L2 LEARNERS' NEURAL SENSITIVITY TO THE KOREAN STOP SOUNDS: THE ROLE OF L2 PROFICIENCY[1]

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ABSTRACT

This study examined the neural sensitivity to the Korean stop sounds /t/(ㄷ), /t'/(ㄸ) and /t^h/(ㅌ) of Chinese learners of Korean using ERP (Event-Related Potentials). The overall results showed that both advanced and intermediate learners were sensitive to the distinction between stop sounds except for the condition /t^{h}a/-/ta/ to which only advanced learners showed MMN (mismatch negativity). These results indicate that the learners' phonological sensitivity develops as their general L2 proficiency improves. The findings of this study provide a new piece of neurophysiological evidence for the L2 phoneme development.

Keywords: Korean stop sound, MMN, ERP, Korean as a foreign language, Chinese learners of Korean

1. INTRODUCTION

This study examined the acquisition of Korean stop sounds /t/(ㄷ), /t′/(ㄸ) and /t^h/(ㅌ) by advanced Chinese learners of Korean using Event-related Potentials(ERPs). The Korean alveolar stop sounds /t/, /t′/ and /t^h/ have a complex plosive system, varying depending on the manner of articulation; /t/: a lax stop (lenis), /t′/: a tensed stop (fortis), and /t^h/: an aspirated stop [1]. On the other hand, Chinese has only two-way contrast: /t/ and /t^h/. In this study, we used ERP (Event Related Potential) to investigate the acquisition of Korean stop sounds by Chinese learners of Korean focusing on the effect of general proficiency on the L2 phoneme development.

2. LITERATURE REVIEW

2.1. Previous Studies on /t/(ㄷ), /t′/(ㄸ) and /th/(ㅌ)

Recent production and perception studies on Korean consonants have shown that the perceptual difference between the lax consonant and the aspirated consonant seems to be slowly fading away. For example, children took longer in distinguishing the difference between the lax consonant and the aspirated consonant than the other consonant sounds [3]. Similar tendency is also found in the production studies; [4] and [2] revealed that the female in their 40's did not show much difference in the VOT (Voice Onset Time) between the lax consonant and the aspirated consonant.

The difficulty of learning the three way contrast of Korean stop sounds by L2 learners of Korean has been frequently reported in the previous studies. However, the findings were mostly based on the behavioural data, which sometimes are found different from the responses in the brain.

In this study, we use ERP (Event Related Potential) to investigate the acquisition of Korean stop sounds by Chinese learners of Korean in order to obtain more direct response data from the brain.

2.2. Previous Studies on MMN

MMN (Mismatch Negativity) is a negative polarity component which is elicited when listeners distinguish any change in a flow of repeating sounds [6][7][8]. The MMN usually peaks at around 100-250ms with its largest amplitude at the fronto-central scalp areas. Most importantly, as the MMN is elicited even when the listeners are not paying any attention to the sound they hear, which makes it appropriate for the speech-sound processing experiments.

Recently, [5] showed native speakers' sensitivity to the three way distinction not only in the behavioural task (high accuracy rates of 96.35) but also in the ERP experiment with elicitation of MMN. This study uses the same method to find out possible changes of MMN amplitude by the increase of the learners' proficiency of Korean compared to native speakers.

2.3. Native Speakers: AX Discrimination Task (Lee et al. 2018)

Overall Accuracy The accuracy rates were high (over 90%), and the difference in the mean accuracy rates between the two groups (20s vs. 50s) was significant (p=0.005)

Younger Generation (n=18)	96.35% (SD 3.13%)
Older Generation (n=17)	90.59% (SD 6.83%)

Overall Reaction Time (RT) There was no significant difference in the average RTs between the two groups.

Younger Generation (n=18)	382.23ms (SD 143.29ms)
Older Generation (n=17)	334.50ms (SD 82.67ms)

2.4. Native speakers: ERP Experiment (Lee et al., 2018)

2.4.1 Standard /ta/ with deviant /t^{h}a/:
300-400ms: Only the older group seemed to elicit MMN and the younger group showed a very low MMN amplitude.
400-550ms: P3a was elicited by both groups.
However, no statistically significant group interaction was found throughout all the time windows.

