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Sensitive Period of Auditory Perception and Linguistic Discrimination

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ABSTRACT

The purpose of this study is to scientifically examine Kuhl's (2011), originally Johnson and Newport's (1989) critical period graph, from a perspective of auditory perception and linguistic discrimination. This study utilizes two types of experiments (auditory perception and linguistic phoneme discrimination) with five different age groups (5 years, 6-8 years, 9-13 years, 15-17 years, and 20-26 years) of Korean English learners. Auditory perception is examined via ultrasonic sounds that are commonly used in the medical field. In addition, each group is measured in terms of their ability to discriminate minimal pairs in Chinese. Since almost all Korean students already have some amount of English exposure, the researchers selected phonemes in Chinese, an unexposed foreign language for all of the subject groups. The results are almost completely in accordance with Kuhl's critical period graph for auditory perception and linguistic discrimination; a sensitive age is found at 8. The results show that the auditory capability of kindergarten children is significantly better than that of other students, measured by their ability to perceive ultrasonic sounds and to distinguish ten minimal pairs in Chinese. This finding strongly implies that human auditory ability is a key factor for the sensitive period of language acquisition.

Keywords: auditory perception, sensitive period, linguistic discrimination

1. Introduction

The belief that children are more sensitive than adults in language learning and acquisition probably results from typical observations of children living in foreign countries: they seem to more rapidly achieve their second/foreign language goals and become more like native speakers than adults (Kim, 2004; Mayberry & Lock, 2003). In the behavioral and brain literature, many studies on developing children show that children's ability, measured very early in infancy, predicts their later performance and learning. For the past three decades, neuroscientists, educators, speech and hearing scientists, linguists and psychologists have increasingly worked together to understand children's sensitivity for learning and how learning can be encouraged once a certain period for learning has passed (Werker & Tees, 2005). To investigate this sensitive period for language acquisition, this study focuses on children's auditory and linguistic discrimination abilities.

Recent studies indicate that children's early processing of the phonetic units in their language predicts future competence in language and literacy, which contributes to theoretical debates about the nature of language and emphasizes the practical implications of research and the potential for early interventions to support language (Kuhl, 2011; Mayberry & Tees, 2003). The "age of exposure" (Kuhl, 2011, p. 335) affects the way a language is represented in the brain. To examine these effects, researchers use cutting-edge medical tools such as functional Magnetic Resonance Imaging (fMRI), Event-related Potentials (ERPs), and Electroencephalography (EEG) (Dehaene et al., 1997; Kuhl, 2011; Yetkin et al., 1996).

Kuhl (2011) extensively reviewed early language learning and literacy with neuroscience implications using MEG (Magneto encephalography). She suggested that the critical period graph,

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redrawn from a study by Johnson and Newport (1989), shows a simplified schema of second language competence as a function of the age of second language acquisition. Johnson and Newport's graph was drawn based on the performance of differently aged native Korean and Chinese speakers on an English grammar task. <Figure 1> shows that infants and young children are superior learners compared to adults despite adults' cognitive superiority.

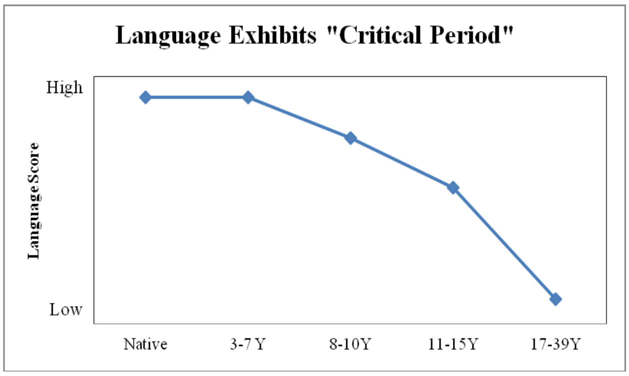

Figure 1. The relationship between ages of acquisition of L2 skill and language performance (adapted from Johnson & Newport, 1989)

However, the critical period graph does not imply that it is impossible to learn a new language after childhood. A new language can be learned at any age, but most researchers agree that a high level of expertise will not be obtainable after puberty. Researchers also agree that the critical period learning curve is representative of data across a wide variety of second language learning studies (Birdsong & Molis, 2001; Flege, Yeni-Komshian & Liu, 1999; Hakuta, Bialystok & Wiley, 2003; Mayberry & Lock, 2003). Bialystok and Hakuta (1999) examined the role of age in linguistic and cognitive factors by testing language proficiency. Based on the results, the researchers insist that "schooling was positively related to proficiency, independent of age of arrival or language" (p. 175).

