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Comparison of Cognitive Loads between Koreans and Foreigners in the Reading Process

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Objective: This study aims to measure cognitive load levels by analyzing the EEG of Koreans and foreigners, when they read a Korean text with care selected by level from the grammar and vocabulary aspects, and compare the cognitive load levels through quantitative values. The study results can be utilized as basic data for more scientific approach, when Korean texts or books are developed, and an evaluation method is built, when the foreigners encounter them for learning or an assignment.

Background: Based on 2014, the number of the foreign students studying in Korea was 84,801, and they increase annually. Most of them are from Asian region, and they come to Korea to enter a university or a graduate school in Korea. Because those foreign students aim to learn within Universities in Korea, they receive Korean education from their preparation for study in Korea. To enter a university in Korea, they must acquire grade 4 or higher level in the Test of Proficiency in Korean (TOPIK), or they need to complete a certain educational program at each university's affiliated language institution. In such a program, the learners of the Korean language receive Korean education based on texts, except speaking domain, and the comprehension of texts can determine their academic achievements in studying after they enter their desired schools (Jeon, 2004). However, many foreigners, who finish a language course for the short-term, and need to start university study, cannot properly catch up with university classes requiring expertise with the vocabulary and grammar levels learned during the language course. Therefore, reading education, centered on a strategy to understand university textbooks regarded as top level reading texts to the foreigners, is necessary (Kim and Shin, 2015). This study carried out an experiment from a perspective that quantitative data on the readers of the main player of reading education and teaching materials need to be secured to back up the need for reading education for university study learners, and scientifically approach educational design. Namely, this study grasped the difficulty level of reading through the measurement of cognitive loads indicated in the reading activity of each text by dividing the difficulty of a teaching material (book) into eight levels, and the main player of reading into Koreans and foreigners.

Method: To identify cognitive loads indicated upon reading Korean texts with care by Koreans and foreigners, this study recruited 16 participants (eight Koreans and eight foreigners). The foreigners were limited to the language course students studying the intermediate level Korean course at university-affiliated language institutions within Seoul Metropolitan Area. To identify cognitive load, as they read a text by level selected from the Korean books (difficulty: eight levels) published by King Sejong Institute (Sejonghakdang.org), the EEG sensor was attached to the frontal love (Fz) and occipital lobe (Oz). After the experiment, this study carried out a questionnaire survey to measure subjective evaluation, and identified the comprehension and difficulty on grammar and words. To find out the effects on schema that may affect text comprehension, this study controlled the Korean texts, and measured EEG and subjective satisfaction.

Results: To identify brain's cognitive load, beta band was extracted. As a result, interactions (Fz: $p=0.48$; Oz: $p=0.00$) were revealed according to Koreans and foreigners,

and difficulty of the text. The cognitive loads of Koreans, the readers whose mother tongue is Korean, were lower in reading Korean texts than those of the foreigners, and the foreigners' cognitive loads became higher gradually according to the difficulty of the texts. From the text four, which is intermediate level in difficulty, remarkable differences started to appear in comparison of the Koreans and foreigners in the beginner's level text. In the subjective evaluation, interactions were revealed according to the Koreans and foreigners and text difficulty (p=0.00), and satisfaction was lower, as the difficulty of the text became higher.

Conclusion: When there was background knowledge in reading, namely schema was formed, the comprehension and satisfaction of the texts were higher, although higher levels of vocabulary and grammar were included in the texts than those of the readers. In the case of a text in which the difficulty of grammar was felt high in the subjective evaluation, foreigners' cognitive loads were also high, which shows the result of the loads' going up higher in proportion to the increase of difficulty. This means that the grammar factor functions as a stress factor to the foreigners' reading comprehension.

Application: This study quantitatively evaluated the cognitive loads of Koreans and foreigners through EEG, based on readers and the text difficulty, when they read Korean texts. The results of this study can be used for making Korean teaching materials or Korean education content and topic selection for foreigners. If research scope is expanded to reading process using an eye-tracker, the reading education program and evaluation method for foreigners can be developed on the basis of quantitative values.

