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L2 proficiency and effect of auditory source in processing L2 stops

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ABSTRACT

The current study investigates whether Korean-speaking adults show differential sensitivities to the sources of auditory stimuli (L1 Korean and L2 English) in utilizing VOT and *f0* in the perceptual mode of L2 stops, and how the L2 proficiency interacts with the learners' low-level phonetic sensitivities in L2 perceptual mode. 48 Korean learners of English participated in the perception experiments where they rated the goodness of English /t/ and /d/ using an analogue scale. Two sets of stimuli (English and Korean sources) were prepared by manipulating VOT (6-steps) and *f0* (5-steps) values of productions by an English male (L2 source condition) and a Korean male (L1 source condition). Findings showed that, in judging /t/-likeness, the listeners responded differently to the two auditory stimulus conditions by relying on VOT significantly more in English source condition than in Korean source condition. The listeners' English proficiency did not interact with these differential sensitivities to the auditory stimulus source either along the VOT dimension or the *f0* dimension. The results of the current study suggest that low-level contextual information of the auditory source can affect the learners in faithfully being in the L2 perceptual mode.

Keywords: L2 speech perception, stop laryngeal contrast, native source sensitivity, L2 proficiency, English stops, language mode

1. Introduction

Under the careful assumption that second language learners are equipped with somewhat separate phonological systems for native and non-native languages, learners with multiple language control might process the same set of sounds differently depending on which language mode they are in (*language mode*, Grosjean, 2001; reference therein). Grosjean (2001) pointed out that bilinguals or L2 learners selectively and gradiently are able to activate the mode of specific language (e.g., monolingual mode of one particular language, or bilingual mode of two languages, or intermediate mode between the two) based on the factors such as the interlocutor's language background and communication contexts including physical locations, topic, and the type of language acts. In the laboratory research setting, phonetic studies in bilingual context or L2 learning situation observed an effect of adaptable language mode in the speech perception and production tasks, showing that the participants with multiple language control produce or perceive speech categories flexibly by the tasks and the stimulus sets of the language (Elman et al., 1977; Sancier & Fowler, 1997; Hazan & Boulakia, 1998). For example, Elman et al., (1977) reported French-English bilingual listeners' responses biased toward the language used in the task when the set of sound stimuli contained ambiguous acoustic information. Experimenters investigating a use of multiple languages, therefore, need to make specific efforts to precisely control instructions, experimenter's language in the field, the type of the tasks, stimulus items and so on so that their results are less likely to be confounded by potential artifacts of listeners being in an

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unintended language mode.

Besides the experimental factors above, the learner's language proficiency also affects how much the intended mode of language would be activated. As the activation of one language mode does not always accompany complete de-activation of the other languages, the speakers can be in an intermediate mode of multiple languages. Escudero & Boersma (2002) showed that the learners' L2 proficiency plays a role in explaining the extent to which the L2 learners are able to process the sounds in the target language mode as instructed. In the vowel identification task where Dutch learners of Spanish are explicitly asked to use their "Dutch ears" or "Spanish ears" in processing the given set of speech stimulus items, more proficient learners of Spanish performed distinctively between the two language tasks, suggesting their ability to employ one processing system over the other system as the language contexts require.

Given that the language mode is partially determined by subtle contextual factors, the current study explores the effect of stimulus source (L1 source and L2 source: the low-level phonetic information) in adult learners' L2 perceptual mode of processing stop consonants and investigates how L2 proficiency interplays with low-level phonetic sensitivity in this L2 mode of perception. We implemented the idea by examining Korean listeners' patterns of utilizing the two acoustic cues (VOT and *f0*) in the task of processing L2 stop laryngeal categories (/d/ vs. /t/) when the auditory stimuli are prepared by synthesizing the L2 English source (target language: more authentic source information) and the L1 Korean source (learners' native language: less authentic auditory source information).