The nature of the critical period for language acquisition is not well understood. Indeed, the mere existence of such a critical period remains controversial, mainly because different researchers use different subjects and methodologies. In this study, we attempt to identify the characteristics of the sensitive period among Korean learners and, to find the similarities with and differences from the previous critical period graphs. The main purpose of our study is to investigate Koreans' sensitive period from an auditory perspective. We used ultrasonic sounds taken from the internet (http://www.ultrasonic-ringtones.com/) to discern the auditory capacity of Korean children and adults. Ultrasonic sounds are commonly used medically to precisely detect human auditory capabilities (Cha, 2011; Kim, 2009). The purpose of this study is to investigate how the sensitivity of children's auditory capability relates to listening in language learning as a follow-up research of Cha (2011) and Cha & Jo (2012).

Secondly, this study explores linguistic discrimination in Chinese. In order to limit the variables, this study chose a foreign language that participants had not been exposed to previously: Chinese.

Most evidence for children and adults' differences in second language learning has come from studies comparing children and adults' second language pronunciation, production, or grammatical accuracy after an extensive experience with or exposure to the second language. However, the superiority observed in child learners can also be attributed to the differences in instruction that children and adults receive throughout their language development (Flege, Yeni-Komshian & Liu., 1999; Jia & Aaronson, 2003). This study aims to provide evidence for children's superiority using two types of perspectives: auditory perception and linguistic discrimination in five separate age groups of Korean learners. Several attempts from many studies investigate language learning and age factor refers a sensitive period research. Due to the limitations of the previous research, this study scientifically explores a sensitive period of auditory perception and linguistic discrimination relating to language acquisition.

The research questions are as follows: 1) How do the curves appear among the five differently aged groups in auditory perception and linguistic discrimination tests? and 2) Are the shapes of Korean's auditory perception and linguistic discrimination curves in accordance with Kuhl's critical period graph?

2. Critical Period and Language Learning

A number of studies delineate the existence of a critical period for second language acquisition. Firstly is Curtiss (1977) study of Genie, a girl isolated from linguistic input from around a year of age until after puberty. He claimed that "first language acquisition during adulthood results in strikingly abnormal linguistic competence" (p. 14). Does the critical period graph show that it is unfeasible to learn a new language after childhood? Several pieces of evidence corroborate the difficulty in post-childhood learning. According to the critical period hypothesis, there is a certain biological/neurological factor which is no longer accessible due to changes in cerebral plasticity.

The critical period hypothesis primarily relates to the acquisition of a first language, and suggests that the period ranges from about two years of age to the end of 12 years of age (Scovel, 1988). The term “critical period” refers to second language acquisition, where limitation on acquisition is not absolute, as is the case of first language. Thus, it is possible to acquire a second language after the end of the sensitive period, but not to the extent of attaining a native-like competence (Krashen, Long & Scarcella, 1979).

The critical period hypothesis has at its center the factor of age, which is one of the most controversial issues among researchers in relation to language learning. Researchers have different views on the age at which the critical period ends: 5 years (Krashen, 1973), 6 years (Long, 1993), 12 years (Lenneberg, 1967), or 15 years (Johnson & Newport, 1989). A language can be learned at any age, but most agree that learners will best perform if exposure to the new language develops before puberty. Many studies in language learning have supported a relationship between the ages of exposure to a language and the proficiency levels achieved by learners (Asher & Garcia, 1969; Johnson & Newport, 1989; Lim, 2005; Pallier, Bosch & Sebastián-Gallés, 1997). The effects of the critical period have been shown for both first and second languages, as well as for measures of proficiency or grammatical ability. For example, Johnson and Newport (1989, 1991) claim that “Chinese or Korean immigrants who move to the United States and exposed to English as a second language show a relation of the children have an advantage over adults in acquiring a second language” (p. 89).

Krashen, Long and Scacella (1979) reviewed about 23 studies concerning age, rate, and attainment in second language. They investigated studies of children-adult differences in second language learning and short-term investigations comparing children and adults acquiring second languages in natural environments. From the results of study, researchers have claimed that young children can catch up to older children and adults in second language learning.