Keywords: EEG, Cognitive load, Text reading, Schema activation

1. Introduction

According to educational statistics released by the Ministry of Education, the number of foreign students studying in Korea were 84,891 based on 2014, up five times more in ten years from 2004. The number of foreign students in the degree earnings courses were 53,636 (Ministry of Education, 2014), and some 30,000 foreign students are estimated to learn the Korean language to enter university. In order to enter university in Korea, a student needs to acquire a certain level of score in the TOPIK (Test of Proficiency in Korean) evaluated from grade 1 to grade 6, or he/she must complete a language course established in each university in Korea (Park, 2013). Therefore, the acquisition of the TOPIK qualification is essential for the foreign students studying within Korea for the purpose of academic study to enter a university within Korea (Kim, 2010). Studying Korean has an important meaning to the foreigners who prepare for study in Korea in their own countries or who are just interested in the Korean culture. The Ministry of Culture, Sports and Tourism set up King Sejong Institute in various countries in the world for foreigners who want to encounter the Korean language overseas, and the ministry continuously makes efforts to diffuse Korean and Korean culture in the world.

Although the attraction of foreign students within Korea and abroad through the diffusion of Korean and Korean culture has been successful, the number of foreign students in Korea is on the decline, based on 2011. There can be various factors here, but the cause can be identified through their satisfaction on university life in Korea. Upon looking at the details of satisfaction on study, the first year foreign university students who understand 60~80% of lectures can be estimated 26.5%, and those who understand more than 80% can be estimated 13%. That is, more than half cannot properly understand lectures (Seo et al., 2012). This means that many foreign students studying in Korea attend university lectures without being equipped with adequate Korean ability, and there is a huge possibility they return to their own countries without achieving the purpose of studying in Korea. Furthermore, some foreign students receiving Korean education for a certain period of time may regard the Korean education system for foreigner has some problems, as well as personal problems.

An attempt and an effort to analyze the problems of foreign students' learning capacity, and to improve it are made in the Korean education sector. Upon looking at relevant studies, a study of Jeon (2004) suggested that the Korean class should be offered for foreigners for academic study, and that reported the importance of reading function among others through a survey of needs. In reality, Korean education for university classes is needed for foreign students to earn university degrees, in addition to communication purpose. To understand the major classes and major textbooks, reading ability is an indispensable factor for university education (Jordan, 1997). Son (2000) compared the class training strategy by reading level and existing class targeting 23 intermediate level learners of Korean at the Institute of Language Research and Education, Yeonsei University. The study of Sohn analyzed the effects of learners' reading strategy training of the Korean language on learning results through class results and survey, and verified realistic efficiency, and presented a direction for more efficient reading teaching-learning activity. Shim (2007) conducted an experiment using a think aloud method targeting ten Chinese and Japanese Korean learners, respectively, as a study on reading strategy according to learner's nationality variable in Korean reading education. As a result, Shim found that the living environment and background knowledge of both countries' learners affected the reading strategies, and the reading strategies were revealed different.

As part of research to improve foreigners' learning ability, there are methods related with reading strategy, and most of them, namely questionnaire survey and interviews with subjects are used as a research method. This study tries to analyze bio-signal, which is a more objective measurement of hindrance factors and stress index in the Korean reading course for foreigners, through which this study aims to acquire more accurate basic data.

In foreign countries, where language education is developed, learners' EEG are utilized for the development of their own language teaching materials, and foreign language teaching materials. To track down whether automatic activation prior to the non-processing of phonological understanding, researches are carried out through EEG study with real time recording of electric signals generated from brain (Barber et al., 2004; Holcomb and Grainger, 2006; O'Rourke and Holcomb, 2002). Actually, fMRI and PET are the most widely used among brain imaging methods to look into things happening in human's brain, while one conducts reading. These days, EEG (electroencephalography) is also used a lot (Goswami, 2008). Kwon et al. (2011) reported that difference of EEG occurred in 200ms range, after presenting a stimulus according to the high and low phonological syllable frequency, when writing-related variables are fixed in a vocabulary judgment task using ERP. The study results of a study of Kim et al. (2011) on

Table 1. The effectiveness of interventions with reading by EEG

Author	Details of interventions	Study result
Richards et al. (2000)	Interventions centered on phonological processing, word decryption, reading comprehension and listening comprehension	The difference of high lactic acid metabolic rate of the dyslexia group from that of the control group disappeared, after interventions.
Richards et al. (2002)	Interventions centered on alphabet princip0le and morphologic perception	A significant difference of lactic acid activation was found before and after interventions.
Shaywitz (2003)	Intensive interventions in alphabet principle (understanding of letter combination and phoneme)	The intervened group showed the improvement in reading proficiency, and activation in the left brain domain and middle part brain.
Richards et al. (2006)	Interventions in spelling and morphologic spelling	After spelling-centered interventions, increased activation was shown in the right inferior frontal and right superior temporal gyrus.
Shaywitz et al. (2006)	Phonology-based reading program	After inventions, brain activation pattern becomes similar to that of a normal child.