The stop consonants of the two languages serve as interesting sets of comparison for the purpose of the current study. Word-initially, the English voiceless stops are phonetically aspirated having long-lag VOT and higher f0 values, while the phonologically voiced stops are phonetically unaspirated by having either short-lag or lead (prevoiced) VOT and lower f0 values. It has been previously shown that the English native listeners primarily rely on the VOT dimension to distinguish voiced stops from voiceless stops, while they used *f0* as one of redundant cues in doing so (Abramson & Lisker, 1985; Goldon et al., 1993; Holt & Lotto, 2006; Francis et al., 2008; Schultz et al., 2012). This is a perceptual pattern different from Korean learners' L1 attention strategies in differentiating the three-way laryngeal categories (i.e., tense, lax and aspirated stops) where *f0* is as important as VOT (e.g., Silva, 2006; Kang & Guion, 2008; Kong et al., 2011; Lee et al., 2013). Due to the recent sound change in the acoustic properties of the Korean stops, the lax and aspirated stops are realized as long-lag VOTs (contrastive with short-lag VOTs for the tense stops), and acoustic distinction between lax and aspirated stops is found at their *f0* values (lower *f0* for the lax and higher *f0* for the aspirated stops). In the L2 learning, Korean learners of English adapted internal acoustic structure of the L2 speech categories, as more proficient learners of English tended to exhibit greater perceptual reliance on VOT than *f0* (Kang & Yoon, 2013, among others). Our interest is in investigating whether there are differential sensitivities to contextual information in employing VOT and *f0* cues to perceive the stop categories in the L2 mode of perception and whether the L2 proficiency plays a role in explaining the learner's sensitivities to the source information. We hypothesize (1) that L2 English learners would show more L2 native-like perceptual cue-weighting patterns (i.e., greater reliance on VOT than on *f0*) in the English (target language) source stimulus condition more than in the Korean source stimulus condition, and (2) that this effect of stimulus source would be greater for more proficient English learners due to their better adaptability to the language mode implied by low-level phonetic information. The findings of the current study would add experimental evidence to the L2 acquisition literature that L2 acquisition of sound categories includes a mastery of fine-grained phonetic details of speech categories.

2. Perception experiment

2.1 Methods

2.1.1 Stimuli

The auditory stimulus sets of the two different language sources were prepared by recording a Korean native male speaker (L1 source) and an English native male speaker (L2 source). Their alveolar stop productions followed by /a/ were manipulated by systematically varying the two acoustic dimensions of VOT and *f0*, yielding 30 different syllables of combining six VOT steps (9ms, 13ms, 19ms, 28ms, 40ms, 59ms) and five *f0* steps (98Hz, 103Hz, 114Ha, 122Hz, 130Hz). These sets of auditory stimulus sounds were the identical sets of sounds previously used in the perception experiments with Korean and English native speakers documented in Kong & Edwards (2011) and Kong & Yoon (2013) (see the methodological details of how to manipulate VOTs and *f0*s in these papers)

2.1.2 Participants & task

48 college students participated in the study who are the standard Korean speakers learning English as their second language. They were given two tasks of responding to the L2 English stop targets (/d/-/t/) and to the L1 Korean stop targets (ㄷ-ㅌ). The latter task was designed to serve as a control condition of perceptual cue-weighting. Each task consisted of two sub-sessions blocked by the stimulus source languages. In each block of the English task, the listeners rated how close the sounds were to /d/-or-/t/ by clicking the location relative to /d/ or /t/ labels: "d" <-----> "t"(Visual Analogue Scaling; Massaro & Cohen, 1983) The pixel locations on the arrow, converted into logit values, were taken as dependent variable of how /t/-like the sounds were in the regression analysis with greater values indicating more /t/-like perception. In each block, a set of 30 different CV syllables was repeated three times in a random order, yielding 90 trials per person. In each block of the Korean task, the listeners judged the sounds in terms of how similar they were to /ㄷ/ or /ㅌ/. In each block of stimulus source language, a set of 25 different CV syllables were presented three times in a random order.