Thompson (1991) explored factors related to acquisition of second language pronunciation. He examined 36 native Russian speakers fluent in English who had to read specially constructed English sentences and a prose passage, and talk about their daily routine. He insists that “the age of arrival was found to be the main factor for pronunciation accuracy. Additional variables such as gender, ability to mimic, and global speaking proficiency were also found to play a role, however, attitude and motivation did not seem to play a significant role in their participants’ acquisition of the second language sound system” (p. 177).

Speech learning models are concerned with age-related limits restrictions on learners’ ability to produce second language vowels and consonants in a native like way (as cited in Baker et al., 2008). The researcher found that second language pronunciation accuracy may decline not because one has lost the ability to learn to pronounce in general, but, because one has learned to pronounce the first language so well. Flege, Yeni-Komshian and Liu (1999) investigated the critical period hypothesis for second language acquisition using 240 native speakers of Korean who differed according to age of arrival in the United States (1 to 23) years. The result of this study showed “the existence of a critical period in the domain of morphosyntax” (p. 22). Another study worth mentioning is Johnson and Newport (1989), which aimed to show a strong correlation between age decline in language proficiency and puberty (15 years of age). The results showed that the critical period for language acquisition extends its effects to second language acquisition. None of the above studies, however, have focused on the effects of auditory perception or linguistic discrimination to investigate the critical period of second language acquisition.

3. Auditory Perception and Linguistic Discrimination

Children’s ability to group perceptually distinct sounds into categories has been demonstrated in several experiments (Kuhl, 1989; Kuhl, Stevens, Hayashi, Deguchi, Kiritani & Iverson, 2006; Kuhl, Williams, Lacerda, Stevens, & Lindblom, 1992). Kuhl (2004) claims that “the rules by which infants perceive information, the ways in which they learn words, the social contexts in which language is communicated and the need to remember the learned entities for a long time probably influenced the evolution of language” (p. 841). Children’s initial capacities in these studies were primarily due to innate mechanisms that defined phonetic units. However, they also showed that adults remained capable of discriminating nonnative contrasts, suggesting that nonnative abilities are not lost completely after a certain age (Rivera-Gaxiola, Csibra, Johnson & Karmiloff-Smith, 2000; Werker & Logan, 1985).

Werker and Tees (2005) reviewed the literature on speech perception and phonological processing in infancy. They focus on the idea that "infants are sensitive to natural boundaries. Without specific listening experience in a language, infants in the first six months of life show sharper discrimination peaks in consonant boundaries in unknown phonemic category" (p. 237). If infants are universal listeners and adults often have difficulty discriminating foreign language phonemic contrasts, then there must be a decline across age in cross-language speech perception performance (Werker, 1995). This contradicts the typical expectation that there will be age-related increases in ability and age-related improvements in performance. To see if the pattern of broad-based abilities in infancy and subsequent decline is accurate, a series of studies tested infants and adults on the same foreign language contrasts in the same procedure. Werker, Gillber, Humphrey and Tees (1981) compared English-speaking adults and infants with Hindi-speaking adults and infants on their capacities to distinguish differences in two pairs of Hindi words that are not used in English. The results indicated that infants can distinguish sounds similar enough to Hindi adults, but English adults do not particularly do so due to articulation dissimilarity. They claim that "infants have broad-based discriminatory abilities" (p. 354).

Stager and Werker (1997) conducted a study to assess infants' ability to recognize minimal pairs of nonsense words (e.g., bih and dih). They found that it is not until 18 months of age that infants can distinguish minimal pairs, when those words have semantic reference; when infants are beginning to learn word meanings, they acquire the ability to discriminate subtle phonetic details. Languages have many different features, such as difficulty in the English, contrast [r] and [l] for Japanese and Korean learners. Adults have difficulty discriminating acoustically similar phonetic sounds that are not used in their native language (Miyawaki, Liberman, Jenkins, & Fujimura, 1975). Interestingly enough, young infants, seem to be able to discriminate phonetic contrast even if they are inexperienced in language learning (Aslin, Pisoni, Hennessy, & Perey, 1981).

