010) found that more advanced Korean learners of English used cognitive and memory strategies more often, and Lai (2009) reported metacognitive and cognitive were the strategies used by advanced Taiwanese learners than less advanced students. Tandoc and Tandoc-Juan (2014) studied the most preferred learning strategies of English among college students in the Philippines. They found those most preferred to be memory strategies for the first-year students, social for the second and third, and affective strategies for the fourth-year students. In the Japanese context, Wakamoto (2000) compared extroverts and introverts regarding their learning strategies of English among English majors. He found that extroverts were more willingly to make mistakes and tried to speak out with few inhibitions. Since extroverts are considered better language learners (e.g., Zafar & Meenakshi, 2012, p. 36), the author implicated that among Japanese college students, successful learners tended to use more socio-affective strategies. In sum, although some differences were found in subgroups among different ethnic groups, many scholars agree that more successful learners use strategies overall more frequently than less successful learners of English.

2.2.4 Research Question

The research question in this study is threefold:

1) Is the “read-aloud instruction package” effective with different students?
2) Does the “read-aloud instruction package” influence the student’s motivation to learn English?
3) Does the “read-aloud instruction package” influence the student learning strategy for English?

2.3 Methodology

2.3.1 Participants

The participants were 32 first-year students whose nationality was Japanese, and who studied in the same college located in a suburb of Tokyo, Japan. They were either 18 or 19 years old at the time of this study. None of them had experienced living in a foreign country more than one year. Based on a placement test （TOEIC IP）, their English proficiency levels were at an elementary level. Informed written consent was obtained from the participants.

2.3.2 The Read-aloud Instruction package and its effectiveness

In this study, the reading materials were obtained from the Japan Times ST, available online. We chose some materials which interested the participants such as those about incidents that occur in our daily lives. The average readability of the materials was from 9 to 10 based on the Flesch-Kincaid Grade Level (FKG) and the Colman-Liau Index (CLI). The average word length of the materials was 66 words. By using the above reading materials, the “read-aloud instruction package”, i.e., slash/chunked reading, reading aloud practice, cloze test and finally simultaneous practice of read aloud and write out were implemented.

The TOEIC Bridge ®Test was administered twice to measure English proficiency before (pretest) and after (posttest) three months’ intensive read-aloud instruction package. Dependent t-tests were applied to determine if there was a significant difference between pretest and post test scores using SPSS (version 14) to answer research question part 1).

2.3.3 Questionnaires

Three questionnaires were used in this research: a student background questionnaire, a motivation survey, and a Japanese version of the Strategy Inventory for Language Learning (SILL) (Oxford, 1990), described below.

- *Student background questionnaire*. This questionnaire collected the following data: age, gender, school year, and number of years of studying English.
- *Motivation survey.* A version modified by Narita (1998), which was originally adapted from the Motivation Questionnaires Battery by Gardener and Lambert (1972), was used to obtain the students' motivational information. The survey consists of 36 Likert-scale items ranging from 1 (strongly agree) to 5 (strongly disagree). The instrument achieved a reliability of 0.86 (Cronbach's alpha).
- *Strategy Inventory for Language Learning.*

The original 50-item English version 7.0 of Strategy Inventory for Language Learning for Speakers of Other Languages Learning English (SILL) (Oxford, 1990) was used to measure the students' learning strategies and answer research question part 3). Each item was translated into Japanese, and its accuracy and appropriateness were proof-read by two English-Japanese bilingual scholars. The questionnaire used a five-point Likert-scale ranging from 1 (never or almost never true of me) to 5 (always or almost always true of me), and each item represented a subscale category of one of the following six learning strategies: A) Memory (e.g., "Remembering more effectively," item 1 - 9); B) Cognitive (e.g., "Using all your mental processes," item 10-23); C) Compensation (e.g., "Compensating for missing knowledge," item 24-29); D) Metacognitive (e.g., "Organizing and evaluating your learning," item 30-38); E) Affective (e.g., "Managing your emotions," item 39-44); and F) Social (e.g., "Learning with others," item 45-50). The instrument achieved a reliability of 0.92 (Cronbach's alpha).

Oxford (1990) suggested interpreting the level of use based on the following range of average SILL scores:

High strategy use	3.5 – 5.0
Medium strategy use	2.5 – 3.4
Low strategy use	1.0 – 2.4

The results of this study are compared to the above scores.

2.4 Results

2.4.1 Read-aloud instruction package and English proficiency

The means and standard deviations for the pretest and posttest, and the results of dependent t tests are shown in Table 2.1. As the Table 2.1 indicates, both listening and reading scores improved significantly after three months' intensive instruction using the "read-aloud instruction package". The listening score increased 9.62 points and the reading score 3.53 points, for a total gain of 13.15 points (from 112.63 to 125.78).

Table 2.1: Pre and Posttest Comparisons of TOEIC Bridge Score

	Pretest (N=32)		Posttest (N=32)			
	Mean	SD	Mean	SD	Post-Pre	*t*-value
Listening Score	53.97	8.13	63.59	5.90	9.62	6.03*
Reading Score	58.66	8.15	62.19	9.03	3.53	2.64*
Total Score	112.63	12.31	125.78	12.45	13.15	6.73**

Note. $*p < .05$, $**p < .001$

2.4.2 Read-aloud instruction package and student motivation to learn English

The following Table 2.2 shows the results of pre and posttests according to each factor of learner motivation. As the results indicate, no significant changes of motivation were found after the instruction. "To communicate with other people" decreased 0.13); "To learn an academic subject in English" decreased 0.01); "To obtain cultural knowledge" decreased 0.02); "To use English as a future career" decreased 0.02); "To meet the expectations of parents" increased 0.13); and "To fulfill graduation requirement" increased 0.20. However, none of these changes were statistically significant.

Table 2.2: Pre and Posttest Comparisons of Motivation Inventory

	Pretest (N=32)		Posttest (N=32)		
	Mean	SD	Mean	SD	*t*-value
A: Communication	3.82	0.63	3.69	0.83	-0.88
B: Academic	2.61	0.79	2.60	0.76	-0.07
C: Culture	3.63	0.62	3.61	0.65	-0.31
D: Career	3.32	0.49	3.30	0.63	-0.26
E: Meet the expectation	3.46	0.68	3.59	0.67	1.16
F: Requirement	2.81	1.16	3.01	1.05	0.99

Note. A: To communicate with other people, B: To learn an academic subject in English, e.g., linguistics and literature, C: To obtain cultural knowledge, D: To use English as a tool for future career, E: To meet the expectation of parents, F: To fulfill graduation requirement. $*p < .05$

2.4.3 Read-aloud instruction package and student learning strategy for English

Table 2.3 shows the results of pretest and posttest of each category of student learning strategy for English as a foreign language. Scores for all strategies fell between 2.5 and 3.4, the range for medium strategy use. Statistically, two out of six categories of student learning strategies changed significantly: "Using all your mental processes" increased 0.23 from pre to posttest and "Learning with others" decreased 0.55. Although no statistically significant changes were found in the other categories, the raw scores increased from pretest to posttest in all four categories.

Table 2.3: Pre and Posttest Comparisons of Learning Strategies

	Pretest (N=32)		Posttest (N=32)		
	Mean	SD	Mean	SD	*t*-value
A: Remembering	2.81	0.49	2.93	0.57	1.40
B: Using mental process	2.69	0.50	2.92	0.58	**3.39***
C: Compensating	2.76	0.62	3.00	0.59	1.84
D: Organizing	2.59	0.63	2.77	0.53	1.73
E: Managing emotions	2.64	0.73	2.73	0.64	0.87
F: Learning with others	2.83	0.71	2.28	0.90	**-3.30***

Note. A: Remembering more effectively, B: Using all your mental processes, C: Compensating for missing knowledge, D: Organizing and evaluating your learning, E: Managing your emotions, and F: Learning with others. $^{*}p < .05$

2.5 Discussion

The current study establishes the effectiveness of the "read-aloud instruction package", which is consistent with the study conducted by Shinozuka et al. (2014). Because the instruction is designed to use all sensory motor skills as explained previously, higher scores for the participants on the TOEIC Bridge® after the instruction might be related to a change in language processing in the brain. The following sections explain the effectiveness of the instruction from neuro-linguistic and cognitive linguistic viewpoints.

First, we analyzed the basis for effectiveness of S/CRP. In this study, EFL students scored significantly higher on both reading and listening subtests after the instruction. Reading processing requires two different but highly interrelated areas in the first place, word recognition and comprehension, regardless of the language in question. It is clear that difficulty in automatic word identification is significantly associated with an EFL reader's ability to effectively comprehend what s/he is reading (Lyon, 1995; Torgersen, Reshot, & Alexander, 2001). The ability to recognize individual elements is crucial for reading (James & Engelhardt, 2012), and improves one's reading skills.

The results are compatible with many previous studies, including findings that S/CRP facilitates reading speed (e.g., Ellis, 2003; Newell, 1990; Nishida, 2009; Ohtagaki & Ohmori, 1991; Tan & Nicholson, 1997) and understanding of meaningful sentences/phrases (Nishida, 2013). Nishida (2013) concluded in her research findings that learning chunking is effective in improving EFL learners' reading comprehension and that it also poses more benefits when taught along with phrase/syntactic structures. The results of this study are also consistent with Cathercole and Baddely (1990), who mentioned that repeated slash/chunked reading instruction should be effective in improving phonological loop function in working memory for not only struggling readers of English as a second language, but also people with learning disability/dyslexia.

Second, the basis for the effectiveness of simultaneous read-aloud and write-out practice was considered. This practice forces the participants to conduct input and output simultaneously, that is to say, comprehensible reading aloud as visual input, and writing with correct spelling and speaking with accurate pronunciation as output. The activity also requires maintaining concentration to focus on listening and writing, and to use almost all perceptual motor skills. From neuro-scientific perspectives (Grafton et al., 1992; Jenkins, Brooks, Nixon, Frackowiak, & Passingham, 1994; Seitz & Rolan, 1992), using various motor skills simultaneously results in acquiring far better memorization. Many scientists consider the simultaneous and sequential motor action and learning practice to be fairly similar to cognitive rehabilitation and kinetic movement for patients with brain injury when it comes to visual-spatial and linguistic function domains in the cerebral cortex (Müller, Kleinhans, Pierce, Kemmotsu & Counchnsens, 2002; Schaechter, 2004; Potgieser, van der Hoorn, & de Jong, 2005). These various forms of input as stimuli and output as response seem to eventually strengthen cognitive language processing as it is reinforced in the brain. Consequently, similar to cognitive and kinetic rehabilitation, the repeated simultaneous read-aloud and write-out practice would lead to improving English skills (Müller, Kleinhans, Pierce, Kemmotsu & Counchnsens, 2002; Schaechter, 2004; Potgieser, van der Hoorn, & de Jong, 2005).

Third, the basis for effectiveness of reading aloud was investigated. Unlike silent reading (subvocal reading/inner speech), reading aloud obliges the reader to vocalize reading materials, which includes accurate stress, rhythm, tone, and intonation. The EFL students were instructed to pay attention to these prosodic aspects of language. Miyasako (2008) found a positive relationship between the level of reading comprehension and reading aloud skill. Kadota (1982) explained that repeated reading aloud practice enhanced automatic language processing and improves English reading skills because the reading aloud practice requires the reader to concentrate on comprehending the contents of what s/he is reading. He also mentioned that the practice is beneficial for much faster speech coding and internalizing reading skills, including knowledge of grammar and vocabulary. As a result, silent reading speed improved as well as grammar and vocabulary knowledge.

The effectiveness of reading aloud poses implications not only for EFL learners, but also for L1 students, especially those who have difficulty with reading comprehension. Considering the benefits of reading aloud, it was reported that elementary school children in the U.S. were able to build automaticity of word recognition and acquire the proper prosodic aspects of English as EFL learners did (Kuhn et al, 2006; National Reading Panel, 2000). Fuchs et al. (2001) proclaimed that being able to read aloud with accurate prosodic aspects could be one of the indicators of reading comprehension ability.

Fourth, regarding the effectiveness of cloze tests, the tests are considered a useful tool for measuring levels of reading comprehension and text readability for native English speakers (Alderson, 1980; Readance, J. E., Balwin, R. S., Bean, T. W., & Dishner, E. K., 1980), as well as for ESL/EFL learners (Aitken, 1977; Bialystok & Howard 1979; Oller, 1976). The most recent study also showed that cloze test practice improved English grammatical accuracy for Iranian EFL learners at the intermediate level (Mashhadi & Bagheri, 2015). Aitken (1977) mentioned that the majority of studies show that cloze performance correlates significantly with other measures of L2 proficiency. Additionally, in a cloze test, the participants need to implement a large number of interrelated skills which are composed of a language system (e.g., lexical, grammatical, and contextual) in order to predict and analyze accurately what word most appropriately fits into each empty space using the brain. It is reasonable to say that a series of cognitive, challenging, and arduous inference skills (Bialystok & Howard, 1979) are required when making an effort to fill in the blanks of cloze tests, effectively contributing to the improvement of L2 skills. Thus, by adopting cloze tests in the instruction package, the EFL learners' awareness of English skills might have improved, resulting in higher posttest scores.