the relationship between reading and EEG are revealed in the following Table 1:

This study analyzes the reading process of Koreans and foreigners using the EEG (alpha and beta bands) used as a method to measure cognitive load in the ergonomics field. The purpose of this study is to comparatively evaluate the cognitive loads of foreigners and Koreans upon reading Korean texts with care using the analysis method above. Through this, this study aims to identify hindrance factors felt by foreigners as they encounter Korean texts, provide basic data to devise an education method for foreigners to more easily understand Korean books, and build a quantitative evaluation method in the future.

2. Method

2.1 Participants

To evaluate cognitive loads of Koreans and foreigners, this study selected 16 healthy participants (eight Koreans and eight foreigners). All the participants were limited to those who did not have an experience of cognitive treatment and ophthalmic treatment that may affect eyesight (Table 2).

Table 2. Information on participants

	Age	Career for leaning Korean
Korean	25±2	Master's degree students in Korea
Foreigner	23±1	Students of language institute (grade four)

2.2 Apparatus

This study used a EEG gauge (Biopac, Mp150) to measure the cognitive loads of Koreans and foreigners. The EEG sensor was attached to the participants' Fz and Oz parts by International 10/20 Electrode System for electrode attachment parts (Figure 1).



(a) (b)

Figure 1. Experimental environments (a: experimental scene, b: EEG)

2.3 Procedure

This study measured EEG during the reading Korean texts with care, and subjective evaluation after the reading under the assumption that there is a difference in cognitive loads between Koreans and foreigners upon reading Koran texts with care. Before the experiment, the purpose and procedure of the experiment were explained to the participants, and they were instructed to write their personal information such as age and Korean learning period. After that, a EEG sensor was attached to the participant's Fz and Oz. Adaptation time of ten minutes was offered before the experiment was implemented to adapt to the EEG sensor (Figure 2).

1. Did you understand what you read?

①	②	③	④	⑤
Not very so	Not so	Common	Much	Very much

2. Were the words difficult?

①	②	③	④	⑤
Very difficult	Difficult	Common	Easy	Very easy

3. Was the grammar difficult?

①	②	③	④	⑤
Very difficult	Difficult	Common	Easy	Very easy

4. How was the text? (word|+grammar+font|comprehension)

①	②	③	④	⑤
Very unsatisfied	Unsatisfied	Common	Satisfied	Very satisfied

Figure 2. Subjective evaluation sheet

When the participants are familiarized with the apparatus, they were instructed to read the Korean text by difficulty from the books (grades 1~8) offered by King Sejong Institute in line with experiment design sequence. To find out whether a participant understood what he/she read, subjective comprehension evaluation was conducted, after the experiment was finished by each condition. To identify in what form schema helps text comprehension, this study selected experimental texts among the eight types of books containing the grammar and words higher than the level of the learners, given that the participants were intermediate level learners. The content of the text was about King Sejong that the participants learned in their regular classes before the experiment was carried out. The higher levels of grammar and words than those of the leaners were provided as a hindrance factor, and the content was what the foreigners already learned, namely, background knowledge was premised in the experiment (Figure 3).

The experiment venue was a quiet and entrance- and exit-controlled classroom. As Kim et al. (2012) reported that 50cm in distance between a book and eyes, and 300lx in luminance would minimize the effect according to the distance between the book and eyes, this study also carried out the experiment in line with such a condition.