There are conflicting theories and evidence regarding the acquisition of the second language phonological system, which has led, researchers to turn to the critical period and auditory perception in language learning. Hence, the present study is an attempt to test the critical period for L2 (second language) learning in terms of auditory perception and linguistic discrimination.

4. Method

4.1 Participants

In winter 2012, one hundred Korean learners in English of five different age groups- kindergarten, elementary school, junior high school, high school and university- participated in this study. The number of students in each group was 20: 20 kindergarten children (5 years), 20 elementary school students (6-8 years), 20 elementary and junior high school students (9-13 years), 20 high school students (15-17 years), and 20 college students (20-26 years). The subjects' ages ranged from 5 to 26 across the five groups.

All participants had learned English for one to twelve years. Since they had already been exposed to English, the researchers chose a new language for linguistic discrimination. None of the research subjects had ever learned Chinese, though some kindergarten children had visited China for a few days with their parents when they were infants. This was thus the language chosen for the study.

Table 1. Average age of participants

Age of group	Average age	Gap of groups
1st (5 years)	5 year	-
2nd (6-8 years)	7 year	+2
3rd (9-13 years)	11 year	+4
4th (15-17 years)	16 year	+5
5th (20-26 years)	22 year	+6

4.2 Materials

The researchers conducted two experiments in this study. The first tested auditory perception with an online tool of ringtones. The experiment was administered individually in a quiet room. At the same time, in order to prevent clicking sounds, the researchers used a hand mouse. The participants were asked to raise their hand when they thought they heard a sound from the ringtone. This is the same way people are administered aural tests at the hospital. All participants were given an initial introduction to the test by the researchers. The purpose of the test was to find out how auditory perception differed across each group. For the second test, the researchers recorded ten minimal pairs of Chinese phonemes. Twenty phonemes were chosen for this study by a native speaking Chinese doctoral student in the field of foreign language education. In the Chinese linguistic system, there are 23 consonants, 24 vowels and 16 compound vowels (http://www.asyywz.gov.cn/next.asp?sh=1383).

Ten minimal pairs were chosen from Chinese for the test. The researchers made a test paper with ten phonemes. The test sheet was written in English. The chosen sample phonemes and recordings were reviewed by a Chinese native speaker. The phonemes were recorded in a quiet room and saved in MP3 format. The native Chinese speaker enunciated each pair two times. The second test was also administered in a quiet room, where participants listened to each pair twice. The participants spent about 10 minutes in the experiment. The auditory perception test lasted three minutes, and the linguistic discrimination test lasted seven minutes.

4.2 Data Analysis

To check the different auditory perceptions of each group, the researchers measured the range of auditory perception with the ringtones. To calculate the distribution of linguistic discrimination, the researchers computed each subject's linguistic discrimination score. Quantitative data analysis was performed, using SPSS 18.0. Quantitative data analysis was performed, using SPSS 18.0. This study had three types of statistical analysis: descriptive statistics, ANOVA, and multiple comparisons.

Table 2. Analysis of Descriptive Statistics

Group	n	Mean	standard deviation
1st (5 years)	20	7.85	1.755
2nd (6-8 years)	20	7.75	1.552
3rd (9-13 years)	20	7.25	1.997
4th(15-17years)	20	6.65	1.565
5th(20-26years)	20	5.30	2.105

<Table 2> demonstrates the result of descriptive statistics. As shown in <Table 2>, the first group's mean was the highest in auditory perception. To identify a significant difference in mean, the researchers constructed ANOVA. The <Table 3> shows the analysis of ANOVA.

Table 3. Analysis of ANOVA

Factor	SS	df	MS	F-value	p-value
Treatment	87.040	4	21.760	6.651	.000
Error	310.800	95	3.272		
Total	397.840	99			

From the results of ANOVA, F-value was 6.651 and p-value was .000. There was a significant difference in mean, and therefore a significant difference identified between groups in a post hoc test using Scheffea as follows in <Table 4>.