Fifth, we carefully examined the influence that the read-aloud instruction had on students' motivation to learn English. Motivation is regarded as one of the crucial factors in successful learning outcomes, and many previous studies have demonstrated that EFL learners with higher proficiency tend to show stronger motivation (e.g., Gan, Humphreys, & Hamp-Lyons, 2004). It was also reported that some intensive instruction, such as group activities and shadowing practice, enhanced students' intrinsic motivation (Hiromori & Tanaka, 2006; Kato, 2012). Therefore, it was expected that the read-aloud instruction would increase some of the factors of motivation and raise English proficiency. However, no significant change was found in any factors of motivation after three months of instruction using the "read-aloud instruction package". One possible reason for this might be insufficient length of instruction. Three months of instruction can improve EFL students' learning outcomes of English, but it may be inadequate to change their level of motivation. Another possible explanation is the content of instruction. Unlike the studies by Hiromori & Tanaka (2006) and Kato (2012), the "read-aloud instruction package" was designed to improve EFL students' English proficiency, but was not designed to promote their motivation. According to Deci and Ryan (1985), the three psychological needs, i.e., competence, autonomy, and psychological relatedness motivate the learners. Perhaps, appropriate and relevant class activities which incorporate these three needs should be included in the instruction package to promote students' motivation. For example, communicative activities with native speakers might be effective in promoting motivation to communicate, and inviting professionals in the front lines as guest speakers might inspire students and eventually increase a motivation factor related to careers, etc.

Finally, the influence of the read-aloud instruction on student learning strategies for English was also discretely examined. The results showed that the learning strategy of using mental processes in learning increased significantly, while learning with other people decreased, and no changes were found in the other categories after the instruction. "Using mental processes" probably increased because the various activities which promoted use of mental processes were included in the instruction. Learning with other people probably decreased not because the EFL learners lost interest in learning with others, but because the instruction required more individual, independent study and encouraged autonomy and self-management of study plans. The current study also found a pattern of EFL students' use of learning strategies among Japanese college students whose English proficiency was elementary level. Frequency of their use of the six categories of learning strategies ranged from 2.5 to 3.0 out of 5.0, which is on the low side of medium frequency of use. Many previous studies agree that learning strategy use differs depending on the students' level of language proficiency. They have found that students of advanced-level proficiency use overall strategies more often than students with lower-level proficiency (e.g., Baker & Boonkit, 2004; Gharbavi & Seyyed, 2012). Considering the low level of English proficiency of the participants in this study, the result of low medium use of learning strategies is consistent with these previous findings.

2.6 Summary and Limitations of Research

The initial purpose of this project was to provide an effective instruction for EFL students at the elementary level of English using the "read-aloud instruction package" which was created by Shinozuka et al. (2014). The study demonstrates that the instruction successfully improved students' English proficiency in both listening and reading sub skills, which supports the earlier study by Shinozuka et al. (2014). In sum, it is reasonable to conclude that the "read-aloud instruction package" was effective regardless of EFL students' learning strategies, and this is because the instruction package included various activities which promoted all sensory-motor skills and accommodated various types of learning styles. It is recommended to include a variety of extra-curricular activities in the instruction to promote their motivation and enthusiasm to learn English, as well as to encourage to use various L2 learning strategies.

There are a number of limitations in this study. First, the pattern of EFL student use of learning strategies was examined only for the elementary level of English. Comparison with Intermediate and Advanced level of EFL learners' groups could be conducted for better understanding of the use of learning strategies for English among Japanese college students. Second, this study utilized as a measurement of learning strategy. Repetitive verification of the results using other instruments is necessary, considering the recent criticism regarding the validity of translated versions of SILL, especially in an ideographic language such as Japanese (Gao, 2004).

Additionally, in order to thoroughly and scientifically investigate the neural basis for this read-aloud instruction package, experiments using neuroimaging machines such as fMRI (functional Magnetic Resonance Imaging), PET (Positron Emitting Tomography) and fNIRS (fictional Near Infrared Spectroscopy) should be carried out to determine how brain activation and function will be changed before and after the instruction package.

Chapter 3:

Language familiarity and proficiency leads to differential cortical processing during translation between distantly related languages (study 2)

3.1 Introduction

In the midst of globalization, English is regarded as an international language, or Lingua Franca (Seidlhofer, 2005; Crystal, 2012; Kirkpatrick, 2012), with the number of worldwide English speakers being over 2 billion (Crystal, 2008). However, it is evident that the English proficiency of Japanese learners is fairly low regarding English test scores including the Test of English for International Communication (TOEIC; Educational Testing Service, 2020a), the International English Language Testing System (IELTS; IELTS Partners, 2020), and the Test of English as a Foreign Language (TOEFL; Educational Testing Service, 2020) in comparison to English learners in other nations.

Difficulty in handling English (second language: L2) for Japanese may be associated with linguistic reasons. The Japanese language (first language: L1) is the most distant from English in terms of linguistic distance (LD), which is mainly based on morphological, phonological, and syntactic elements (Chiswick and Miller, 2005). LD to English ranges from the lowest score (hardest to learn) of 1.00 for Japanese to the highest score (easiest to learn) of 3.00 for Afrikaans, Norwegian and Swedish. The LD score is determined by the ease/difficulty that Americans have learning different foreign languages, and it corresponds fairly well with differences in foreigners' ease/difficulty in learning English. For L1 speakers to process a L2 with a large LD is not an easy process. However, little is known about cognitive aspects of processing a distantly related L2. One possible approach may be to understand the neural basis for L2 handling by linguistically distant L1 speakers. In particular, we focused on exploring the neural basis of translation because it is an indispensable part of L1 speakers' handling of L2. Before exploring specific aspects of L2 with a large LD, we will first introduce existing models of the word product (output) system underlying translation for L2 speakers in general.

We will then review important behavioral and neuroscience experiments on translation conducted for L2 speakers in general. Finally, we will interpret the results of these experiments from a cognitive processing perspective.

The bilingual lexico-semantic system is an analytical cognitive model of L2 speakers' second language acquisition of words themselves and their meanings (Votaw, 1992). The system consists of several distinct elements: how the word looks (orthography), how it sounds (phonology), what it means (semantics), what syntactic properties it has (lemmas), and how it is pronounced (an output system that specifies the pronunciation of word forms) (Patterson et al., 1987; Indefrey and Levelt, 2000; Meyer et al., 2016). The bilingual lexico-semantic system is known to support a variety of linguistic activities such as reading, speaking, and switching between languages in translation in other (second) languages (Votaw, 1992; Price et al., 1999). Particularly, word translation by L2 speakers requires the speaker to generate the translation equivalent of the presented word rather than to merely name it (Green, 1986). In addition, these cognitive operations are assumed to be accomplished by modulating the activation of the language system (Grosjean, 1997; Paradis, 1997) with the inhibition control system, which is described under the scheme of the inhibition control (IC) model (Green, 1998; Ong and Zhang, 2010). This model sets and maintains the target, avoids naming words in L1, and instead produces the equivalent translation as a response. Therefore, it is assumed that the bilingual lexico-semantic system works accurately when the inhibition control system (Green, 1998; Ong and Zhang, 2010) adequately controls language processing.

Moreover, psycholinguistic data emphasize two different routes for translation (Kroll and Stewart, 1994; Kroll and De Groot, 2002; Duyck and Brysbaert, 2008): a non-semantic direct route (lexical route) in which the word forms of translation equivalents are linked at the lemma level (Jescheniak and Levelt, 1994) and an indirect route (semantic route) in which they are connected via their meaning (i.e., their lexical concepts). According to the IC model, word selection along either route involves lemma activation and the inhibition of lemmas with a non-target language tag. The involvement of these two routes is thought to differ depending on the direction of word translation (L1-into-L2 or L2-into-L1) (Jescheniak & Levelt, 1994; Price et al., 1999). In L1-into-L2 translation the semantic route is dominant, whereas in L2-into-L1 translation the lexical route is dominant, reflecting the acquisition of the L2 word in the context of a pre-existing lexical concept-word form link in L1 (Price et al., 1999). In fact, Kroll & Stewart (1994) suggested through experimental studies that L1-into-L2 translation may produce more semantic processing than L2-into-L1 translation does. Thus, it is of great importance to explore the neural basis of translation by examining cortical activation patterns in both directions, L1-into-L2 and L2-into-L1.

There are some behavioral experiments using word translation tasks. De Groot and Poot (1997) examined the performance of balanced bilinguals, translating one set of words from L1, Dutch, to L2, English, and vice versa. The LD between Dutch and English is known to be close, scored as 2.75 (Chiswick and Miller, 2005). Reaction time for word-translation of L1 into L2 was longer than that of L2 into L1 and there were high error rates while translating L1 into L2. Kroll et al. (2010) also conducted a similar experiment in which balanced bilinguals translated simple L1 (English) sentences into L2 (French with a LD of 2.5) and vice versa (Chiswick and Miller, 2005). Their results were mostly in line with those by De Groot & Poot (1997), replicating more prolonged reaction time and higher error rate while translating L1 into L2 than L2 into L1. From these behavioral studies, it could be said that translation from L1 into L2 is cognitively more loaded than that from L2 into L1. Moreover, considering that these experiments were conducted for balanced bilinguals, it is also suggested that the mental lexicon in L2 may be smaller than that in L1 regardless of bilingualism levels (De Groot and Poot, 1997; Kroll et al., 2010).

With advancements in functional brain imaging, many studies have started to focus on brain activation patterns during translations between L1 and L2. Many of these studies recruited balanced bilinguals and examined brain activities during translation between languages with close LDs. Most studies performed thus far used PET (positron emission tomography), which is invasive in terms of the intake of radioactive substances, but is relatively unrestrictive regarding body motion and language—related behaviors, and thus is suitable for functional neuroimaging during translation. On the other hand, probably due to technical constraints, fMRI (functional magnetic resonance imaging) has not yet been applied directly for neuroimaging examination of bidirectional translation between L1 and L2, to our knowledge. Rather, fMRI has been used to reveal the cognitive mechanisms behind more fundamental processes of translation, such as the learning process of unknown L2 words (Mayer et al., 2015) and judging the correctness of translated texts (Lehtonen et al., 2005). Fortunately, Hervais-Adelman et al. (2015) examined the neural basis of translation with a focus on language translation from L1 to L2 only. They aimed to clarify how multilinguals who had a high level of language proficiency in at least 3 languages exhibited brain activation during simultaneous interpretation of L1 (their most fluent language: English or French) to L2 (9 target languages such as French, Spanish, Italian, and German). As a result, they confirmed the involvement in the translation of the anterior portion of Broca's area (BA 45). This finding cannot be discussed from a LD-based perspective (Chiswick & Miller, 2005) because participants did not necessarily translate English as the L2, but it is important in clarifying the neural basis of translation. There are also studies showing that the functional connectivity of the brain is different between L1-into-L2 and L2-into-L1 translation (Zheng et al., 2020). Zheng et al. (2020) demonstrated that functional connectivity between a core semantic hub (the left anterior temporal lobe, ATL) and key nodes of attentional and vigilance networks (left inferior frontal, left orbitofrontal, and bilateral parietal clusters) increased during L1-into-L2 translation, whereas functional connectivity was observed only between the left ATL and the right thalamus, regions implicated in the automatic relaying of sensory information to cortical regions, during L2-into-L1 translation. These results may imply that enhanced functional connectivity between semantic and attentional mechanisms is involved during L1-into-L2 translation (Zheng et al., 2020). The finding in Zheng et al. (2020) is consistent with the assumption in the IC model that two different routes are involved depending on the direction of word translation (L1-into-L2 or L2-into-L1) (Jescheniak & Levelt, 1994; Price et al., 1999).

Some PET studies have examined brain activation during bidirectional language translation between L1 and L2 directly, and we will review them in detail here. Klein et a1. (1995) used PET to investigate brain activation patterns during a word translation task between French and English with a close LD of 2.50 (Chiswick and Miller, 2005). Participants whose L1 was English but were also proficient in French (L2) translated L1 into L2 and vice versa. While translating L1 into L2, the left frontal ventrolateral cortex (BA 10/47), the left dorsolateral cortex (BA 8), the left temporal inferotemporal cortex (BA 37/20), the left parietal cortex (BA 7), and the cerebellum (Vermis) were activated. While translating L2 into L1, the left frontal ventrolateral cortex (BA 10/47; BA 9/46), the left dorsolateral cortex (BA 8), the left temporal inferotemporal cortex (BA 37/20), the left parietal cortex (BA 7), the cerebellum (right), and the thalamus/pulvinar were activated. Price et al. (1999) examined brain activities during translation between German (L1) and English (L2), having a close LD of 2.25 (Chiswick and Miller, 2005), on balanced bilinguals using PET. While translating both L1 words into L2 and vice versa, the left anterior cingulate, the left supplementary motor area and the left medial fusiform, the bilateral subcortical structures, the anterior insula, and the cerebellum were activated. Quaresima et al. (2002) examined brain activation while balanced bilinguals of Dutch (L1) and English (L2), with a close LD of 2.75 (Chiswick and Miller, 2005), translated easy sentences from L1 into L2 and vice versa, using fNIRS (functional near infrared spectroscopy), which offers noninvasive hemodynamic assessment in a natural environment, and thus is useful for this purpose. Among the lateral frontal and temporal regions covered in the fNIRS measurement, the left cortical area surrounding Broca's area (BA 44/45) was activated irrespective of translation direction.