2.1.3 L2 proficiency group

The learners were divided into three groups in terms of their L2 proficiency measured by reported scores of TOEIC: (1) High L2 proficiency group (N=14; scores ranged from 840 to 970), (2) low L2 proficiency group (N=14; scores ranged from 300 to 690) and (3) intermediate L2 proficiency group (N=20). The score boundaries of the groups were chosen to have balanced number of samples in both ends of the proficiency groups given the range and distribution of the scores in the current data set. All 48 participants were included in the analysis but the intermediate group was excluded in the analysis where the learners' L2 proficiency was tested as a factor.

2.1.4 Analysis

The mixed-effects regression model was built with responses of each task implemented in *R* using *lme4* package (Bates et al., 2012; Morrison & Kondaurova, 2009). For the English task, the perceptual judgment of /t/-likeness is explained by the two acoustic parameters (continuous variables of VOT and *f0*, fixed effect) of the stimuli and their interaction with stimulus source language type (Korean vs. English): VOT + *f0* + VOT×StimLg. + *f0*×StimLg. In order to compare the effect of VOT change with that of *f0* from the model, the units are standardized. The listeners were considered as a random effect in a way that the intercepts and slopes of the fixed effects (VOT and *f0*) were allowed to vary at the listener level. Another model of the same structures was made for the Korean task where the dependent variable was the perceptual judgment of /ㅌ/-likeness.

2.2 Results

2.2.1 L2 and L1 perception tasks

The top and middle panels of <Figure 1> present the averaged /t/-likeness perception of each stimulus sound at VOT and *f0* combinations, in which darker color indicates more /t/-like or /ㅌ/-like perception. In both language tasks, the stimulus conditions at the top-right corners (sounds of longer VOT paired with higher *f0*) were relatively darker, indicating stronger tendency of being heard as aspirated stops. Similarly, in both language tasks, the stimulus conditions at the bottom-left corners (sounds of shorter VOT paired with lower *f0*) were relatively lighter, suggesting a stronger tendency of being heard as /d/ (in English task) or /ㄷ/ (in the Korean task). The noticeable difference between tasks (left vs. right panels) is observed in the relative darkness at the top-left corners (shorter VOT paired with high *f0*). This section of the panel is less darker in the left panels (English task) than the right panels (Korean task) indicating that higher *f0* were not strongly affect the listeners'perception of /t/ in the English task as long as VOT was shorter. The darkness difference between the stimulus source languages (top vs. middle panels) was not immediately evident in this type of visual presentation, although stimuli with higher *f0* values tend to be slightly darker in the Korean stimulus condition (middle panel).

The bottom left panel of <Figure 1> shows the model estimated perceptual /t/-likeness in the English task as VOT values (black lines) and *f0* values (grey lines) increase separated by the stimulus source language. It can be observed that while increases of VOT and *f0* values were positively correlated with greater likelihood of /t/ perception in both source types, the tendency was stronger in VOT dimension. The slope coefficients were greater for VOT than *f0* in both stimulus language condition [$\beta_{VOT(E.stim)}$=1.20, $\beta_{f0(E.stim)}$=0.62; $\beta_{VOT(K.stim)}$=0.86, $\beta_{f0(K.stim)}$=0.67]. The coefficient difference between the two source languages in the VOT dimension was significant [$\beta_{VOT\times stimLg}$ = 0.33, t = 5.18], revealing a greater sensitivity to VOT in English source condition than in Korean one. The interaction of the source language type with *f0* was not significant [$\beta_{f0\times stimLg}$=0.05, t =-1.02]. The effects of interaction terms as well as independent

variables are estimated in the ANOVA of the mixed effects regression models, as summarized in <Table 1>.