2.4.2. Standard /ta/ with deviant /t'a/
300-400ms: MMN was elicited by both groups and the difference was statistically significant (Ant*Group Interaction: $F(1.32, 1.96)=3.579$, $p=0.053$). The negativity was significantly larger at the frontal and central area for the older group. Older group were more sensitive to the sound change than younger group.
400-500ms: P3a was also elicited by both groups, but no significant statistical difference was found.

2.4.3. Standard /t^{h}a/ with deviant /ta/
The opposite condition showed very low MMN amplitude in the 250-400ms time window in both groups but no statistical significance was found.
500-650ms: Only the older group showed a significant positivity in the frontal-central area (P3a) (Ant*Group Interaction: $F(2, 35)=2.502$, $p=0.089$ (marginally significant)). The older group was more sensitive to the difference between /t^{h}a/ and /ta/, eliciting a unconscious attentional switching component (P3a).

2.4.4. Standard /t'a/ with deviant /ta/
200-300ms: The older group showed a larger MMN amplitude than the younger group.
400-550ms: A larger P3a amplitude was elicited by the younger group. However, no significant statistical difference was found.

2.5. Research Goals of the Current Study

This study examined the acquisition of Korean stop sounds /t/, /tʹ/ and /t^h/ by advanced and intermediate Chinese learners of Korean using data from brain responses as well as behavioural responses. This study used an ERP experiment for brain responses and an AX discrimination task for behavioural responses. We focused on the discrimination between lax and tensed stop sounds in which the Chinese learners of Korean are expected to have difficulty in distinguishing due to the lack of tensed sound in Chinese. The specific research questions are as follows:

1. Do advanced Chinese learners of Korean show sensitivity in their behavioural responses to the perception of Korean lax and tensed stop sounds?
2. Do advanced Chinese learners of Korean show sensitivity in their neural responses to the perception of Korean lax and tensed stop sounds?
3. Do advanced Chinse learners of Korean show different patterns between behavioural and neural responses to the perception of Korean lax and tensed sounds?
4. Do advanced Chinese learners of Korean show different sensitivity to the Korean stop sounds from intermediate learners of Korean?

3. METHOD

3.1. Participants

A total of 27 learners of Korean participated in this study. They were divided into two groups according to their TOPIK score (Advanced:16 with TOPIK 6, score range; 237-303; Intermediate: 11 with TOPIK 3-5, score range=146-214). Participants were all right-handed, normal with uncorrected hearing. They had no history of mental disorder.

3.2. Stimuli

Monosyllable sounds consisted of a stop consonant and a vowel *a*: /ta/, /tʹa/, and /t^{h}a/. The sound files were recordings of naturally produced tokens provided by National Institute of Korean Language. The stimuli were matched in duration (600ms) and pitch (110 Hz), spoken by a female speaker of Korean. The sound stimuli were designed in four five-minute blocks:

- [Block 1] /ta/ with deviant /t^{h}a/
- [Block 2] /ta/ with deviant /t'a/
- [Block 3] /t^{h}a/ with deviant /ta/
- [Block 4] /t'a/ with deviant /ta/

3.3. Tasks

Behavioural task: AX (same-different) discrimination task

A pair of speech sounds were presented over headphones and the participant was asked to judge if the two sounds were the same or different by pressing the buttons (either “M(=same)” or “N(=different)”) as quickly and accurately as possible. Accuracy and reaction time were measured. Reaction time was measured from the onset of the second vowel token in each pair. There were 7 conditions with 5 tokens per each condition. Each participants heard 35 trials of the two randomized sounds.

Condition	Standard	Deviant
Same	/ta/(다)	/ta/(다)
Different	/ta/(다)	/t’a/(따)
Different	/ta/(다)	/t^ha/(타)
Same	/t’a/(따)	/t’a/(따)
Different	/t’a/(따)	/ta/(다)
Same	/t^ha/(타)	/t^ha/(타)
Different	/t^ha/(타)	/ta/(다)

ERP experiment

Oddball paradigm: The stimuli were divided into two categories, standard and deviant stimuli, and the MMN is elicited when the auditory perceptual system detects a mismatch between a neural representation of a frequently repeated stimulus (standard) and a stimulus deviating in at least one parameter (deviant). There were four conditions. The sound stimuli were designed in four five-minute blocks:

Condition	Standard	Deviant
MMN 1	/ta/(다)	/t^ha/(타)
MMN 2	/ta/(다)	/t’a/(따)
MMN 3	/t^ha/(타)	/ta/(다)
MMN 4	/t’a/(따)	/ta/(다)

The order of blocks was counter-balanced across the participants. Each block consisted of 250 standard and 50 deviant stimuli, and the block was also pseudo-randomized.