In addition, there are a few studies focusing on brain functions during translation for English learners whose L1 is moderately distant from English. In a PET study, Rinne et al. (2000) examined brain activation of professional interpreters during translation from Finnish (L1) to English (L2) having a moderately close LD score of 2.0 (Chiswick and Miller, 2005). Activation patterns were asymmetric as to direction of translation. While translating L2 into L1, activations of the left ventrolateral frontal cortex (BA 46), and the left premotor cortex (BA 6) were observed. On the other hand, while translating L1 into L2, the left ventrolateral frontal cortex (BA 45), the left: inferior temporal cortex (BA 20/28), the left premotor cortex (BA 6), and the cerebellum were activated.

To summarize the major functional neuroimaging studies on translation presented above, various regions were activated while translating from L1 into L2 and vice versa. Moreover, the brain activation patterns were different depending on translation direction. Though there were different activation patterns during translation across studies, the area surrounding the left prefrontal cortex, such as the left ventrolateral frontal cortex involved in Broca's area and the left dorsolateral prefrontal cortex (DLPFC), was activated consistently. This was applicable to the studies focusing on language translation with close LDs (Klein et al., 1995; Price et al., 1999; Quaresima et al., 2002) but also to those with moderate LDs (Rinne et al., 2000). Broca's area, in particular, has been reported to be active regardless of the direction of translation (L1-into-L2 and L2-into-L1) in a study focusing on translation from both directions (Quaresima et al., 2002). This region is responsible for retrieving linguistic information (Klein et al., 1995) and is also related to verbal working memory (Paulesu et al., 1993), morphosyntactic processing (Laine et al., 1999), and semantic analysis (Cabeza and Nyberg, 1997). The left DLPFC plays an important role for working memory associated with translation (Klein et al., 1995) and language encoding and semantic processing (Rinne et al., 2000). These frontal regions are more widely activated during L1-into-L2 translation (Rinne et al., 2000). In addition, the left inferior temporal activation was observed in Klein et al. (1995) and Rinne et al. (2000). This region belongs to the so-called `basal temporal language area' which has been related to word-finding (Lüders et al., 1991; Damasio et al., 1996) and semantic processing (Vandenberghe et al., 1996; Seghier and Price, 2012). The function of these temporal regions during language translation is thought to be primarily responsible for the semantic processing of language (Klein et al., 1995; Rinne et al., 2000).

The functional meaning of these brain regions is consistent with the mental representational model of second language acquisition. That is, these areas are involved in both word production and word perception (Lüders et al., 1991; Indefrey and Levelt, 2000; Indefrey and Levelt, 2004; Hamberger and Cole, 2011), and are therefore likely to be active in common even between languages with a close or moderate LD. On the other hand, the widespread activation including the temporal region during L1-into-L2 translation may reflect the dominance of the semantic route (Jescheniak and Levelt, 1994; Price et al., 1997). Thus, it is likely that the left prefrontal cortex and surrounding area are the regions generally involved in language translation, and that other regions might be differentially recruited depending on differences in LD and on the direction of translation.

Although these findings provided valuable insights into understanding the cognitive processes underlying L2 handling, there are limitations to applying them to understanding cognitive processes of Japanese speakers handling English, a most distantly related language with a LD of 1.0. First, previous studies have mainly been conducted on balanced bilinguals who could effortlessly translate L1 into L2 and vice versa. Because their performance is not expected to be similar to Japanese learners of English, whether brain activation patterns observed in previous studies are also applicable to the language translation process of Japanese learners or not is unclear. Second, those previous studies focused on language translation between English and other languages whose LD is close or moderate. The LD between Japanese and English is the most distant along with that between Korean and English (Chiswick and Miller, 2005). In fact, it has been shown that differences in LD produce different patterns of brain activation during language processing, such as sentence comprehension (Jeong et al., 2007). Accordingly, the results of previous studies might not be directly adapted to translation between Japanese and English.

Therefore, in the current study, we aimed to investigate brain activation patterns while Japanese learners of English translated Japanese words into English and vice versa. In so doing, we have to take the following issues into consideration. First, the large LD, literally entailing difficulty in L2 learning, leads to the emergence of various levels of Japanese learners of English. Since the level of English acquisition may affect the brain activation patterns during translation, we examined both advanced Japanese learners of English who might easily translate L1 into L2 and vice versa and elementary learners who might not easily do the same thing. Second, it is often too difficult for elementary-level English learners to translate Japanese sentences into English and vice versa. Thus, we adopted word translation as vocabulary knowledge is indispensable for acquiring L2 and allows the measurement of individual English skills (Laufer and Nation, 1999). Third, we have to consider the familiarity issue. When adopting L1 and L2 words as stimuli, it might be difficult to distinguish whether the observed cognitive reactions are attributed to qualitative differences of languages or to quantitative differences of cognitive loads. Thus, in order to examine the effects of word familiarity, we adopted high— and low-familiarity L1 and L2 words as stimuli.

Language translation is a linguistic activity that is commonly practiced on a daily basis in an environment where a second language is used. Thus, it is desirable to measure brain activations while translating in a less-restrictive environment that is as close as possible to normal daily life. Although most previous studies used PET and a large body of linguistic studies used fMRI, their experimental environments presented a rather restricted and unfamiliar environment in which participants performed translation. However, fNIRS can measure brain activation patterns by simply placing probes on the head under conditions close to everyday life, such as participants having freedom of movement, and was proven to be useful in a pioneering study by

Quaresirna et al., (2002) on translation. fNIRS has been successfully adopted in other language-related studies including language acquisition (Obrig et al., 2010; Homae et al., 2011; Obrig et al., 2017; May et al., 2018; Sugiura et al., 2018), speech perception (Minagawa-Kawai et al., 2002; Minagawa-Kawai et al., 2004; Minagawa-Kawai et al., 2007), and speech comprehension (Lei et al., 2018). Hence, we used fNIRS to measure brain activations during translation of Japanese (L1) and English (L2) words, taking into consideration language direction and word familiarity as within subject factors in both high- and low-proficiency English learners.

3.2 Methods

3.2.1 Participants

Forty-three healthy right-handed Japanese young adults (23 males and 20 females, mean age 20.81±1.37, age range 18 - 25) participated in this study. All participants had taken the TOEIC® Listening and Reading test within the past year. TOEIC® is the most widely used standardized examination with a yearly participation rate of over two million and its sufficiency in reliability and validity has been reported by Lawson (2008). Participants who received a score of over 730 points were assigned to the advanced group and participants who received a score below 470 points were assigned to the elementary group based on the TOEIC® official standard (Educational Testing Service, 2020a). This official standard indicates that those who scored 730 points or more "have the ability to communicate appropriately in any situation" or "can communicate adequately at a similar level to a native speaker", while those who scored 470 or less "have a minimum level of communication in a daily conversation" or "cannot communicate at all".

Among the initial 43 participants, three were excluded from the data analysis. One misunderstood the instructions. Another was excluded due to instrumental trouble during the fNIRS experiment, and the third was recognized as left-handed, based on the Edinburgh inventory (Oldfield, 1971). The remaining participants consisted of 21 in the advanced-level group and 19 in the elementary-level group. Participants' average score in the advanced group was 826.36±67.93 (max: 975, min: 740) and that in the elementary group was 377.50±69.80 (max: 460, min: 225).

The experimental protocols were approved by the Institutional Review Board (IRB) of Chuo University and it was in accordance with the Declaration of Helsinki guidelines. written informed consent was obtained from all participants in advance.

3.2.2 Stimuli and Experimental Design

In this study, participants were asked to perform a word translation task between Japanese and English as quickly as possible. As Figure 3.1 shows, the stimuli in this experiment were divided into three task blocks, namely non-translation as baseline blocks, English-into-Japanese task blocks and Japanese-into-English task blocks. There were four task conditions in the task blocks: translation direction (English-into-Japanese/Japanese-into-English) × familiarity (high/low familiarity). All participants were required to answer by typing the spelling of the words in English or in Japanese using Roman letters on a keyboard. Japanese people habitually use Roman letters when typing Japanese words. For this reason, we decided that the balance of control was not affected between typing English letters and Japanese Roman letters. In baseline blocks, they were asked to transcribe Japanese words written in black into Roman letters without translating into Japanese or English (e.g., "平成" to "heisei" in Roman letters). In Japanese-into-English task blocks, they were asked to translate Japanese words written in red into corresponding English words and to type them (e.g., "車" in Japanese Kanji character(s) to car in English). In English-into-Japanese task blocks, they were asked to translate English words written in red in Roman letters into corresponding Japanese words and to type them in Roman letters, (e.g., "world" to "sekai" in Roman letters). In all the task blocks, the participants were asked to press the "SPACE" bar immediately after they produced the translated or control word in their mind, type it on the keyboard, and finally press the "ENTER" key immediately after typing the translated words. If the participants did not produce the translated word, the next trial stimulus appeared on the computer monitor in five seconds. In baseline blocks, the times of the stimuli presentation were randomized, with the words appearing four or five times on a computer monitor, to avoid prediction of the timing of the subsequent trial. The number of stimuli presentation were three times for task blocks. The inter stimuli interval lasted 2 sec.

Response time and the accuracy of the response were obtained while the participants conducted word translation. Concerning seemingly correct answers, we defined typing errors of two or more letters in a single word to be incorrect, but with one letter to be correct (e.g., mistyping "money" as "mooney" would be considered correct). We judged whether the answers included typing errors with independent visual examinations by three raters (KN, KO, and TT (6th author). For stimuli presentation and response recording,

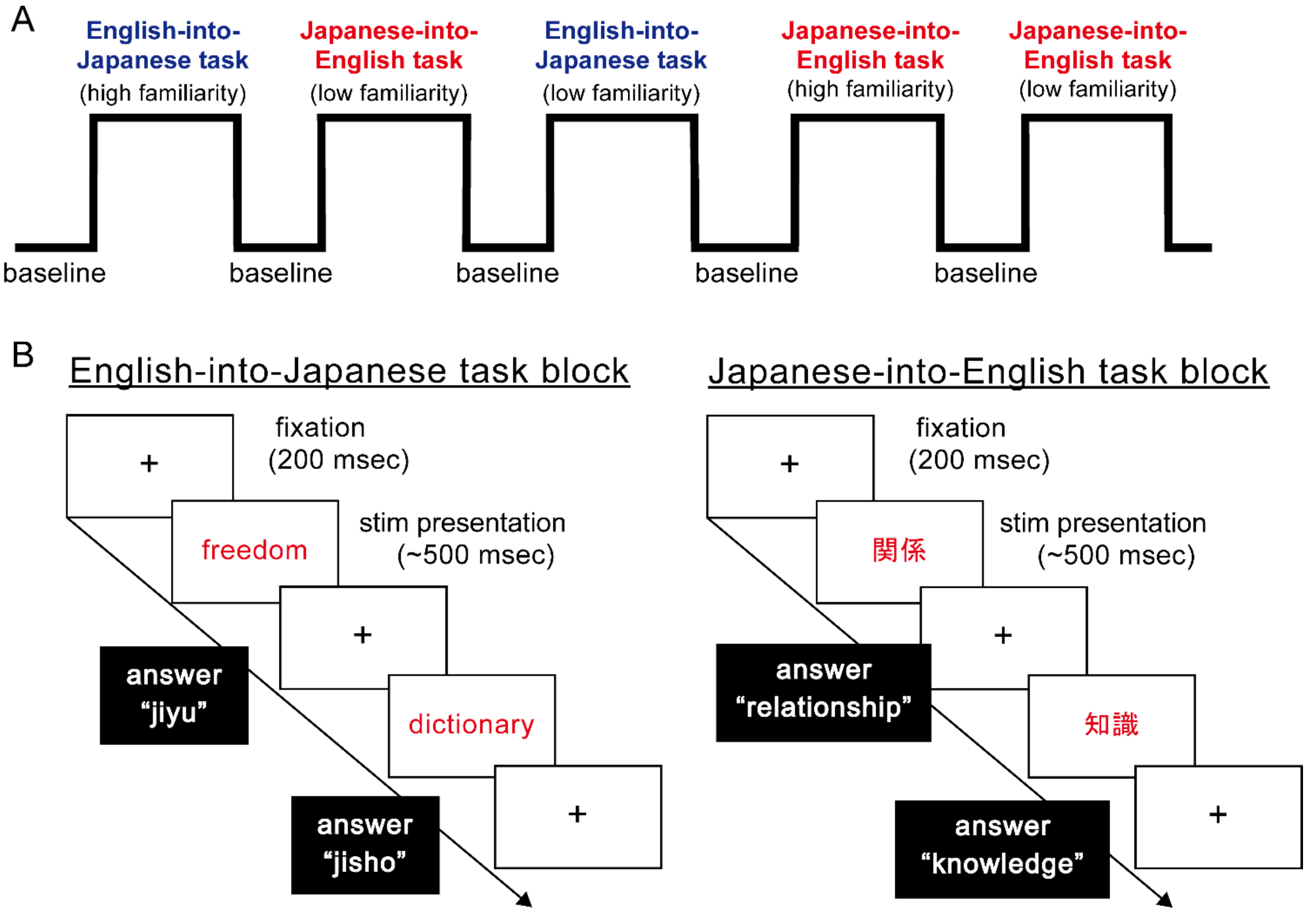

Figure 3.1. The structure of the word translation task paradigm. A: The word translation task paradigm consisted of baseline and task blocks. There were four types of task blocks arising from combinations of translation direction (English-into-Japanese/Japanese-into-English), and high and low familiarity. B: For each task block, a fixation point was presented for 200 msec. Then, a stimulus word shown in English or Japanese was presented in the center of the display. When English words were presented, participants were asked to translate and type corresponding Japanese words in Roman letters. When Japanese words were presented, participants were asked to translate and type corresponding English words.