The bottom right panel of <Figure 1> displays the estimated perceptual /t^h/(ㅌ)-likeness in the Korean task separated by the stimulus source languages, as VOT and *f0* values increase. Unlike the model based on the English task, the L1 perception task model exhibited a greater coefficient of *f0* than that of VOT when the Korean source of stimuli was given [$\beta_{VOT(K.stim)}$= 0.81, $\beta_{f0(K.stim)}$=1.09]: The slope of *f0* was steeper than that of VOT. When the stimulus source language was English, this relationship changed by revealing a greater VOT coefficient than *f0*: [$\beta_{VOT(K.stim)}$=1.09, $\beta_{f0(K.stim)}$=0.81]. The interaction effect of the stimulus language type was significant with both VOT and *f0* dimensions: [$\beta_{VOT\times Stim.Lg}$= -0.27, t = -5.88; $\beta_{f0\times Stim.Lg}$=0.27, t = 6.98]. The ANOVA summary of the regression model in <Table 1> shows that the effects of source language interactions with VOT and *f0* were statistically significant.

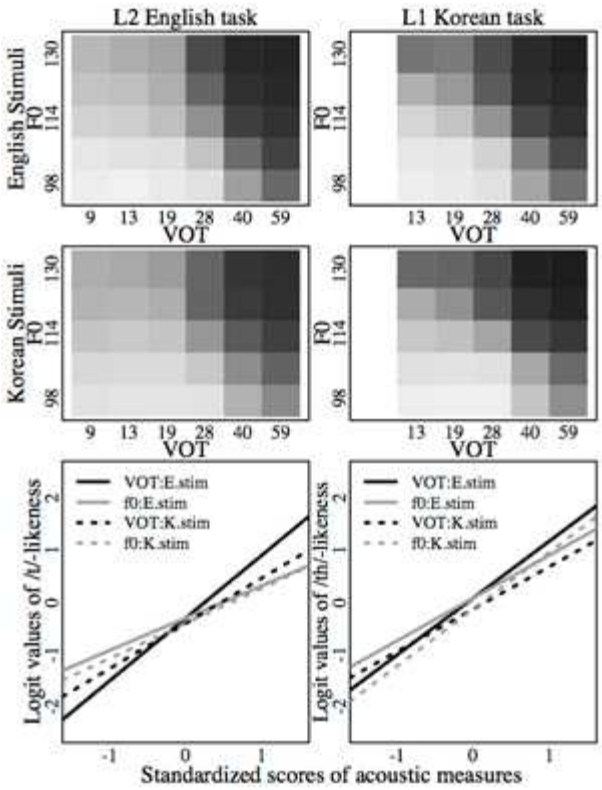

Figure 1. Estimated log-likelihood of /t/-like perception as a function of VOT and *f0* (in standardized unit): L2 task ("d" –"t") in the left panel, L1 task ("ㄷ" - "ㅌ") in the right panel.

Table 1. ANOVA summary of the mixed effects regression model: English task and Korean task

	Df	Sum Sq	Mean Sq	F value
[English task]				
VOT	1	512.01	512.01	407.31
f0	1	190.97	190.97	151.92
Stim.Lg	1	0.13	0.13	0.09
VOT×Stim.Lg	1	33.33	33.33	26.51
f0×Stim.Lg	1	1.32	1.32	1.04
[Korean task]				
VOT	1	450.84	450.84	349.41
f0	1	349.73	349.73	271.05
Stim.Lg	1	11.22	11.22	8.69
VOT×Stim.Lg	1	8.14	8.14	6.30
f0×Stim.Lg	1	63.01	63.01	48.83

2.2.2 Effect of L2 proficiency in L2 stop perception

The response patterns of the L2 English task were further investigated by dividing the listeners into two subgroups according to their L2 proficiency. This factor of L2 proficiency (high vs. low, excluding the intermediate level of L2 proficiency) was included in the regression model as a main effect and an interaction effect with each acoustic parameter (*f0* and VOT) and the stimulus type.