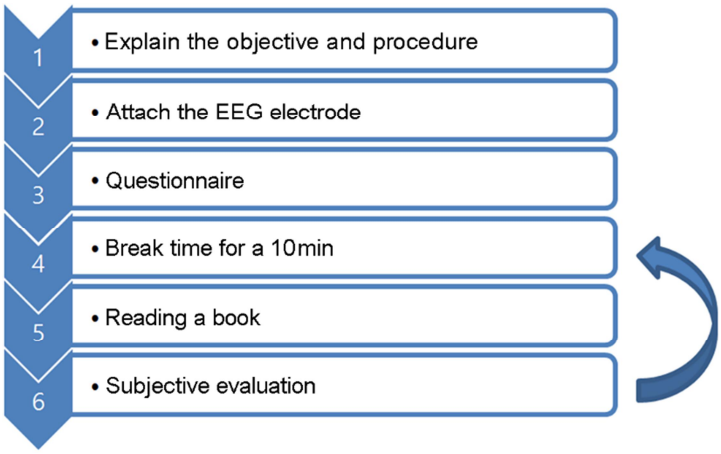


Figure 3. Flow of experiment

2.4 Design

To evaluate cognitive loads measured with EEG of Koreans and foreigners, this study designed with 2×8 within-subject design (groups: 2, difficulty of text within the book: eight grades). The dependent variables were the alpha band, a EEG revealed when a participant's mind and body become stable, the beta band which is a stress wave, and subjective evaluation (questionnaire survey: comprehension, difficulty of words, difficulty of grammar, and overall satisfaction). Independent variables were level of two groups (Koreans and foreigners), and difficulty of text (1~8 levels). As for text difficulty, each text was selected within the books from level one to level eight provided by King Sejong Institute affiliated with the Ministry of Culture and Tourism. To remove participant's carry-over effect, the Latin squared design was used (Wakeling and MacFie, 1995) (Figure 4).



Figure 4. Experiment scene

3. Results

To find out the effects of dependent variables according to independent variables, an analysis of variance (ANOVA) was conducted

(Table 3). As a result, significant differences were shown in the main effective group (p>0.01) and text level (p>0.01) in the EEG and subjective evaluation. A significant difference was shown in the group x text level (p>0.05), which is an interaction.

Table 3. The summary of analysis of variance (ANOVA)

Source				Type III sum of squares	df	Mean square	F	p-value
EEG	Alpha	Fz	Group	1478.502	1	1478.502	329.882	.000***
			Level of text	112.741	7	112.741	37.415	.000***
			Level of text x group	20.933	7	20.933	6.947	.025**
		Oz	Group	1365.063	1	1365.063	319.003	.000***
			Level of text	109.682	7	109.682	44.394	.000***
			Level of text x group	42.052	7	42.052	17.020	.002***
	Beta	Fz	Group	2002.226	1	2002.226	588.978	.000***
			Level of text	1114.089	7	159.156	51.445	.000***
			Level of text x group	46.820	7	6.689	2.162	.048**
		Oz	Group	1850.998	1	1850.998	1308.080	.000***
			Level of text	217.790	7	31.113	14.182	.000***
			Level of text x group	1154.456	7	164.922	75.176	.000***
Subjective evaluation	Understanding article		Group	.000	1	3.113	13.500	.009***
			Level of text	11.600	7	1.657	18.019	.000***
			Level of text x group	8.000	7	1.143	12.427	.000***
	The difficulty of words		Group	2.813	1	2.813	12.500	.008***
			Level of text	12.188	7	1.741	5.478	.000***
			Level of text x group	13.888	7	1.984	6.242	.000***
	The difficulty of grammar		Group	2.813	1	3.813	15.500	.009***
			Level of text	6.750	7	0.964	3.484	.004***
			Level of text x group	6.000	7	0.857	3.097	.008***
	Overall satisfaction		Group	5.513	1	5.513	17.640	.003***
			Level of text	8.288	7	1.184	6.437	.000***
			Level of text x group	2.788	7	.398	2.165	.051**

*: p<0.1, **: p<0.05, ***: p<0.01

3.1 EEG (electroencephalogram)

EEG showed significant differences in the main effective group (p<0.01) and the difficulty of text (p<0.01, and interactions were also shown according to group and difficulty of text (Table 3). This study also conducted a post-hoc analysis on the alpha and beta bands having significant differences. As a result, Koreans' frontal lobe alpha band was 1.46 times higher (p<0.01), and beta

band was 1.33 times lower ($p<0.01$) than the foreigners, respectively. The Koreans' occipital lobe alpha band was 1.22 times higher ($p<0.01$), and beta band was 1.36 times lower ($p<0.01$) than the foreigners, respectively. As the difficulty of text was higher, the cognitive loads of the Koreans and foreigners showed higher at statistically significant level (Figure 5).