we used the Psychoplrysics Toolbox (Brainard, 1997; Pelli, 1997; Kleiner et al., 2007), which operated in a Matlab (Mathworks, Natick, MA) environment.The response for word translation task on the computer was synchronized temporally with fNIRS records through a serial port to record hemodynamic responses. Specific Japanese and English word stimuli were selected based on the following considerations. First, we set the word stimuli to comprise of only nouns because verbs, adjectives or other parts of speech tend to be polysemic, possibly making participants confused in grasping the meanings of the presented words. Second, we set word stimuli to be presented visually with Kanji, or Chinese characters, based on consultation with two professional simultaneous interpreters suggesting that Japanese words have many homonyms and cause higher chances of confusion when auditorily presented. In accordance, English words were also presented visually.

Basically, the stimuli in this study were chosen on a word familiarity basis both for Japanese and English words. This is because the most frequently used British National Corpus (BNC) was established based on English word frequency created by British English speakers, which was not suitable as word translation stimuli for Japanese (British National Corpus, 2007). Thus, we utilized the NTT Psycholinguistic Databases "Lexical Properties of Japanese" for the Japanese stimuli (Amano and Kondo, 1998) and English words familiarity ratings among Japanese for English stimuli (Yokokawa et al., 2007). Both corpora were based on familiarity ratings for English and Japanese words, respectively, for Japanese people. Word familiarity in both English and Japanese ranges from 1.0 to 7.0, with 7.0 being the most familiar, and 1.0 being the least.

Further, we utilized three English Japanese Dictionaries, namely the online Cambridge dictionary (Cambridge University Press, 2020), the OLEX English-Japanese Dictionary (Nomura et al., 2016) and the Genius English-Japanese Dictionary (Konishi and Minamide, 2001) to confirm whether the primary meaning of each selected noun was the same across the three dictionaries. In addition, we arranged visually presented Japanese words in Kanji, or Chinese characters, when necessary, to be included in the specific set of basic Kanji, “Joyo-Kanji”, which consists of 2135 characters intended for daily use (Agency for Cultural Affairs, 2010). For English words, the number of syllables was set from one to three. The mora of Japanese words was set from two to six. This was to enable participants to answer the questions (they were asked to translate

Japanese/English words and type the spelling) within the limited time. We regarded two morae to be equivalent to one syllable as per Kubozono (1989).

Finally, for selecting high and low familiarity words both in Japanese as L1 and English as L2, we generated composite familiarity scores by adding the familiarity scores from the two corpora (Amano and Kondo, 1998; Yokokawa et al., 2007). Accordingly, 92 words with the highest and lowest scores, were selected as high and low familiarity words, respectively. Each averaged familiarity was 6.19 for high-familiarity words and 4.40 for low-familiarity words. They were significantly different in familiarity ($t(182) = 41.93$, $p < .01$, $d = 3.108$). In addition, we selected 147 relatively common Japanese words as baseline words from Amano & Kondo (1998). Combinations of Kanji with Katakana or Hiragana characters (e.g., "子育て"; parenting, "銅メダル"; bronze medal) were excluded from these baseline word sets. All baseline words were written in Kanji characters like the task words. The averaged word familiarity was 6.02. There were no stimuli words which overlapped between baseline and task words.

3.2.3 Data Acquisition

During the word translation task, we recorded hemodynamic responses using fNIRS measurement. We used a 52-channel continuous wave system (ETG-4000, Hitachi, Japan). Optical data from individual channels were collected at two different wavelengths, 695 nm and 830 nm, and analyzed using the modified Beer-Lambert Law (Delpy et al., 1988). Changes in the oxygenated hemoglobin (oxyHb) and deoxygenated hemoglobin (deoxyHb) signals were calculated in units of millimolar × millimeter (mM × mm) (Maki et al., 1995). The sampling rate was set to 10 Hz.

The probe was fixed using one 9 × 34 cm rubber shell over the frontal and temporal areas (Figure 3.2) in reference to previous studies (Niioka et al., 2018; Kawabata Duncan et al., 2019). The shell of 33 probes, consisting of a 3 × 11 array with 17 emitters and 16 detectors, allowed us to measure the relative concentration of hemoglobin at 52-channels. We defined the midpoint of a pair of illuminating and detecting probes as a channel location. We defined channel locations in accordance with the international 10-20 system for EEG (Klem et al., 1999; Jurcak et al., 2007). The fNIRS probes were placed such that Fpz coincided with the sixth probe in the middle column of holders in the 3 × 11 probe holder and the lower line substantially matched the horizontal reference curve, where the horizontal reference curve was determined by a straight line connecting FPz—T3—T4 (Jurcak et al., 2007). The inter-optode distance was 3 cm. For spatial profiling of fNIRS data, we adopted the probabilistic registration method (Okamoto and Dan, 2005; Singh et al., 2005; Tsuzuki et al., 2007; Tsuzuki and Dan, 2014) to register fNIRS data to Montreal Neurological Institute (MNI) standard brain space, which further allows us to estimate macroanatomical locations of the channels (Rorden and Brett, 2000).

3.2.4 fNIRS data analysis

We used Matlab 2007b (The Mathworks, Inc., Natick, MA, USA) for fNIRS data analysis with several in-house toolboxes to realize the procedures to be described hereafter. Since the oxyHb signal is the most sensitive indicator of regional cerebral hemodynamic response (Huppert et al., 2006; Homae et al., 2007; Cui et al., 2010), we analyzed oxyHb signal changes. Individual timeline data for the oxyHb signal of each channel were preprocessed in the following way. First, we moving-averaged raw data for 5 sec. Then, channels with a signal variation of 10 % or less were considered defective measurements and excluded from analysis. To remove the influence of measurement noise such as breathing, cardiac movement and so on from the remaining channels, we applied wavelet minimum description length (Wavelet-MDL) (Jang et al., 2009).

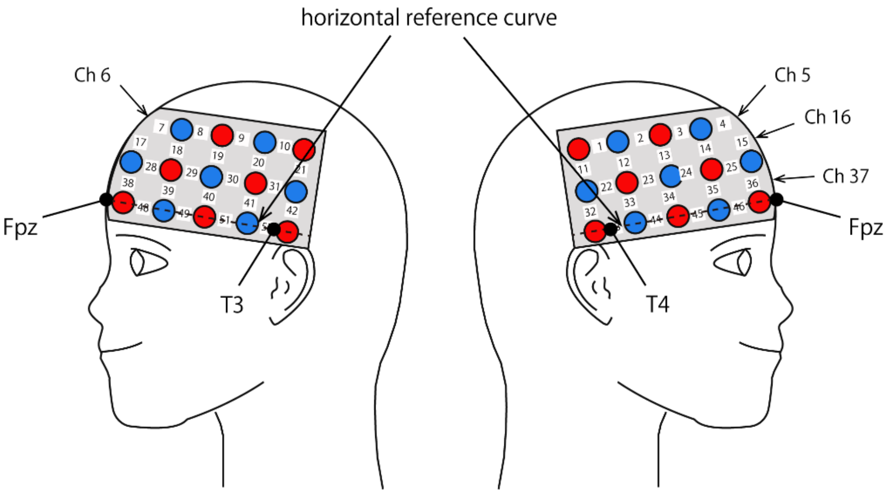

Figure 3.2. Spatial profiles of fNIRS channels. Left and right sides views of the probe arrangements are exhibited with fNIRS channel orientation. Detectors are indicated with blue circles, illuminators with red circles, and channels with white squares. Corresponding channel numbers are shown in black. Ch 5, 6, 16 and 37 are not visible, but located around or over the midline.

After pre-processing oxyHb timeline data for each individual on each channel, we conducted General Liner Model (GLM) analysis with regression to hemodynamic response function (HRF). The regressors were created by convolving (Equation 2) the boxcar function N (τ_p,t) with the HRF shown in Equation 1 (Friston et al., 1998).

$$h(\tau_p, t) = \frac{t^{\tau_p} e^{-t}}{(\tau_p)!} - \frac{t^{\tau_p+\tau_d} e^{-t}}{A(\tau_p + \tau_d)!} , \quad (1)$$

$$f(\tau_p, t) = h(\tau_p, t) * N . \quad (2)$$

Following the conventional usage, we set the first peak delay, τ_p, to 6 s, the second peak delay, τ_d, to 10 s, and A, the amplitude ratio between the first and second peak, to 6 s. The first and second derivatives were included to reduce the influence of noise of individual data further. The specific design matrix is shown in Figure 3.3. Columns 1, 2 and 3 in Figure 3.3 respectively represent the HRF of the baseline block and its first and second derivatives. Columns 4, 5 and 6 respectively represent the HRF of the English-into-Japanese/high-familiarity task block and its first and second derivatives. Columns 7, 8 and 9 respectively represent the HRF of the English-into-Japanese/low-familiarity task block and its first and second derivatives. Columns 10, 11 and 12 respectively represent the HRF of the Japanese-into-English/high-familiarity task block and its first and second derivatives. Columns 13, 14 and 15 respectively represent the HRF of the Japanese-into-English/low-familiarity task block and its first and second derivatives. Column 16 represents the constant.

We used the β value as an indicator of the oxyHb signal for each regressor. Among 16 β values, the four β values (β_4, β_7, β_{10}, β_{13}) representing the task block served for further statistical analyses, while the others were regressed out. β_4 was the indicator of the brain activity during the task period English-into-Japanese / high familiarity and β_7 is the indicator of the brain activity during the task period English-into-Japanese / low familiarity. Similarly, β_{10} is the indicator of the brain activity during the task period Japanese-into-English / high familiarity and β_{13} is the indicator of the brain activity during the task period Japanese-into-English / low familiarity.

A one-sample *t*-test against zero was performed on β values for each task block and channel at the group level. Family-wise errors for the *p* values were corrected using Bonferroni correction. With the Bonferroni method, the statistical significance level (α) is divided by the number of channels, resulting in it being too conservative. The present study is the first to focus on Japanese-English translation, which has a large LD, entailing difficulty in L2 learning, and it was necessary to avoid the type II errors of missing the channels that were truly activated. Therefore, we will discuss "activated channels" based on sufficient effect sizes being obtained not only for significant channels ($\alpha = .05$), but also for marginally significant channels ($\alpha = .10$).

Further, we conducted a three-way mixed analysis of variance (ANOVA) with group (advanced/elementary) as the between subject factor and direction (English-into-Japanese/Japanese-into-English) and familiarity (high/low) as the within-subject factors on β values for each task block. β values were averaged between channels corresponding to the same anatomical label for channel activated in a one-sample *t*-test against zero. A simple main effect test was performed when an interaction between factors was significant. Statistical significance was set a priori at $p < .05$ for all comparisons.