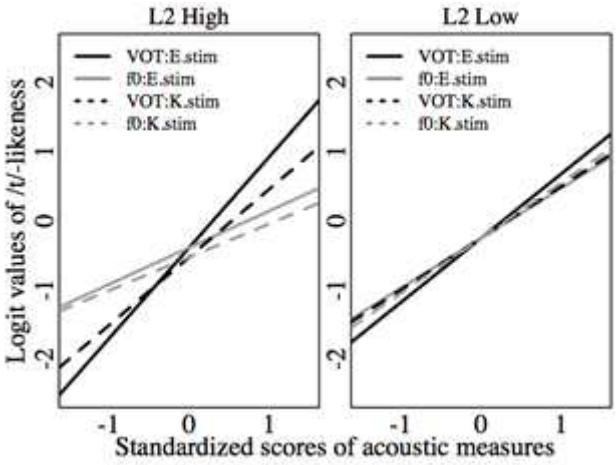

Figure 2. Estimated log-likelihood of of /t/-like perception as a function of VOT and *f0* (in a standardized unit), separated by L2 proficiency groups (left: high L2, right: low L2).

<Figure 2> shows the estimated /t/-likeness as a function of VOT and *f0*, separated by L2 proficiency group. The left panel of <Figure 2> for high L2 proficiency learners revealed that the perceptual judgment of /t/ in the English task was affected by VOT changes more greatly than *f0* changes, indicated by steeper

VOT slopes (black lines) than *f0* slopes (grey lines) [β_{VOT}=1.31, t=9.52; β_{f0}=0.53, t=5.35]. In the high L2 proficiency group, this slope relationship was consistent across the stimulus source language types. In terms of the source language sensitivity, the coefficient differences between Korean source and English source were significantly large along the VOT dimension, but not along the *f0* dimension [$\beta_{VOT\times Stim.Lg}$= -0.33, t = -2.35; $\beta_{f0\times Stim.Lg}$=-0.04, t =-0.58].

The right panel of <Figure 2> shows the response patterns of low L2 proficiency group, in which the listeners exhibits the similar relationship between VOT and *f0* to the high L2 proficiency group: steeper VOT slope than *f0* slope [β_{VOT}=0.92, t=6.73; β_{f0}=0.72, t=7.27]. However, this relationship was only observed in the L2 source stimulus condition. The reverse relationship (slightly more steeper *f0* slope than VOT slope) was found in the L1 source stimulus condition [β_{VOT}=0.74, t=5.42; β_{f0}=0.79, t=8.04]. According to the output of the mixed effects regression model, the coefficient differences between the stimulus source language types were not statistically significant in both dimension: [$\beta_{VOT\times Stim.Lg}$=-0.18, t =-1.29; $\beta_{f0\times Stim.Lg}$=0.07, t=0.93].

Although our visual examination suggested that the slope relationship (VOT and *f0*) looked different between the high and low proficiency learner groups interacting with the two language source conditions (e.g., steeper VOT than *f0* in the high proficiency group regardless of source types but a lack of this relationship in the low proficiency group in the Korean source condition), this difference was not sufficiently great to bear a statistical significance according to the three-way ANOVA of the regression model as summarized in <Table 2>. The effect of three-way interaction (stimulus source language×L2 proficiency group×acoustic parameter) was not significant, indicating that the sensitivities to the stimulus source language difference along VOT or *f0* were not different between high and low L2 proficiency groups.

Table 2. ANOVA summary of the mixed effects regression model (with L2 proficiency factor included): English task

	Df	Sum Sq	Mean Sq	F value
VOT	1	306.8	306.803	270.52
f0	1	112.04	112.042	98.79
Stim.Lg	1	0.001	0.001	0.0008
Prof.Group	1	0.668	0.668	0.58
VOT×Stim.Lg	1	7.549	7.549	6.65
f0×Stim.Lg	1	0.068	0.068	0.05
VOT×Prof.Group	1	1.686	1.686	1.48
f0×Prof.Group	1	4.453	4.453	3.92
Stim.Lg×Prof.Gr	1	0.377	0.377	0.33
VOT×Stim.Lg×Prof.Gr	1	0.642	0.642	0.56
f0×Stim.Lg×Prof.Gr	1	1.3	1.3	1.14