Table 4. Analysis of Multiple Comparisons (Scheffea)

Group (I)	Group (J)	Difference of mean (I-J)	Standard error	p-value
1st (5 years)	2nd(6-8years)	.100	.572	1.000
	3rd(9-13years)	.600	.572	.893
	4th(15-17years)	1.200	.572	.361
	5th(20-26years)	2.550	.572	.001
2nd (6-8 years)	1st(5years)	-.100	.572	1.000
	3rd(9-13years)	.500	.572	.943
	4th(15-17years)	1.100	.572	.453
	5th(20-26years)	2.450	.572	.002
3rd (9-13 years)	1st(5years)	-.600	.572	.893
	2nd(6-8years)	-.500	.572	.943
	4th(15-17years)	.600	.572	.893
	5th(20-26years)	1.950	.572	.026
4th (15-17 ears	1st(5years)	-1.200	.572	.361
	2nd(6-8years)	-1.100	.572	.453
	3rd(9-13years)	-.600	.572	.893
	5th(20-26years)	1.350	.572	.242
5th (20-26 ears)	1st(5years)	-2.550	.572	.001
	2nd(6-8years)	-2.450	.572	.002
	3rd(9-13years)	-1.950	.572	.026
	4th(15-17years)	-1.350	.572	.242

In the results of Scheffea, there was a significant difference between groups as follows: Group 1 and 5, Group 2 and 5, Group 3 and 5.

5. Findings and Discussion

5.1 Sensitive Period in Auditory Perception

The first research question concerned the appearance of the auditory perception and linguistic discrimination curves for the five age groups. <Table 3> shows the range of the ringtones from A (strongest level) to F (the weakest level).

Table 5. Ringtone scales

Level	Auditory perception range (kHz)
A	14.1
A#	14.9
B	15.8
C	16.7
C#	17.7
D	18.8
D#	19.9
E	21.1
F	22.4

<Table 5> shows the average of the auditory perception test with all participants. Group 1 (5 years) had the highest average (19.6 kHz), and Group 5 (20-26 years) had the lowest average (15.9 kHz).

Table 6. The average of auditory perceptual ability

Group	Average
1st (5 years)	19.6
2nd (6-8 years)	19.3
3rd (9-13 years)	17
4th (15-17 years)	16
5th (20-26 years)	15.9

According to <Table 6>, the results of the auditory perception test shows differences across all age groups. The youngest group (5 years) was shown to be the most sensitive in auditory perception, whereas, the adult group (20-26 years) showed the least sensitivity. Additionally, the youngest group's average is significantly higher than that of other groups.

This result is similar to Cha and Jo's (2012) study, which showed that kindergarteners' auditory perception is significantly higher than that of college students. This finding provides strong support for the presence of a sensitive period given that children are better than adults at auditory perception. From this finding, the researchers were able to draw a sensitive period curve for auditory perception.

<Figure 2> shows the difference between groups in auditory perception. The graph shows that a sharp decline occurs after the age of 8 years. Though there may be different factors contributing to this decline in auditory perception, it is thought to be mainly due to biological or neurological mechanisms (Knudsen, 2004).

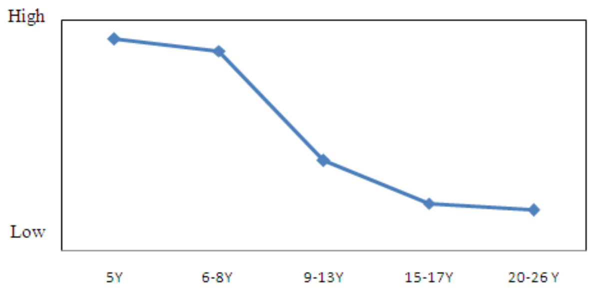

Figure 2. The difference between groups in auditory perception

5.2 The Capacity of Linguistic Discrimination

The second research question concerned the shapes of Koreans' auditory perception and linguistic discrimination curves in accord with Kuhl's critical period graph. In order to identify the differences within groups, each group's linguistic discrimination was precisely measured. From the numerical data, the researchers drew a graph of the linguistic discrimination insensitive period. The researchers drew a feature of Korean's sensitive period in linguistic discrimination in <Figure 3>.

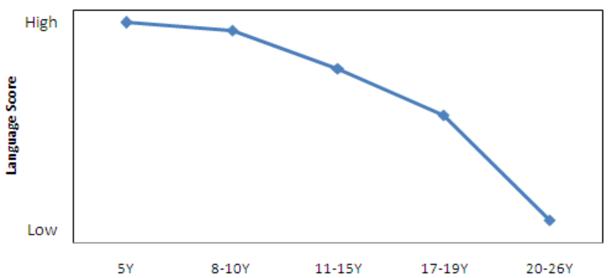

Figure 3. The differences between groups in linguistic discrimination

<Figure 3> indicates the curve of the differences between groups in linguistic phoneme discrimination. The graph almost matches Kuhl's (2011) graph. From this result, we can be aware of a connection with the sensitive period in language learning. The results enhance and expand our previous findings cross-linguistically (Cha & Jo, 2012). Many studies have focused on young infants' speech perception (Jusczyk, 1999; Kuhl, 1993) and have led to cross-cultural speech perception (Miyawaki et al., 1975; Werker et al., 1981).