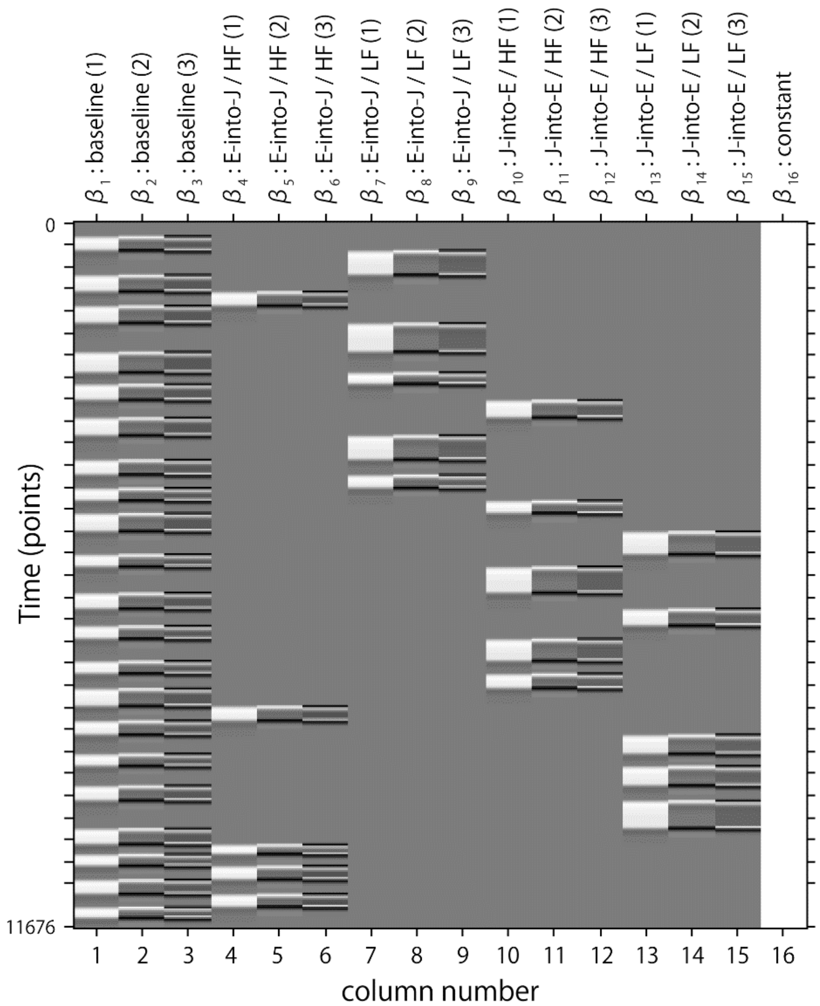

Figure 3.3. An example of a design matrix, X. The rows indicate time from top to bottom. The first to third columns indicate the canonical HRF, and the first and second derivatives, respectively, for baseline trials. The fourth to sixth columns indicate the canonical HRF, and the first and second derivatives, respectively, for task trials (English into Japanese/high familiarity). The seventh to ninth columns indicate the canonical HRF, and the first and second derivatives, respectively, for task trials (English into Japanese/low familiarity). The tenth to twelfth columns indicate the canonical HRF, and the first and second derivatives, respectively, for task trials (Japanese into English/high familiarity). The thirteenth to fifteenth columns indicate the canonical HRF, and the first and second derivatives, respectively, for task trials (Japanese into English/low familiarity). The sixteenth column indicates the constant.

3.2.5 Behavior data analysis

We used IBM SPSS Statistics 25 for behavior data analyses. First, we averaged reaction time and accuracy at the individual level for each of the four task blocks. Then, at the group level, we conducted a three-way mixed analysis of variance (ANOVA) with group (advanced/elementary), direction (English-into-Japanese/Japanese-into-English), and familiarity (high/low) as the within-subject factors on RTs and accuracy for each task block. A simple main effect test was performed when an interaction between factors was significant. A two-way interaction contrast for each of group was tested to confirm how familiarity contrasts differ depending on translation direction (English-into-Japanese/Japanese-into-English) when a three-way interaction was significant. Thus, for each group, we first calculated the contrast between translation direction (English-into-Japanese minus Japanese-into-English) under each familiarity condition to generate two contrasts: English-into-Japanese minus Japanese-into-English contrast for high and low familiarity words, respectively. From these, we further generated a two-way interaction contrast for each group to represent the difference between high and low familiarity words, namely, [English-into-Japanese minus Japanese-into-English for high familiarity words] minus [English-into-Japanese minus Japanese-into-English for low familiarity words]. For each group, a one-sample t-test against zero was performed on the obtained contrast. Statistical significance was set a priori at $p < .05$ for all comparisons.

3.3 Results

3.3.1 fNIRS data

The results of the group analysis with a one-sample *t*-test showed that, for the advanced group, significant oxyHb signal increase was found in one channel for β_7, the indicator of the canonical HRF for task trials (English-into-Japanese / low familiarity) (channel 50 ($t(20) = 4.20$, $p < .05$, $d = 0.92$) and in twelve channels for β_{13}, the indicator of the canonical HRF for task trials (Japanese-into-English / low familiarity) (channel 10, $t(20) = 4.48$, $p < .05$, $d = 0.98$; channel 25, $t(20) = 4.53$, $p < .05$, $d = 0.99$; channel 35, $t(20) = 5.32$, $p < .05$, $d = 1.16$; channel 36, $t(20) = 5.63$, $p < .05$, $d = 1.23$; channel 39, $t(20) = 4.34$, $p < .05$, $d = 0.95$; channel 40, $t(20) = 4.48$, $p < .05$, $d = 0.98$; channel 42, $t(20) = 3.88$, $p < .05$, $d = 0.85$; channel 46, $t(20) = 4.40$, $p < .05$, $d = 0.96$;

channel 47, $t(20) = 4.11$, $p < .05$, $d = 0.90$; channel 48, $t(20) = 4.39$, $p < .05$, $d = 0.96$; channel 49, $t(20) = 5.47$, $p < .05$, $d = 1.19$; and channel 50, $t(20) = 6.36$, $p < .05$, $d = 1.39$) when correcting multiplicity with the Bonferroni method (Figure 3.4, Table 3.1). In contrast, the elementary group showed significant oxyHb signal increase in one channel for β_4, the indicator of the canonical HRF for task trials (English-into-Japanese / high familiarity) (channel 41, $t(18) = 3.94$, $p < .05$, $d = 0.86$), in two channels for β_7, the indicator of the canonical HRF for task trials (English-into-Japanese / low familiarity) (channel 30, $t(18) = 3.77$, $p < .10$, $d = 0.82$ and channel 42, $t(18) = 3.75$, $p < .10$, $d = 0.82$), in four channels for β_{10}, the indicator of the canonical HRF for task trials (Japanese-into-English / high familiarity) (channel 20, $t(18) = 3.96$, $p < .05$, $d = 0.87$; channel 30, $t(18) = 3.96$, $p < .05$, $d = 0.86$; channel 41, $t(18) = 4.34$, $p < .05$, $d = 0.95$; and channel 42, $t(18) = 3.65$, $p < .10$, $d = 0.80$), and in one channel for β_{13}, the indicator of the canonical HRF for task trials (Japanese-into-English / low familiarity) (channel 41, $t(18) = 4.67$, $p < .01$, $d = 1.02$) (Figure 3.5, Table 3.2).

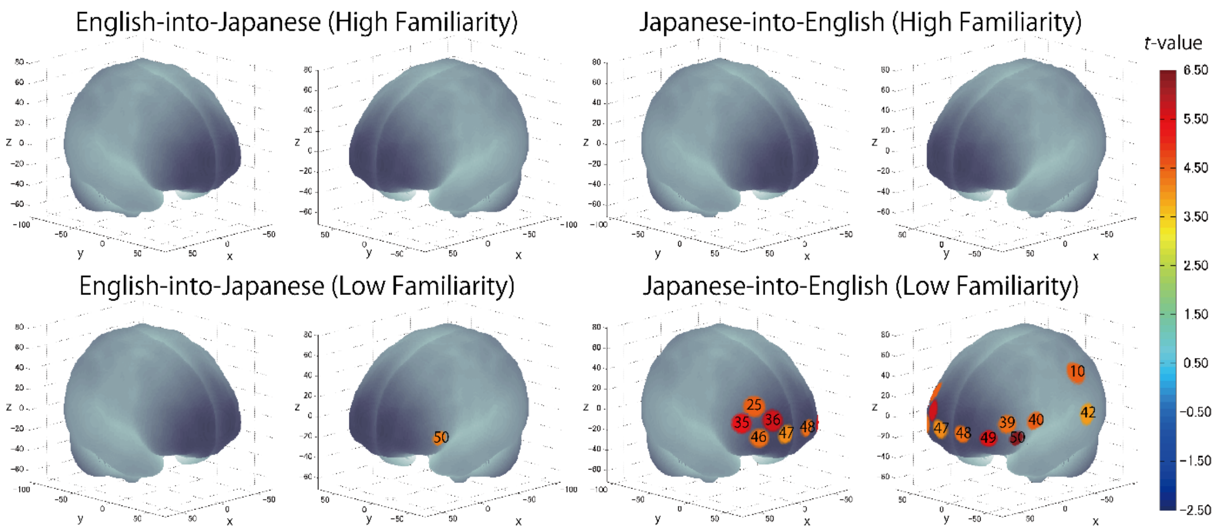

Figure 3.4. The results of the group analysis for the advanced group. Family-wise errors due to multichannel measurement were corrected using the Bonferroni method. Significant *t*-values for MNI-registered channels are indicated by the color scale.

Table 3.1. Most likely estimated locations of activated channels from the probabilistic registration method in the advanced group.

	x	y	z	SD	Anatomy	%	*t*	*p*	*d*
English (L2) into Japanese (L1)/low familiarity									
Ch 50	-54.3	38.3	-3.3	8.0	L-Broca's area (BA 45)	71.5	4.20	.0004	0.92
Japanese (L1) into English (L2)/low familiarity									
Ch 10	-62.0	-33.7	49.3	12.6	L-Wernicke's area (BA 40)	63.2	4.48	.0002	0.98
Ch 25	38.3	54.7	27.7	11.9	R-DLPFC (BA 46)	90.5	4.53	.0002	0.99
Ch 35	50.0	49.3	12.3	10.8	R-DLPFC (BA 46)	67.1	5.32	< .0001	1.16
Ch 36	27.7	68.3	14.3	11.5	FPA (BA 10)	95.5	5.63	< .0001	1.23
Ch 39	-49.3	46.3	11.3	10.0	L-Broca's area (BA 45)	54.9	4.34	.0003	0.95
Ch 40	-59.7	19.3	11.3	10.3	L-Broca's area (BA 44)	33.5	4.48	.0002	0.98
Ch 42	-70.0	-40.7	8.7	12.0	L-STG (BA 22)	75.2	3.88	.0009	0.85
Ch 46	40.3	63.7	-1.3	10.5	FPA (BA 10)	61.9	4.40	.0003	0.96
Ch 47	14.3	73.0	-0.3	10.6	FPA (BA 10)	66.6	4.11	.0005	0.90
Ch 48	-15.0	73.0	0.0	9.8	FPA (BA 10)	61.3	4.39	.0003	0.96
Ch 49	-39.7	61.3	-2.0	9.2	FPA (BA 10)	65.1	5.47	< .0001	1.19
Ch 50	-54.3	38.3	-3.3	8.0	L-Broca's area (BA 45)	71.5	6.36	< .0001	1.39

Notes. SD indicates standard deviation in the spatial estimate; BA indicates Brodmann area; DLPFC indicates dorsolateral prefrontal cortex; FPA indicates frontopolar area; STG indicates superior temporal gyrus; L and R indicates left and right hemisphere.

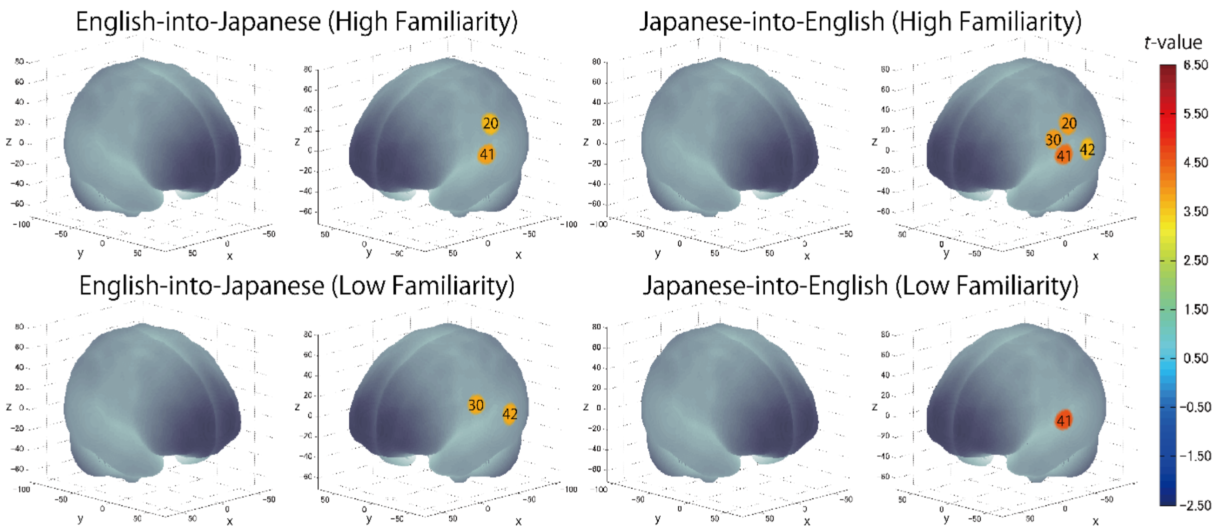

Figure 3.5. The results of the group analysis for the elementary group. Family-wise errors due to multichannel measurement were corrected using the Bonferroni method. Significant *t*-values for MNI-registered channels are indicated by the color scale.