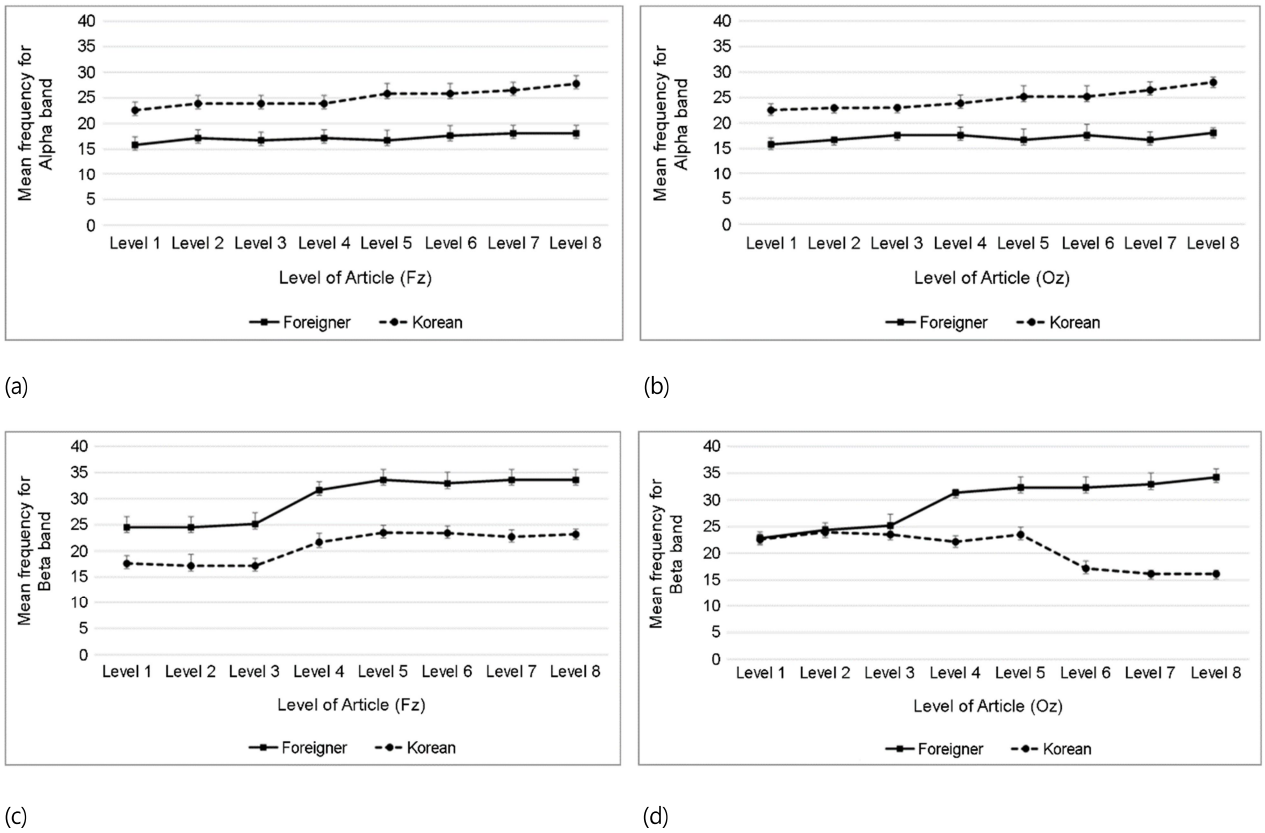


Figure 5. Alpha band and beta band of EEG on group and level of text

3.2 Subjective evaluation

EEG showed significant differences in the main effective group ($p<0.01$) and the difficulty of text ($p<0.01$), and interactions were shown according to group and difficulty (Table 3). This study carried out a post-hoc analysis on the comprehension, difficulty of words, difficulty of grammar and overall satisfaction. As a result, the foreigners' comprehension was 1.11 times lower ($p<0.01$), and the difficulty of words showed 1.1 times lower ($p<0.01$) than the Koreans, respectively. Concerning the difficulty of grammar, the foreigners showed 1.06 times higher ($p<0.01$) than the Koreans, and 1.16 times lower ($p<0.01$) than the Koreans in overall satisfaction (Figure 6).