3. Discussion & Conclusion

The current study explored the patterns of Korean listeners' sensitivities to the stimulus source differences in utilizing VOT and *f0* for their perceptual judgment of L2 English stops. Our research goals were to examine (1) whether and how the L2 learners show different degrees of source-related context-dependency in the L2 perceptual mode and (2) whether L2 proficiency would interplay with these perceptual sensitivities to the auditory sources in the L2 perception mode. The findings showed that Korean learners of L2 English indeed exhibited context-dependent sensitivities to the stimulus source conditions, supporting that canonicity of the sound stimuli influenced learners' L2 speech processing (e.g., Kuhl & Iverson, 1995). Specifically, we found that the degrees of sensitivities to the canonical sounds were different between the two acoustic dimensions we manipulated in this study: VOT and *f0*. It was along the VOT dimension but not along the *f0* dimension where the learners were more sensitively responded to the stimulus source conditions in the L2 English perception mode, indicating that Korean learners of English primarily attended to VOT than *f0* in the English mode of perception. This resembles to what is known as the English native speakers' cue-weighting pattern in the stop perception.

A greater dependence on VOT than *f0* in the L2 English stop perception task is to be understood as an outcome of the learners' active auditory adjustment to the perceptual mode of the target language. This interpretation is supported by the experimental evidence that the same set of listeners revealed a reversed pattern of a cue-weighting strategy - greater dependence on *f0* over VOT - in the L1 task of judging the Korean stops. In other words, the learners' greater perceptual dependence on VOT over *f0* cannot be attributed to their listeners' underlying auditory preference to VOT which is readily responsible for distinguishing a stop laryngeal contrast of any languages, but rather it is one of learned strategies of the listeners that is effective in their L2 English mode of stop perception (learner's selective attention to the L2 primary cue: Francis & Nasbaum, 2002).

What was little expected among the current findings is the null effect of learners' L2 proficiency in utilizing VOT and *f0* in the two different source conditions in the English stop perception, because one would expect highly proficient learners to be more native-like based on their robust L2 representation (e.g., Flege, Bohn & Jang, 1997). Contrary to this expectation, there were no group differences between higher and lower L2 proficiency learners in their sensitivities to the stimulus source conditions. As for this null effect, one reasonable speculation can be made such that the criterion of high vs. low proficiency groups in this particular study might not be best chosen. Although many studies have employed standardized scores of English test as a way to categorize the learners into English proficiency groups, there has not been a consensus on exactly what scores can serve to indicate high or low L2 proficiency. In the current study, we endeavored to sample the learners at the two extremes of TOEIC score ranges that we collected but their L2 proficiency difference might have not been sufficiently distinct enough to test the effect of L2 proficiency in utilizing the cue-weighting strategies in the two source conditions. With wider sampling, the differences observed in <Figure 2> might have been statistically confirmed to be significant.

Alternatively, our findings might point to that the L2 proficiency plays little role in the listeners' sensing a low-level phonetic context. It is pointed out that the relative attention pattern by low L2 proficient group did follow the English native listeners' cue-weighting trend when the stimulus source was English (i.e., greater attention to VOT than *f0*), suggesting that the learners are able to process the speech stimuli in the L2 perceptual mode regardless of their proficiency level. A recent finding by Lee (2014) revealed that the very beginner level of L1 English learners of L2 Korean tended to attend to *f0* in judging the L2 Korean stop sounds, which is only a secondary cue in the L1 English. Consistent with Lee's result, our finding might indicate that the learners' L2 mode of perception is initiated at relatively early stage of L2 learning with little interaction with their L2 proficiency.

To conclude, the present study provided experimental evidence that the stimulus source (low-level phonetic) information is, in part, responsible for learners' L2 mode of perception. The weak relationship of L2 proficiency with this contextual phonetic sensitivity calls for further research exploring population with wider range of L2 proficiency.

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