Table 3.2. Most likely estimated locations of activated channels from the probabilistic registration method in the elementary group.

	x	y	z	SD	Anatomy	%	*t*	*p*	*d*
English (L2) into Japanese (L1)/high familiarity									
Ch 20	-66.0	-18.3	36.3	11.6	L-S1 (BA 2)	43.9	3.70	.0007	0.81
Ch 41	-67.0	-11.7	8.7	11.5	L-STG (BA 22)	71.6	3.94	.0004	0.86
English (L2) into Japanese (L1)/low familiarity									
Ch 30	-65.0	-0.3	24.7	10.5	L-Subcentral area (BA 43)	70.2	3.77	.0007	0.82
Ch 42	-70.0	-40.7	8.7	12.0	L-STG (BA 22)	75.2	3.75	.0007	0.82
Japanese (L1) into English (L2)/high familiarity									
Ch 20	-66.0	-18.3	36.3	11.6	L-S1 (BA 2)	43.9	3.96	.0006	0.87
Ch 30	-65.0	-0.3	24.7	10.5	Subcentral area (BA 43)	70.2	3.96	.0004	0.86
Ch 41	-67.0	-11.7	8.7	11.5	L-STG (BA 22)	71.6	4.34	.0002	0.95
Ch 42	-70.0	-40.7	8.7	12.0	L-STG (BA 22)	75.2	3.65	.0009	0.80
Japanese (L1) into English (L2)/low familiarity									
Ch 41	-67.0	-11.7	8.7	11.5	L-STG (BA 22)	71.6	4.67	.0009	1.02

Notes. SD indicates standard deviation in the spatial estimate; BA indicates Brodmann area; S1 indicates primary somatosensory cortex; DLPFC indicates dorsolateral prefrontal cortex; STG indicates superior temporal gyrus; L and R indicates left and right hemisphere.

3.3.2 Cortical activation patterns

By integrating the statistical analysis, spatial registration of the channels, and subsequent macroanatomical labeling, the cortical activation patterns observed in the current study are described as below. For the advanced group, there was no significant activation region while translating high-familiarity words from Japanese (L1) into English (L2) and vice versa; however, some regions were activated while translating low-familiarity words. The advanced group elicited greater cerebral hemodynamic responses in one channel registered at Brodmann area 45, the pars triangularis Broca's area, while translating English (L2) words with low-familiarity into Japanese (L1). On the other hand, the advanced group elicited greater cerebral hemodynamic responses in twelve channels registered at Brodmann areas: 10, the frontopolar area; 22, the superior temporal gyrus; 40, the supramarginal gyrus part of Wernicke's area; 44, the pars opercularis part of Broca's area; 45, the pars triangularis Broca's area; and 46, the dorsolateral prefrontal cortex, while translating Japanese (L1) words with low familiarity into English (L2). For the elementary group, there was significantly or marginally significantly activated regions while translating both from Japanese (L1) into English (L2) and vice versa regardless of word familiarity. When the elementary group translated English (L2) words with high familiarity into Japanese (L1), one channel registered at Brodmann area 22, the superior temporal gyrus, was activated. Also, when the elementary group translated English (L2) words with low familiarity into Japanese (L1) words, one channel registered at Brodmann area 22, the superior temporal gyrus, was marginally significantly activated. For the opposite translation direction, when the elementary group translated Japanese (L1) words with high familiarity into English (L2), four channels registered at Brodmann areas were significantly or marginally significantly activated: 2, the primary somatosensory cortex; 22, the superior temporal gyrus; 43, and the subcentral area. When the elementary group translated Japanese (L1) words with low familiarity into English (L2), one channel registered at Brodmann area 22, the superior temporal gyrus, was significantly activated.

These results show that different brain areas were recruited during word translation between the advanced and the elementary groups. In the advanced group, the frontal area (English-into-Japanese) or the frontal area to the left temporal area (Japanese-into-English) were recruited only during low-familiarity word translation. The results suggest that these regions were involved in the cognitive mechanism with word translation for the advanced group. On the other hand, the results suggest that the activation of the left temporal region was related to translation in the elementary group, regardless of the direction and word familiarity of the translation. A detailed functional description of these areas is given in the Discussion section.

3.3.3 Comparison between the advanced and elementary groups

We conducted a three-way mixed analysis of variance (ANOVA) with group (advanced/elementary) as the between-subject factor and direction (English-into-Japanese/Japanese-into-English) and familiarity (high/low) as the within-subject factors to compare brain activations between the advanced and elementary groups (Table 3.3). Before this, β values were averaged between channels corresponding to the same anatomical label for channels activated in a one-sample t-test against zero (BA 2: channel 20, BA 10: channels 36, 46, 47, 48, and 49, BA 22: channels 41 and 42, BA 40: channel 10, BA 43: channel 30, BA 44/45: channels 39, 40, and 50, BA 46: channels 25 and 35).

In a channel corresponding to the left primary somatosensory cortex (BA 2), there was no significant main effect for group (advanced/elementary), direction (English-into-Japanese/Japanese-into-English), and familiarity (high/low). On the other hand, the interaction between group and familiarity was significant ($F(1,38) = 9.27$, $p < .01$, $\eta_p^2 = .20$). The simple main effect of group was larger for low-familiarity words than for high-familiarity words in the advanced group ($p < .05$). In channels corresponding to the frontopolar area (BA 10), there was a significant main effect for direction (Japanese-into-English > English-into-Japanese; $F(1,38) = 14.58$, $p <.001$, $\eta_p^2 = .27$). The interaction between group and familiarity was significant ($F(1,38) = 8.39$, $p < .01$, $\eta_p^2 = .18$). A simple main effect of familiarity was larger for the advanced group than for the elementary group for low-familiarity words ($p < .01$). The interaction between group and direction was significant ($F(1,38) = 7.67$, $p < .01$, $\eta_p^2 = .17$). The simple main of group effect was larger for the Japanese-into-English direction than for the English-into-Japanese direction in the advanced group ($p < .001$). Also, the simple main effect of direction for the advanced group was larger than that for the elementary group in the Japanese-into-English direction ($p < .05$). In channels corresponding to the left superior temporal gyrus (BA 22), there was no significant main effect for group, direction, or familiarity. The interaction between group and familiarity was significant ($F(1,38) = 6.19$, $p < .05$, $\eta_p^2 = .14$). The simple main effect of group was larger for high-familiarity words than for low-familiarity words in the advanced group ($p < .05$). In a channel corresponding to the left Wernicke's area (BA 40), there was no significant main effect for group, direction, or familiarity. The interaction between group and familiarity was significant ($F(1,38) = 6.29$, $p < .05$, $\eta_p^2 = .14$). The simple main effect of group was larger for high-familiarity words than for low-familiarity words in the elementary group ($p < .05$). Also, the simple main effect of familiarity was larger for the advanced group than for the elementary group for low-familiarity words ($p < .05$). In channels corresponding to the left subcentral area (BA 43), there was no significant main effect for group, direction, or familiarity. Moreover, there were no interactions. In channels corresponding to the left Broca's area (BA 44/45), there was no significant main effect for group, direction, or familiarity. The interaction between group and familiarity was significant ($F(1,38) = 6.29$, $p < .05$, $\eta_p^2 = .14$). The simple main of group effect was larger for high-familiarity words than for low-familiarity words in the elementary group ($p < .05$). Also, the simple main effect of familiarity was higher for the advanced group than for the elementary group for low-familiarity words ($p < .05$). In channels corresponding to the right DLPFC (BA 46), there was a significant main effect for direction (Japanese-into-English > English-into-Japanese; $F(1,38) = 8.97$, $p < .01$, $\eta_p^2 = .19$). The interaction between group and familiarity was significant ($F(1,38) = 11.01$, $p < .01$, $\eta_p^2 = .23$). The simple main effect of group was larger for low-familiarity words than for high-familiarity words in the advanced group ($p < .05$). The simple main effect of group was larger for high-familiarity words than for low-familiarity words in the elementary group ($p < .05$). Also, the simple main effect of familiarity was larger for the advanced group than for the elementary group for low-familiarity words ($p < .01$).

These results suggest that language direction and word familiarity had different effects on brain activation between the advanced and elementary groups, with significant interactions in the six regions (the left primary somatosensory cortex: BA 2, the frontopolar area: BA 10, the left superior temporal gyrus: BA 22, the left Wernicke's area: BA 40, the left Broca's area: BA 44/45, and the right dorsolateral prefrontal cortex: BA 46). On the other hand, no main effect or interaction was observed for the activation in the left subcentral area (BA 43), which does not support different activation between the two groups.

3.3.4 Behavioral data

The averaged reaction times (RTs) and accuracy for each group are shown in Figure 3.6. The three-way mixed ANOVA on RTs (Table 3.3) showed significant main effects of direction (English-into-Japanese < Japanese-into-English; $F(1,34) = 22.49$, $p < .001$, $\eta_p^2 = .40$) and familiarity (high < low; $F(1,34) = 49.19$, $p < .001$, $\eta_p^2 = .59$). No main effect of group (advanced/elementary) appeared ($F(1,34) = 1.59$, *n.s.*, $\eta_p^2 = .04$). No significant interaction between group and direction ($F(1,34) = .07$, *n.s.*, $\eta_p^2 < .0001$), group and familiarity ($F(1,34) = 3.24$, *n.s.*, $\eta_p^2 = .08$), direction and familiarity($F(1,34) = 0.13$, *n.s.*, $\eta_p^2 < .0001$), or group, direction, and familiarity ($F(1,34) = 1.03$, *n.s.*, $\eta_p^2 < .0001$) appeared. The three-way mixed ANOVA on accuracy (Table 3.3) showed significant main effects of group (advanced > elementary; $F(1,37) = 120.88$, $p < .001$, $\eta_p^2 = .77$)

and familiarity (high > low; $F(1,37) = 325.32$, $p < .001$, $\eta_p^2 = .90$). There was no significant main effect of direction ($F(1,37) = 3.75$, *n.s.*, $\eta_p^2 < .0001$). The interaction between group and familiarity was significant ($F(1,37) = 133.30$, $p < .001$, $\eta_p^2 = .78$). The simple main effect of familiarity was larger for high-familiarity words than for low-familiarity words in the advanced group ($p < .001$). Also, the simple main effect of familiarity was larger for high-familiarity words than for low-familiarity words in the elementary group ($p < .001$). The interaction between group, direction, and familiarity was significant ($F(1,37) = 18.85$, $p < .001$, $\eta_p^2 = .34$). All simple main effects of familiarity at each level of direction, and all simple main effects of direction at each level of familiarity were larger for the advanced group than for the elementary group (for the high-familiarity words and in the English-into-Japanese direction ($p < .01$), for the high-familiarity words and in the Japanese-into-English ($p < .001$), for the low-familiarity words and in the English-into-Japanese direction ($p < .001$), and for the low-familiarity words and in the Japanese-into-English direction ($p < .001$)). Since significant three-way interaction was observed for ACC, a two-way interaction contrast was examined for each group. As a result, for the advanced group, the mean value of the contrasts was -0.95 with a standard deviation of 2.72, which was not significant compared to zero ($t(19) = -1.56$, *n.s.*). On the other hand, for the elementary group, the mean value of the contrasts was 2.63 with a standard deviation of 2.41, which was significantly larger than zero ($t(18) = 4.76$, $p < .001$). Further, probing this interaction contrast in the elementary group, we found that, for high familiarity words, the contrast, English-into-Japanese minus Japanese-into-English, was larger than zero ($p < .001$). Conversely, for low familiarity words, the contrast, English-into-Japanese minus Japanese-into-English, was smaller than zero ($p < .05$).

To summarize, there were no differences for RTs between the advanced group and the elementary group, whereas there were significant differences for accuracy: the advanced group responded significantly more accurately than did the elementary group. The slower RTs and the lower accuracy for low familiarity words suggest that it is more difficult to translate low-familiarity words than high-familiarity words, regardless of the direction of the translation, for both advanced and elementary groups. However, for the elementary group, there was an interaction between familiarity and direction with the accuracy, suggesting that the elements of the difficulty were different between the advanced and the elementary groups. In addition, regarding ACC, the advanced group exhibited no significant two-way interaction between word familiarity and translation directions. However, the elementary group exhibited a significant two-way interaction. For high-familiarity words, they answered more accurately during English-into-Japanese translation, whereas for low familiarity words, they answered more accurately during Japanese-into-English translation.