4. Discussion

This study conducted an experiment by analyzing and evaluating the cognitive loads of the Koreans and foreigners upon reading Korean texts with care using EEG, and the resulting EEG and subjective evaluation are summarized as follows (Table 4):

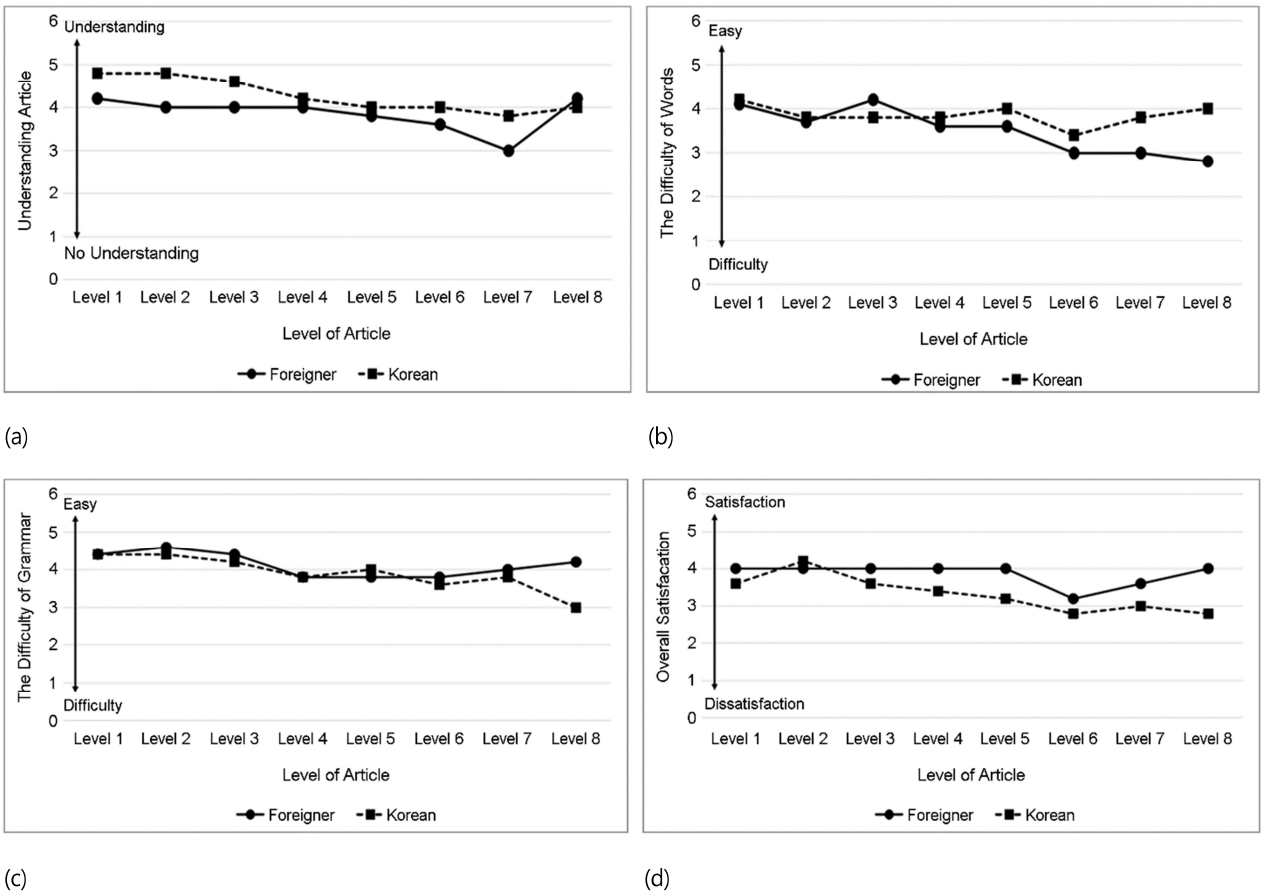


Figure 6. Subjective evaluation on group and level of text

Table 4. The summary of result

			Group
EEG	Alpha band	Fz	Foreigner < Korean
		Oz	Foreigner < Korean
	Beta band	Fz	Foreigner > Korean
		Oz	Foreigner > Korean
Subjective evaluation	Understanding article		Foreigner > Korean
	The difficulty of words		Foreigner > Korean
	The difficulty of grammar		Foreigner > Korean
	Overall satisfaction		Foreigner > Korean