The participants were introduced to a sound-attenuated shield room and sat approximately 70cm in front of a computer screen. They watched the silent movie: “Oggy and the Cockroaches, 2013” while the series of sounds were coming from the headphone.

The EEG was recorded with Brainamp(Brain Products GmbH, München, Germany) from 32 Ag/AgCl electrodes placed according to the 10-20 system. To detect the eye movements more precisely, 4 electrodes were used as vertical electro-oculogram(VEOG) and horizontal electro-oculogram(HEOG). Online filters were set between 0.1Hz – 70Hz with the sampling rate of 500 Hz and the electrode impedance was kept below 20kΩ.

During the EEG recording, the participants were told to ignore the series of sounds and to concentrate on the silent movie.

For statistical analysis, repeated measured ANOVAs were conducted with ant-pos (anterior, central, posterior), std-dev (standard, deviation) as within-groups factors and group (advanced, intermediate) as a between-groups factor.

3.4. Results

Behavioural results

Accuracy rates by condition (No significant difference among conditions and between groups)

Condition	/ta/-/ta/	/ta/-/t’a/	/ta/-/t^ha/	/t’a/-/ta/	/t’a/-/t’a/	/t^ha/-/ta/	/t^ha/-/t^ha/
Total	74.8 % (SD = 0.26)	80.1 % (SD = 0.24)	82.9 % (SD = 0.21)	76.2 % (SD = 0.25)	80.7 % (SD = 0.23)	79.2 % (SD = 0.25)	83.7 % (SD = 0.22)
Advanced	80.0 % (SD = 0.21)	88.3 % (SD = 0.13)	86.2 % (SD = 0.17)	78.6 % (SD = 0.22)	87.2 % (SD = 0.17)	82.5 % (SD = 0.20)	86.3 % (SD = 0.28)
Intermediate	67.2 % (SD = 0.30)	68.2 % (SD = 0.30)	78.2 % (SD = 0.26)	72.7 % (SD = 0.29)	71.3 % (SD = 0.31)	74.5 % (SD = 0.32)	80.0 % (SD = 0.22)

Reaction time by condition (No significant difference among conditions and between groups)

Condition	/ta/-/ta/	/ta/-/t’a/	/ta/-/t^ha/	/t’a/-/ta/	/t’a/-/t’a/	/t^ha/-/ta/	/t^ha/-/t^ha/
Total	526.3 ms (SD = 0.23)	451.9 ms (SD = 0.21)	452.3 ms (SD = 0.21)	454.1 ms (SD = 0.25)	402.7 ms (SD = 0.20)	410.4 ms (SD = 0.21)	334.6 ms (SD = 0.20)
Advanced	549.3 ms (SD = 0.27)	404.3 ms (SD = 0.21)	364.3 ms (SD = 0.26)	397.9 ms (SD = 0.26)	358.1 ms (SD = 0.19)	409.3 ms (SD = 0.24)	332.6 ms (SD = 0.20)
Intermediate	492.9 ms (SD = 0.18)	521.2 ms (SD = 0.19)	514.0 ms (SD = 0.15)	535.8 ms (SD = 0.21)	467.6 ms (SD = 0.21)	412.0 ms (SD = 0.15)	337.6 ms (SD = 0.22)

ERP Results

Standard /ta/ with deviant /t^ha/ MMN was elicited (F(1,25)=6.28, p=0.02) and there was no difference between groups.

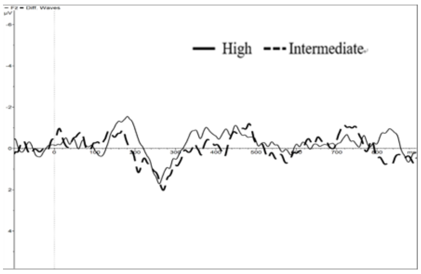

Figure 1. Difference waves at electrode Fz for Standard /ta/ with deviant /t^ha/

Standard /ta/ with deviant /t’a/ MMN was elicited in the anterior and central regions (anterior: $F(1,25)=6.49$, $p=0.017$, central: $F(1,25)=4.99$, $p=0.035$) with no difference between groups.