Table 3.3. Three-way mixed ANOVA results for behavioral and fNIRS data

Dependent Value	Reaction times				Accuracy				Activation on BA 2				Activation on BA 10			
Factor	***SS***	***MS***	***F***	η_p^2	***SS***	***MS***	***F***	η_p^2	***SS***	***MS***	***F***	η_p^2	***SS***	***MS***	***F***	η_p^2
Group	12.69	12.69	1.59	0.05	1223.67	1223.67	120.88***	0.77	< 0.01	< 0.01	0.19	< .01	0.03	0.03	2.06	0.05
Error-Group	272.05	8			374.56	10.12			1.23	0.03			0.57	0.02		
Familiarity	111.28	111.28	49.19***	0.59	1358.82	1358.82	325.32***	0.9	< 0.01	< 0.001	0.08	< .01	< 0.001	< 0.001	< 0.01	< .01
Familiarity×Group	7.33	7.33	3.24	0.09	556.76	556.76	133.30***	0.78	0.01	0.02	9.27**	0.2	0.03	0.03	8.39**	0.18
Error (Familiarity×Group)	76.91	2.26			154.54	4.18			0.08	< 0.01			0.16	< 0.01		
Direction	52.75	52.75	22.49***	0.4	7.73	7.73	3.75	0.09	< 0.01	< 0.01	1.06	0.03	0.01	0.01	14.58***	0.28
Direction×Group	0.17	0.17	0.07	< .01	0.65	0.65	0.32	< .01	< 0.01	< 0.001	0.1	< .01	< 0.01	< 0.01	7.67**	0.17
Error (Direction×Group)	79.76	2.35			76.24	2.06			0.05	< 0.01			0.03	< 0.01		
Familiarity×Direction	0.21	0.21	0.13	< .01	6.89	6.89	4.16*	0.1	< 0.01	< 0.001	0.52	0.01	< 0.001	< 0.001	0.02	< .01
Familiarity×Direction×Group	1.75	1.75	1.03	0.03	31.25	31.25	18.85***	0.34	< 0.01	< 0.001	0.6	0.02	< 0.001	< 0.001	0.02	< .01
Error (Familiarity×Direction×Group)	57.81	1.7			61.34	1.66			0.04	< 0.01			0.05	< 0.01		

Dependent Value	Activation on BA 22				Activation on BA 40				Activation on BA 44/45				Activation on BA46			
Factor	***SS***	***MS***	***F***	η_p^2	***SS***	***MS***	***F***	η_p^2	***SS***	***MS***	***F***	η_p^2	***SS***	***MS***	***F***	η_p^2
Group	0.02	0.02	0.88	0.02	0.04	0.04	2.98	0.07	< 0.01	< 0.01	0.18	< .01	0.05	0.05	3.36	0.08
Error-Group	1.06	0.03			0.51	0.01			0.76	0.02			0.56	0.01		
Familiarity	< 0.01	< 0.01	1.05	0.02	< 0.001	< 0.001	0.43	0.01	< 0.01	< 0.01	2.55	0.06	< 0.001	< 0.001	0.1	< .01
Familiarity×Group	0.03	0.03	6.19*	0.14	0.01	0.01	6.29*	0.14	0.06	0.06	14.38**	0.27	0.03	0.03	11.01**	0.22
Error (Familiarity×Group)	0.17	< 0.01			0.06	< 0.01			0.15	< 0.01			0.11	< 0.01		
Direction	< 0.01	< 0.01	1.26	0.03	< 0.01	< 0.01	3.96	0.09	< 0.01	< 0.01	3.51	0.08	0.02	0.02	8.97**	0.19
Direction×Group	< 0.001	< 0.001	0.01	< .001	< 0.001	< 0.001	0.95	0.02	< 0.001	< 0.001	0.11	< .01	< 0.01	< 0.01	2.54	0.06
Error (Direction×Group)	0.1	< 0.01			0.03	< 0.001			0.06	< 0.01			0.07	< 0.01		
Familiarity×Direction	< 0.001	< 0.001	0.02	< .001	< 0.01	< 0.01	1.04	0.03	< 0.001	< 0.001	0.13	< .01	< 0.001	< 0.001	0.02	< .001
Familiarity×Direction×Group	< 0.01	< 0.01	5.44	0.01	< 0.001	< 0.001	0.01	< .01	< 0.01	< 0.01	0.48	0.01	< 0.001	< 0.001	0.05	< .01
Error (Familiarity×Direction×Group)	0.11	< 0.01			0.04	< 0.01			0.08	< 0.01			0.04	< 0.01		

*Notes. *** indicates p < .001, ** indicates p < .01, * indicates p < .05. The degrees of freedoms (dfs) for the main effects and interactions of all factors equal 1. The dfs for Errors equal 34 for RT, 37 for ACC, and 38 for activation in brain regions.*

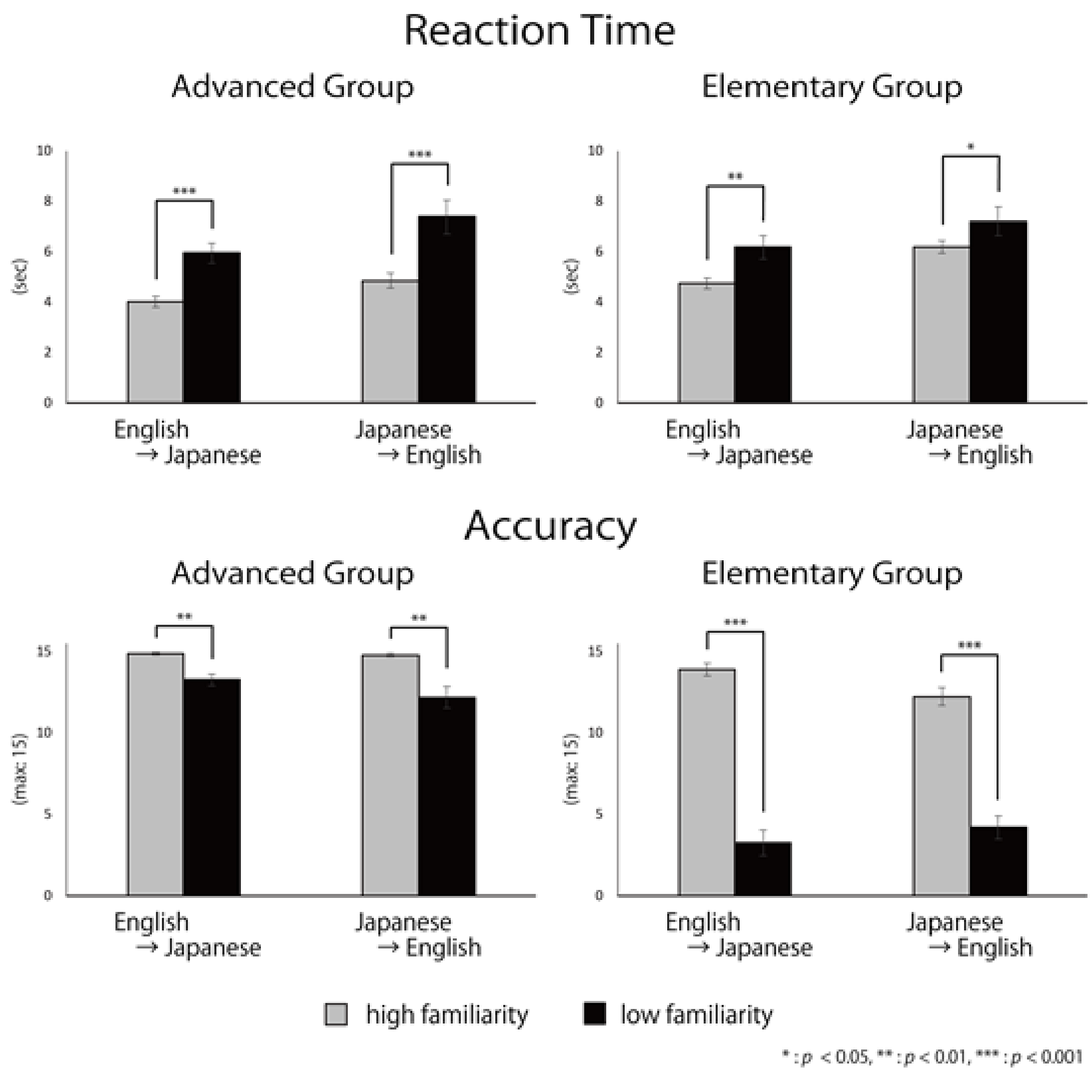

Figure 3.6. Mean reaction time and accuracy. Error bars indicate standard errors (SE).

3.4 Discussion

We revealed that there were different brain activation patterns while English learners of Japanese translated Japanese (L1) words into English (L2) and vice versa depending on their English proficiency. Specifically, the advanced group elicited greater activation on the left prefrontal cortex around Broca's area while translating words with low familiarity, but no activation was observed while translating words with high familiarity. On the other hand, the elementary group evoked greater activation on the left temporal area including the superior temporal gyrus (STG) irrespective of word familiarity. These results suggest that different cognitive processes could be involved in word translation depending on English proficiency in Japanese learners of English. Hereafter we will discuss the activation patterns observed in the current study macro-anatomically in reference to previous neuroimaging studies.

3.4.1 Interpretation of Results

3.4.1.1 Consistent activation in Broca's area (BA 44/45)

In the current study we observed activation in the language-related regions which were also reported in the former studies. First of all, the activation on Broca's area (BA 44/45) during translation was consistently observed in previous studies (Klein et al., 1995; Rinne et al., 2000; Quaresima et al., 2002; Kovelman et al., 2008a), in which balanced bilinguals translated between languages with close or moderate distances. It has been suggested that the left prefrontal cortex, including the pars opercularis and the pars triangularis of Broca's area, is related to language comprehension and semantic processing (Devlin et al., 2003). Also, the areas have been revealed as being involved with understanding and retrieval of semantic ambiguity (Rodd et al., 2005). In our study, the advanced group elicited greater activation on Broca's area when translating words with low familiarity, which should demand higher cognitive loads. It is expected that Broca's area plays an important role in language processing with high cognitive loads. Considering the previous studies' results (Klein et al., 1995; Rinne et al., 2000; Quaresima et al., 2002; Kovelman et al., 2008a), it is likely that even balanced bilinguals experience considerable cognitive loads when translating languages with close or moderate LDs. This should be all the more so for advanced English learners translating words in a language with a large LD. For the elementary group, it was difficult to translate words with low familiarity as shown by their low accuracy (Figure 3.6). Due to the difficulty, they could not translate words with low familiarity and gave up answering correctly. In other words, the elementary group was not able to perform well in word perception itself, which is necessary for word production (Lüders et al., 1991; Indefrey and Levelt, 2000; Indefrey and Levelt, 2004;

Hamberger and Cole, 2011). Thus, it is appropriate to interpret that the elementary group did not experience cognitive load or experienced a different kind of cognitive load than the advanced group, thus failing to recruit Broca's area (BA 44/45).

3.4.1.2 Consistent activation in the dorsolateral prefrontal cortex (BA 46)

The right dorsolateral prefrontal cortex (R-DLPFC: BA 46) was activated in some previous studies (Klein et al., 1995; Rinne et al., 2000; Kovelman et al., 2008a) and the advanced group in the current study also elicited significant activation in the region while translating Japanese (L1) words with low familiarity into English (L2). The DLPFC is related to verbal working memory (Salmon et al., 1996; Zurowski et al., 2002), which plays an important role in keeping information in mind and processing it simultaneously in a short time (Baddeley, 2003). This region has also been consistently activated during tasks requiring effortful retrieval, maintenance or control of semantic information (Cabeza and Nyberg, 1997). Activation of the right DLPFC was also observed in some previous studies (Klein et al., 1995; Rinne et al., 2000; Kovelman et al., 2008b) focusing on balanced bilinguals. In the present study, the behavioral results showed that the advanced group processed the stimuli more accurately during translation than did the elementary group. Based on the function of the right DLPFC, we considered that such high performance in the advanced group was made possible by their ability to make good use of their verbal working memory. To sum up, the left Broca's area and the right DLPFC were consistently activated in not only balanced bilinguals whose L1 is closely or moderately related to English, but also in the advanced Japanese learners of English. Therefore, we conclude that these areas are involved with word translation regardless of LDs.

3.4.1.3 Activation patterns specifically obtained in the current study

It should be noted that there were several areas that were found to be activated only in the current study. The elementary group elicited greater activation on the left superior temporal gyrus (BA 22) when translating

Japanese (L1) into English (L2), and vice versa irrespective of word familiarity. This region was also activated when the advanced group translated Japanese (L1) low familiarity words into English (L2). The STG (BA 22) is reported to play an important role on semantic processing (Warburton et al., 1996) and word retrieval (Hirshorn and Thompson-Schill, 2006). The word translation task in this study required participants to retrieve Japanese (L1) and English (L2) words. However, the cognitive loads with word retrieval depend on the level of automatization of language processing (Segalowitz and Segalowitz, 1993; Ellis, 2002; Suzuki and Sunada, 2018). That is, if word recognition becomes faster and recognition time becomes more stable, then surely there has been a shift toward automatization (Segalowitz, Segalowitz, & Wood, 1998). This would imply the fact that with increasing expertise in a second language, learners acquire a richer lexical network for words in L2 (Kroll & De Groot, 2002). In the current study, it appears that language processing of English (L2) for the advanced group was automatized but that for the elementary group was not. This can explain the results that the elementary group elicited significant activation on the STG (BA 22) during both translation directions (Japanese-into-English/English-into-Japanese) irrespective of word familiarity. The STG (BA22) plays an important role in phonological storage within the phonological loop, a subsystem of working memory (Aboitiz, Aboitiz, & García, 2010; Kekang, 2019; Paulesu, Frith, and Frackowiak., 1993). The activation of the STG (BA 22) in the elementary group may reflect that they temporarily stored the stimulus words in the phonological storage before word translation. On the other hand, though we believe that language processing of English (L2) for the advanced group would be rather automatized, translation of unfamiliar Japanese (L1) words into English (L2) would still require high cognitive loads. This might be reflected by the significant activation on the STG (BA 22). This view is also supported by the results of previous behavioral experiments (De Groot and Poot, 1997; Kroll et al., 2010), which showed that cognitive loads when translating L1 into L2 were more burdensome.

