



## Research Article

# Individual differences in phonetic cue use in production and perception of a non-native sound contrast



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## ABSTRACT

The current work examines native Korean speakers' perception and production of stop contrasts in their native language (L1, Korean) and second language (L2, English), focusing on three acoustic dimensions that are all used, albeit to different extents, in both languages: voice onset time (VOT),  $f_0$  at vowel onset, and closure duration. Participants used all three cues to distinguish the L1 Korean three-way stop distinction in both production and perception. Speakers' productions of the L2 English contrasts were reliably distinguished using both VOT and  $f_0$  (even though  $f_0$  is only a very weak cue to the English contrast), and, to a lesser extent, closure duration. In contrast to the relative homogeneity of the L2 productions, group patterns on a forced-choice perception task were less clear-cut, due to considerable individual differences in perceptual categorization strategies, with listeners using either primarily VOT duration, primarily  $f_0$ , or both dimensions equally to distinguish the L2 English contrast. Differences in perception, which were stable across experimental sessions, were not predicted by individual variation in production patterns. This work suggests that reliance on multiple cues in representation of a phonetic contrast can form the basis for distinct individual cue-weighting strategies in phonetic categorization.

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## 1. Introduction

The concept of the native language as a “filter” through which foreign sounds are perceived and produced is both intuitive and empirically well-established. A large body of experimental work has found that native-like production and perception are particularly elusive when the acoustic dimensions that are most important in defining a given foreign contrast are not used in similar native contrasts. The current work turns to a different situation, focusing on how listeners perceive a foreign contrast defined by acoustic dimensions that *are* used in a similar native contrast, but in very different ways. In particular, we examine native Koreans' production and perception of the stop contrasts in their L1 (Korean) as well as their L2 (English) on three acoustic dimensions: duration of voice onset time (VOT) (a primary cue to the distinction in both languages), fundamental frequency at vowel onset ( $f_0$ ) (a primary cue to the Korean distinction and a secondary cue to the English distinction), and stop closure duration (a secondary cue to the distinction in both languages). Alongside analysis of group patterns of acoustic cue use, we focus on individual variability in both production and perception.

### 1.1. Background

Speech sounds contrast on many acoustic dimensions, and a major challenge for language learners is perceiving and acquiring the specific constellation of acoustic “cues” that define the sound contrasts of the L2. As listeners, L2 learners need to determine which cues are relevant to pay attention to, as well as what relative importance, or “weight,” to assign each cue. At the same time, as speakers, they must mirror native speakers' use of the cues in their productions in order to attain native-like pronunciation patterns. The majority of work on L2 sound discrimination has focused on how L2 learners cope with foreign contrasts that rely primarily on cues that are not used in similar native contrasts. In these cases, the challenge of learning novel cue mappings is augmented by the fact that throughout development, listeners lose

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the ability to make use of “foreign” dimensions as cues to category membership, and it is difficult for adult listeners to learn to redirect their attention to the relevant cue. The notorious difficulty of the English /l-/ɭ/ distinction for Japanese learners, for example, can be attributed to the fact that the English contrast relies primarily on a difference in third formant (F3) values, whereas Japanese listeners distinguish the categories primarily on the basis of second formant (F2) values (Iverson et al., 2003; Miyawaki et al., 1975). Another well-studied challenge for many L2 English learners is the /i-/ɪ/ distinction, which native listeners distinguish primarily with spectral differences (Hillenbrand, Clark, & Houde, 2000; Stevens, 1959). In contrast to native listeners, L2 learners whose native languages do not have spectral distinctions in this region of the vowel space often distinguish this contrast primarily on the basis of duration (e.g. Flege, Bohn, & Jang, 1997 for Spanish and Mandarin, Kondaurova & Francis, 2008 for Russian, Cebrian, 2006 for Catalan, Morrison, 2008, 2009 for Spanish; see also Bohn & Flege, 1990 and Escudero, Benders, & Lipski, 2009).

In the examples discussed above, the difficulty for non-native listeners arises from their lack of sensitivity or attention to the cue that is most relevant for native listeners. Less well-studied are cases in which an L1 contrast primarily relies on *more* cues than the corresponding L2 contrast, and cases in which an L1 contrast has a *heavier* reliance on a given dimension. In these situations, instead of “filtering out” dimensions that are not relevant in native contrasts, the L1 sound system might be expected to “filter in” dimensions that *are* relevant to native contrasts, even though they may be unreliable cues to the L2 contrast and ultimately lead to non-native-like categorization. Examining these sorts of scenarios is therefore important for understanding to what extent listeners learn to ignore inefficient or unreliable cues (arising from L1 bias) during L2 sound category acquisition. As a case study, we examine how Korean listeners, who use multiple primary cues to make phonemic distinctions in their L1 stop contrast (VOT and f0), use these cues to produce and perceive the English stop voicing contrast, which relies primarily on only one of these dimensions (VOT), as well as how they use closure duration, which is a secondary cue in the stop distinction in both languages. We test the same listeners' use of the three cues across production and perception in both languages in order to be able to examine cross-language patterns and the production–perception link on an individual level, as well as the nature and the extent of individual variability in cue-weighting strategies. After a brief overview of issues of individual variability in L2 phonetic categories and background on the Korean and English stop contrasts, the remainder of the introduction turns to how the parallel cross-language, cross-modal dataset collected in the current work can inform theoretical issues about L1–L2 influence as well as the perception–production interface.