Furthermore, the results of the linguistic discrimination test indicate the relative significance of this factor among the three youngest groups. The purpose of this study is to examine Kuhl's critical period graph from the point of auditory perception and linguistic discrimination. Thus, the researchers combined all three sensitive period graphs. <Figure 4> shows the three graphs superimposed on one another (Kuhl's graph, auditory perception (AD) and linguistic discrimination (LD). These results are in accordance with the sensitive period in auditory capacity and linguistic discrimination for Koreans.

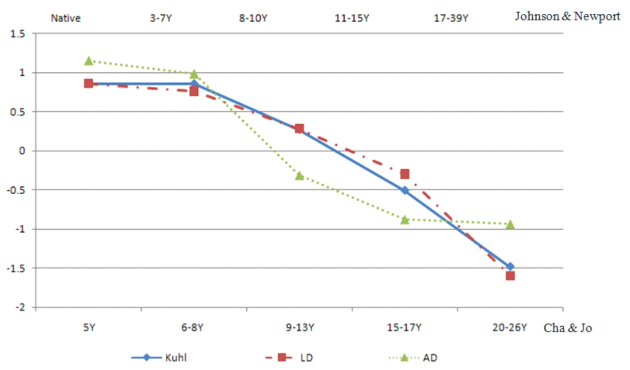

Figure 4. The results of three types with sensitive periods

From the results, we suppose that auditory capacity and linguistic discrimination begins to diminish at the age of 8. This indicates that young learners have an advantage in language learning, and that human beings' auditory capacity is important for the sensitive period of language learning. To summarize, the researchers found evidence for a sensitive period of auditory sensitivity, and that this superiority is related to their linguistic discrimination ability.

6. Conclusion

The present study identified children's sensitivity to auditory perception and its correlation with linguistic discrimination. It further showed that age is closely related to auditory capacity and linguistic discrimination. Maye, Werker and Gerken (2002) demonstrated that infants are sensitive to the statistical distribution of speech sounds in a language and that this sensitivity influences linguistic perception.

The current study is a follow up to Cha and Jo's (2012) study on children's auditory perception and linguistic discrimination, which showed that children are more sensitive than adults in auditory perception, and that they perform significantly better on linguistic discrimination tasks. These results are evidence for children's superiority in language learning due to the critical period hypothesis. The results further demonstrate a feature of children's superiority in auditory perception and linguistic discrimination. However, there was a need to investigate a sensitive period for L2 learning in diverse contexts. Therefore, the researchers took a more scientific approach and diverse perspective.

From the findings of the current study, the researchers suppose that auditory capacity begins to diminish rapidly at the age of 8 years. This decline can be both a symptom of biological aging and environmental in nature (overuse of the listening organs, with devices such as MP3 players, smartphones, and computer games).

The major finding of our research strongly implies that human auditory capacity is the one of the most essential factors for the sensitive period of language acquisition. The results of this study also have several pedagogical implications. The first finding, which demonstrates children's sensitivity in auditory perception, can be drawn on to maximize efficiency in language learning. Cha (2011) suggests that "plausible educational implication from the research results is that at an early stage, perception-oriented oral language (listening, pronunciation, and speaking) should be the focus" (p. 23). Based on previous studies (Cha, 2011; Cha & Jo, 2012) and the current study, we can assume that children have an advantage in auditory capacity over adults. Second, the challenge for further research is to explore neurology and linguistics from a language learning perspective. Finally, auditory perception and linguistic discrimination are strongly correlated with the sensitive period. In sum, auditory perception and linguistic discrimination plays a key role in successful language learning.

Despite the originality of the research method, this study has some limitations. Since this study was conducted in an exclusively Korean context, it is hard to generalize to other contexts. A suggestion for further research would be to use more advanced medical instruments such as fMRI, EGG, or ERPs.

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