Wernicke's area is involved in various language processes including language comprehension (Ardila et al., 2016). In particular, the left supramarginal gyrus part of Wernicke's area (BA 40) is related to word recognition (DeWitt and Rauschecker, 2013). In the current study, the advanced group elicited significant activation in BA 40 when translating unfamiliar Japanese (L1) words into English (L2). The cognitive mechanisms required in language translation are considered to be different depending on the differences in language direction. That is, L1-into-L2 translation has stronger lexical and semantic demands associated with processing input in L2 as opposed to L1 compared to L2-into-L1 translation (Christoffels et al., 2013). Generally behavioral performance is typically worse for L1-into-L2 translation than L2-into-L1 (De Groot & Poot., 1997; Kroll & Stewart, 1994; Kroll et al., 2010). In the present study, a main effect of language direction was observed for RT during translation. Therefore, the higher lexical and semantic demands associated with the processing of input in L2 may have elicited the activation of Wernicke's area (BA 40) in the advanced group.

The activation in the STG mainly found in the elementary group and the activation in Wernicke's area specifically found in the advanced group are consistent with the existing dual-route process model of second language acquisition (Duyck, & Brysbaert, 2008; Kroll & Stewart, 1994; Kroll & De Groot, 1997). In the elementary group, semantic route processing seems to have been dominant, regardless of the translation direction and word familiarity. In the elementary group, the word concept was processed with the semantic route because a sufficient amount of vocabulary was not stored. Accordingly, the semantic route may have elicited activation of the STG, but not Wernicke's area, associated with vocabulary storage (Aboitiz, Aboitiz, & García, 2010； Kekang,2019; Paulesu, Frith, and Frackowiak., 1993). On the other hand, in the advanced group, because of the relatively rich vocabulary storage, lexical route processing (Duyck, & Brysbaert, 2008; Kroll & Stewart, 1994; Kroll & De Groot, 1997) for English(L2)-into-Japanese(L1) translation similar to bilingual second language processing (e.g., Green, 1998) may have taken place, resulting in activation in Wernicke's area.

The frontopolar area (BA 10) has been reported to serve a function in the processing of cognitive branching (Koechlin and Hyafil, 2007), in which we maintain in working memory a primary goal, while at the same time processing tasks related to a secondary goal (Ramnani and Owen, 2004). This region was activated when the advanced group translated Japanese (L1) words with low familiarity into English (L2). As in the case of BA 22, we suggest that BA 10 activation is another indicator of the large cognitive loads that advanced English learners have when translating unfamiliar L1 words into L2.

3.4.2 Limitations and Perspectives of this experiment

Although we affirmed the brain activation patterns for Japanese learners of English during word translation with a large LD, there are some limitations as to the investigation of the mechanism of Japanese learners acquiring English. First, our study did not make clear how brain activation patterns for the elementary group change into those for the advanced group. It is unclear whether it would be continuous or discrete. For the future, examining brain activation patterns for Japanese learners of English with an intermediate level would allow us to clarify the transition of cognitive mechanisms with increasing English levels. Alternatively, longitudinal studies on how elementary learners become advanced would provide clearer evidence for the differential activation. Second, we did not investigate brain activation patterns for Japanese learners of English who are balanced bilinguals. Thus, cortical activation patterns for Japanese learners who completely acquire English remains uncertain. In our study, we recruited an advanced group whose TOEIC® scores were over the average score of Japanese learners. However, there are few Japanese learners in the advanced group who are considered balanced bilinguals. Therefore, to fully understand the mechanism of acquiring English by Japanese learners with a large LD, we need to examine brain activation patterns on balanced bilinguals whose L1 is Japanese and L2 is English. Finally, we measured only the frontal and temporal regions with multichannel fNIRS due to the inherent spatial limitations of the fNIRS setup. With this limitation in mind, we carefully selected the measurement areas based on previous results (e.g., Klein et a1., 1995; Price et al., 1999; Quaresima et al., 2002) related with language translation. Though we have these limitations to consider, we present significant findings that brain activation patterns for Japanese learners of English vary depending on the level of acquired English and cognitive loads of translation tasks. This study provides the first evidence revealing the cognitive mechanisms during word translation between languages at a large LD from a functional neuroimaging perspective. Furthermore, our study may serve to provide an effective cognitive strategy for Japanese learners of English at the elementary level. Our results show that cortical activation on the left STG was observed for the elementary group, while Wernicke's area was activated for the advanced group. These results may reflect whether the semantic or lexical route was dominant when English learners processed words such as during translation. However, since our data were not longitudinal and we have yet to provide definitive evidence for proving this hypothesis, we still need to verify that the differences in performance and cortical activation between the advanced and elementary groups reflect the improvement of English proficiency as a second language. There has been a lot of discussion about cognitive strategies in language acquisition. The depth of lexical knowledge is related to word perception (Ouellette, 2006). For processing with the lexical route, it is necessary to improve the mental lexicon for the second language and to increase accessibility to it (Talamas et al., 1999; Kroll and Tokowicz, 2001; Ouellette, 2006). It will be interesting to incorporate these plausible factors in future studies to examine the relationship between cortical activation in Japanese learners of English at the elementary level during word translation and cognitive strategies. Together with the current findings, such an integrated examination may provide insight into effective cognitive strategies for second language acquisition.

Chapter 4:

General Discussion

4.1 Summary

The purpose of this dissertation is to explore Second Language Acquisition (SLA) mechanisms in Japanese learners of English. This is of special importance because the LD between Japanese and English is the most distant from a linguistics point of view. In study 1, I revealed how the "read-aloud instruction package", including active input and output, affected the second language acquisition of elementary-level learners of English. After the implementation of intensive instruction, the results showed that participants' TOEIC Bridge® scores significantly increased, suggesting that active English input and output were associated with the improvement of English proficiency. No significant change was found in any factors of their motivation for learning English after this instruction. On the other hand, there was a significant change in their learning strategies. They were less likely to learn with others, but more likely to use all their mental processes. These findings might imply that active English input and output facilitated participants' use of the cognitive processes necessary for SLA and led to improved English proficiency. The "read-aloud instruction package" included the translation activity of translating English into Japanese for comprehension. Translation activities are the most basic of language-learning activities, and they are inevitably required at any stage of English learning. Thus, in study 2, I explored the neural basis of word translation. Specifically, I examined cortical activation patterns during word translation between Japanese words and English words while also considering the learners' English proficiencies. The advanced group and the elementary group showed different cortical activations depending on the translation direction and familiarity of the words. The advanced group elicited greater activation on the left prefrontal cortex around Broca's area during translation of words with low familiarity. In particular, activation of Wernicke's area was also recruited only while translating Japanese into English. However, no activation was observed while translating high familiarity words. In contrast, the elementary group showed greater activation on the left temporal area including the superior temporal gyrus (STG), regardless of translation direction and word familiarity. These results were interpreted as reflecting different cognitive processing depending on differences in English proficiency. In the advanced group, because of the relatively rich vocabulary storage, lexical route processing might be dominant while translating English (L2) into Japanese (L1), resulting in activation in Wernicke's area. Conversely, in the elementary group, word concepts were processed with a semantic route because a sufficient amount of vocabulary was not stored. Accordingly, the semantic route may have elicited activation of the STG, but not Wernicke's area, associated with vocabulary storage.

4.2 Second language acquisition for Japanese learners of English

Japan is an EFL (English as a foreign language) environment and people are not exposed to English in their daily lives without deliberately creating opportunities to use English. The “read-aloud instruction package” used in study 1 included as much comprehensible input and output as possible, which is indispensable to acquiring an L2 (Krashen, 1982; 1985; Swain, 1985; Swain & Lapkin, 1995). The effectiveness of the “read-aloud instruction package” was evidenced in the increase of English proficiency among Japanese learners of English who were at an elementary level. One of the components of the instruction package, slash (chunked) reading, requires readers of English to comprehend English sentences using syntactic knowledge (Nishida, 2013). Because elementary English learners generally do not have sufficient grammatical knowledge, they cannot understand where one semantic unit begins and another ends without knowing how to divide certain words (Nishida, 2013; Rasinski, 1989). The instruction package provided the participants with easily understandable grammatical explanations when conducting slash (chunked) reading, which is a part of TILT (Translation in Language Teaching: translating L2 into L1). TILT encourages the improvement of English proficiency. In other words, using L1 or translating L2 into L1 to understand L2 can help learners to more effectively and successfully acquire English as part of their English education (Cook, 2010; Hall & Cook, 2012; Widdowson, 1978). From the perspective of cognitive linguistics, Zhao (2018) stated that a translation activity itself elicits cognitive language processing, and that translation is a natural strategy. In addition to slash (chunked) reading, including translation activities, the participants were required to perform reading aloud, cloze test and simultaneous reading aloud and writing out activities. These activities contributed to participants' use of more mental processing in their learning strategies. The "read-aloud instruction package" itself might have been slightly cognitively demanding for the participants. In other words, as put forth in the comprehensible input hypothesis (Krashen, 1982; 1985), the combined activities may have produced an ideal input (reading and listening) level for the participants: the principle of "i+1" (Krashen, 1982; 1985) was applicable to the "read-aloud instruction package", leading to improved English proficiency among the participants, which is one of the benefits of the instruction package. From the perspective of this principle, the effectiveness of the "read-aloud instruction package" for Japanese learners of English could be partially supported by the results of study 2. In particular, cortical activation patterns elicited during the translation of English into Japanese required by the "read-aloud instruction package" could provide us with an important implication. While translating high-familiarity words, the elementary group could have been under a slightly higher cognitive load, which should correspond to "i+1". Activation on the left superior temporal gyrus (STG) in the elementary group may reflect such a cognitive state. On the other hand, while translating low-familiarity words, the advanced group might have been under a slightly heavier cognitive load, which could also be related to "i+1". This may explain the greater activation on the left Broca's area. Conversely, high-familiarity word translation may have put the advanced group under a lower cognitive load because they could easily find the targeted words. This would correspond to "i-1" or "i-2". This may be the cause of the lack of activation in the cortical area examined. As mentioned above, when appropriate words were inputted, the relevant brain activation patterns were observed. The activated areas were different depending on participants' English proficiencies. This suggests that the different cognitive processing of language corresponding to "i+1" and, depending on English proficiency, could be recruited during word translation activities. Based on the points discussed above, it may be possible to provide effective English learning methods for Japanese learners of English for SLA. Each English learner has various and different cognitive language processing skills and neural mechanisms underlying them. Therefore, choosing English tasks based on the principle of "i+1" adjusted to the level of Japanese learners of English could be important for English proficiency. If the tasks are too easy or too difficult for each learner, it could be difficult for him/her to improve them English proficiency. In addition, when English is processed based on an appropriate “i+1” level, if English learners could monitor their cognitive language processing by themselves (self-monitoring), they could evaluate their own English proficiency (self-evaluation). By developing such English teaching and learning methods, Japanese learners of English could, with increased certainty, improve their English proficiency.

4.3 Scope of future work

In study 1, elementary level Japanese learners of English were recruited. However, in future research, intermediate and advanced level groups should be included to investigate the very important question of whether or not this instruction method is effective for learners at other levels. By doing so, we could reveal which levels of Japanese learners of English the “read-aloud instruction package” is most effective for. Exploring how brain activation patterns change before and after implementation of the instruction would be very beneficial neuroscientific findings for English education. In study 2, both elementary and advanced level Japanese learners of English were recruited as participants. Intermediate level learners should be included in future studies as different findings might be obtained. Finally, showing brain activation patterns while conducting sight translation, a part of TILT (Translation in Language teaching), would be beneficial because to date there has been no neuroscientific evidence for TILT. With such scientific evidence, TILT might be persuasively introduced into current English education.

4.4 Conclusions

This dissertation has described two findings. First, the “read-aloud package instruction” could contribute to improving English skills at the elementary level. Due to the introduction of the instruction, learners could use more mental processing as part of their learning strategy. Second, conducting word translation between English and Japanese revealed different brain activation patterns for Japanese learners of English at elementary and advanced levels. Taken together, these two findings could contribute to providing an effective English teaching method for SLA.

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