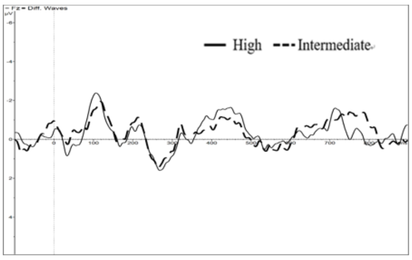

Figure 2. Difference waves at electrode Fz for Standard /ta/ with deviant /t'a/

Standard /t^{h}a/ with deviant /ta/ MMN was not elicited. The difference between groups was also not significant.

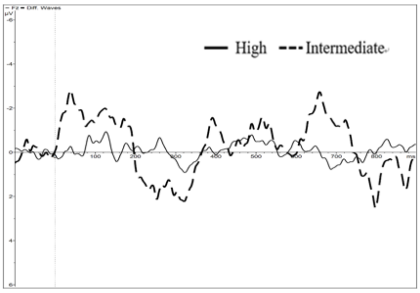

Figure 3. Difference waves at electrode Fz for Standard /t^{h}a/ with deviant /ta/

Standard / t'a / with deviant /ta/ MMN was elicited ($F(1,25)=8.58$, $p=0.007$) with no significant difference between groups.

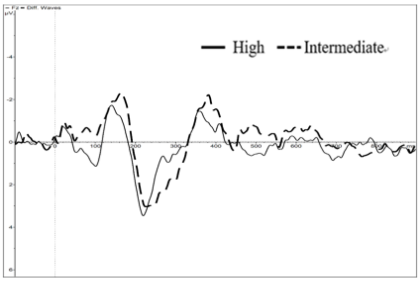

Figure 4. Difference waves at electrode Fz for Standard / t'a / with deviant /ta/

4. DISCUSSION

RQ 1. Do advanced Chinese learners of Korean show sensitivity in their behavioural responses to the perception of Korean lax and tensed stop sounds? The answer is *yes*; they are sensitive to the Korean lax and tensed stop sounds.

RQ 2. Do advanced Chinese learners of Korean show sensitivity in their neural responses to the perception of Korean lax and tensed stop sounds? The answer is *yes* with standard /ta/ with deviant /t^{h}a/, where MMN was elicited. With standard /t^{h}a/ with deviant /ta/, MMN was not elicited. With standard /ta/ with deviant /t'a/, MMN was elicited. With standard / t'a / with deviant /ta/: MMN was elicited at 100-200 ms and P3a was elicited at 200-300 ms.

RQ 3. Do advanced Chinse learners of Korean show different patterns between behavioural and neural responses to the perception of Korean lax and tensed sounds? The answer is *yes*; they showed sensitivity to the difference between the two sounds in their behavioural responses with high accuracy and similar response time. On the other hand, their neural response showed mixed results (/ta/ with deviant /t^{h}a/ MMN vs. /t^{h}a/ with deviant /ta/ No MMN).

RQ 4. Do advanced Chinese learners of Korean show different sensitivity to the Korean stop sounds from intermediate learners of Korean? The answer is *yes*; even though the two groups did not differ in their behavioural responses, their neural sensitivity was different; the advanced learners were more sensitive than the intermediate learners. These results shows the effect of general proficiency on the L2 phonological development. As the learners' proficiency develop, their neural sensitivity to L2 phoneme distinction improves. These results indicate that automatic processing of the L2 phoneme is possible when the learners become highly proficient in L2.

Now, comparing the advanced learners' data with the native speakers' from Lee et al. (2018), the learners' behavioural responses were less accurate than native speakers (NS: 90-95% vs. L2 learners: 85%; $t=3.01$, $p=0.002$). Their neural responses were less sensitive than native speakers. In particular, with the distinction between /ta/ vs. /t^{h}a/, native speakers showed MMN in both directions whereas L2 learners showed no MMN in /t^{h}a/ vs. /ta/.

5. CONCLUSION

The overall ERP result implies that both advanced and intermediate Chinese learners of Korean are sensitive to the distinction between stop sounds except for the condition /t^{h}a/-/ta/, but their sensitivity is weaker than native speakers'. Their behavioural responses also show similar results to the neural responses with lower accuracy rate compared to native speakers'. These results indicate that the learners' phonological sensitivity develops as their general L2 proficiency improves. The findings of this study provide a new piece of neurophysiological evidence for the L2 phoneme development, contrary to the critical period hypothesis.

6. REFERENCES

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