<>: $p=0.05$

The Koreans' alpha band in the Fz and Oz parts was higher than that of the foreigners in terms of EEG. The alpha band is a stability band revealed mainly in the relaxed and comfortable state in the frequency range of 8~12Hz. The study result that

amplitude increases, as one is in more comfortable state was reported in the studies of Kang et al., 2003; Kim and Choi, 2001. The Koreans' alpha band was higher than that of the foreigners. A bigger difference was shown between the foreigners in the 7 or higher level of text beyond the intermediate level and Koreans. As shown in the subjective evaluation, although Koreans discriminated or perceived that the difficulty of grammar and words went up within the text, which did not affect the stable EEG, alpha band, in the reading process. Such a result means that the difficulty of words or grammar does not function as a big hindrance factor in reading comprehension to the Koreans who do not feel difficulties in judging they have higher level of comprehension ability than the difficulty of text, or who do not feel they have difficulties in reading comprehension. Therefore, building the learning and evaluation atmosphere is conjectured to be required for Korean education in consideration of learners' confidence and emotional aspect on learning so that the difficulty of words and grammar cannot work as a hindrance facto to foreigners with fear towards the Korean language in reading process.

As a result of comparing the beta bands of the Koreans and foreigners, foreigners' beta band was higher. The frequency range of beta band was 15~30Hz. Beta band is revealed in all conscious activities, when one is awake and when one is speaks. Especially it is reported to be revealed more when one handles complex calculation (Kim and Choi, 2001; Baek, 2008; Ray and Cole, 1985; Mantini et al., 2007). In this study, the beta band of the foreigners was higher than that of the Korean learners, which can be interpreted that the foreigners conducts more complex calculation, and do more conscious activities in reading Korean texts or books. Also, from the grade 4 of the difficulty of words, which is intermediate level or higher in terms of difficulty of text, the difference was bigger. This is clearly demonstrated in Oz in charge of vision. Because the words or grammar with higher difficulty than foreigner's reading ability were contained in the texts or books that foreigners encounter, it can be interpreted that they receive stress more according to increase in tension and concentration.

As shown in Figure 4, the Koreans' beta band decreased, and alpha bands of the two groups increased according to the increase of difficulty. Although the increase range of alpha band related with mental and physical stability was small (maximum value, minimum value and range value of foreigners' alpha band: 28.0, 22.6 and 5.45, respectively), it can be interpreted as significant in that it did not fall, despite rise in the difficulty of text. Namely, this can be a result that Koreans and foreigners are familiarized with the Korean texts, as time to encounter Korean texts become longer. The Koreans' beta band change range was huge (foreigners' beta band: maximum value, minimum value and range value: 34.2, 22.9 and 11.4, respectively), which can be judged that tension and stress of the Koreans are conjectured to be the factors that can be overcome within short-term, compared to the foreigners, because Koreans' language ability level is higher than the difficulty of text.

To find out the effects of schema affecting reading comprehension, this study carried out a EEG analysis and a subjective evaluation. The content of the experimental text 8 is about King Sejong that the foreigners learned during the regular class a week before, and the text was presented to the foreigners on the premise that content schema existed. As a result, the foreigners showed satisfaction higher than common level in text comprehension, despite the difficulty level of grammar and words showing higher than the learning level of the foreigners from the subjective evaluation aspect. However, as a result of EEG analysis, actual decrease of cognitive load level was not shown. This can be the foundation of an assertion of Widdoswson (1983), and Kim (2002) that schema reduces the difficulties in reading due to difficult words or grammar, or can be utilized as a device to make easier approach to reading texts. However, the status of schema is not a factor to decrease actual cognitive load, and schema can be interpreted as a motivating factor by enhancing reading efficacy and friendliness.

5. Conclusion

This study measured cognitive loads felt by the Koreans and foreigners in Korean text reading by using EEG and subjective satisfaction. As a result, the foreigners' cognitive load was higher than that of the Koreans upon reading Korean texts with care, which was drawn by actual and quantitative values, and the differences increased according to the difficulty of text. This study

found that schema formation can have a positive effect on reading process through a EEG analysis and a subjective evaluation. This study is differentiated from existing studies in that an experiment was carried out by dividing the Korean reading texts by difficulty of the texts, and into two groups, namely Koreans and foreigners. The existing studies mainly interpreted EEG patterns with an ERP (event related potential) experiment on phoneme and phonological dimension. However, this study is meaningful in that this study compared targeting the entire reading process. The study results and quantitative method are expected to be utilized as effective data for text and teaching materials development beyond the reading sentences that foreigners can easily approach.

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