## 1.2. Individual variability in L2 cue weighting

A large body of work has considered linguistic (e.g. influence from the L1) and non-linguistic (e.g. length of exposure to the L2) factors that contribute to differences in L2 cue weighting. For example, one systematic effect of L1 is the fact, discussed above, that L2 learners are generally less successful at directing attention to a dimension not used in their native language. The failure to use spectral cues in vowel contrasts such as English /i-/ɪ/ is seen in listeners whose L1s do not make use of spectral contrasts for vowels in that region of the acoustic space (e.g. Cebrian, 2006 for Catalan, Flege et al., 1997 for Spanish and Mandarin, Kondaurova & Francis, 2008 for Russian), whereas L2 learners whose L1 is German, a language that *does* use spectral cues in a similar vowel distinction, show more native-like spectral reliance in production and perception of this contrast (Flege et al., 1997). However, the fact that these L2 listeners instead relied on *durational* cues cannot be directly attributed to L1 transfer, given that the languages in question do not use duration for phonemic vowel distinctions. Therefore, factors other than L1 transfer appear to play a role; this phenomenon has been variously attributed to a focus on duration in L2 pedagogy (Flege et al., 1997), different stages of learning (Escudero & Boersma, 2004; Morrison, 2008), and overall perceptual salience of duration (Bohn, 1995). Furthermore, group effects can mask a large range of individual differences within the same language group. For example, although a main finding from the work of Escudero et al. (2009) was that L1 Spanish–L2 Dutch listeners used durational cues more than spectral cues in distinguishing the Dutch /a-/ɶ/ contrast, 14 out of the 38 native Spanish listeners actually used spectral cues more. A further complication is the fact that some listeners actually showed reversals of native-like cue use (e.g. with *longer* duration signalling /ɪ/, vs. /i/, categorization, opposite of the native pattern; see Escudero & Boersma, 2004; Flege et al., 1997; Morrison, 2008), which is not well-explained by any of the proposed mechanisms (though see Morrison, 2009 for a developmental hypothesis).

Similarly, L2 proficiency (along with related factors, such as length of L2 exposure) has been shown to influence L2 cue-weighting strategies. Broad differences in language experience or proficiency on a group level are often linked to differences in perception, and in general, studies that split up early vs. late learners (or more vs. less proficient speakers) show the expected pattern of more native-like cue weighting for more experienced groups. For example, Flege et al. (1997) found that experienced listeners from different language backgrounds both produced and perceived L2 English vowel contrasts with more native-like cue-weighting strategies (see also Baker & Trofimovich, 2005; Bohn & Flege, 1997; Flege, Takagi, & Mann, 1996; Kong & Yoon, 2013, among many others). However, efforts to find individual correlations between proficiency and native-like perception on an individual level have proven elusive; variation in cue-weighting strategies for L2 vowel contrasts by L1 Catalan and Spanish listeners (Cebrian, 2006; Morrison, 2008) and for the L2 English /l-/ɭ/ distinction (Hattori & Iverson, 2009) by L1 Japanese listeners was not correlated with experience or proficiency. These studies did not have the large numbers of participants required to make strong claims about the effect of proficiency, and direct investigation of the relationship is therefore warranted. Nevertheless, although it seems clear that cue-weighting strategies change during the course of L2 development (see Escudero & Boersma, 2004 and Morrison, 2009 for specific proposals), proficiency effects do not appear to fully account for the variability found in L2 cue-weighting strategies within similar language groups.

Some work has explored factors that could account for the residual within-group variability not explained by language experience or proficiency. Polka (1991) suggests that different strategies for L1–L2 category mapping (even within a single language group) underlie some of the individual variability found in English listeners' discrimination of the Hindi retroflex-dental stop contrast (on the other hand, Hattori & Iverson, 2009 show that differences in L1–L2 mapping do not account for variability in native Japanese identification performance on the English /l-/ɭ/ contrast). Escudero and Boersma (2004) show that foreign cue-weighting strategies can reflect the specific dialect of the L2 being learned (in

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