

# Using ultrasound tongue imaging to study covert contrasts in second-language learners' acquisition of English vowels

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**Background:** Research attempting to understand the intermediate stages of first-language (L1) acquisition and disordered speech has led to the discovery of a covert contrast. A covert contrast is a statistically reliable difference between targeted phonemes that is produced by a language learner, but in a way that is not perceived by the listener. In the present study, we aimed to extend the investigation of covert contrasts to the domain of second-language (L2) acquisition. In particular, we used ultrasound tongue imaging to examine whether L2 learners produced articulatory distinctions between targeted phonemes, in addition to producing acoustic differences. Despite recent L1 acquisition studies demonstrating covert contrasts through ultrasound measurements (McAllister Byun, Buchwald, & Mizoguchi, 2016; Zharkova, Gibbon, & Lee, 2017), no such studies have been carried out for adult L2 learners.

**Methods:** We investigated the acquisition of two pairs of English vowel contrasts: tense /i/ vs. lax /ɪ/ (as in *seat* vs. *sit*) and mid /ɛ/ vs. low /æ/ (as in *set* vs. *sat*). We collected speech recordings from 21 speakers (7 Korean speakers, 7 Spanish speakers, 7 English controls) while they produced words illustrating the relevant English vowel contrasts. For each of the four target vowels, there were 12 target words, which were repeated twice. In total, 1,598 word tokens were analyzed. The video of tongue movements was collected using a Sonosite 180 Plus ultrasound machine and a C11/7-4 MHz 11-mm broadband curved array transducer.

**Analysis:** Here we will use the tense and lax contrast as an example to explain how we analyzed the collected data to test the hypothesis, but the same analysis applies to the mid and low vowel contrast. After data collection, phonetically trained native speakers of English listened to each vowel production and transcribed what they heard using the IPA symbols. On the basis of phonetic transcriptions, each vowel production was coded as one of the followings: 1) CORRECT TENSE (the target /i/ perceived as /i/), 2) CORRECT LAX (the target /i/ perceived as /ɪ/), 3) WRONG TENSE (the target /i/ perceived as /ɪ/), and 4) WRONG LAX (the target /i/ perceived as /i/). For example, CORRECT TENSE and WRONG LAX sounded identical to the transcriber, but for CORRECT TENSE, the target was /i/, and for WRONG LAX, the target was /ɪ/. We examined whether there were significant acoustic and ultrasound differences between the productions that were coded as CORRECT TENSE and WRONG LAX, as well as those designated as CORRECT LAX and WRONG TENSE, that is, all pronunciations that were perceived as the same. If there were any reliable differences between these utterances, this would be indicative of a covert contrast. We employed three acoustic measures (vowel duration, F1, F2) and two ultrasound measures (tongue advancement and height). Lingua (Ménard, Aubin, Thibeault, & Richard, 2012) was used to extract the ultrasound measurements.

**Results:** Table 1 summarizes the instances of covert contrasts for L2 participants in the production of two sets of vowel contrasts. The results showed that approximately 36% (5/14) of our L2 participants implemented various patterns of covert contrast in vowel articulation. Three participants (sf1, sm1, km1) produced an acoustic distinction only; one participant (kf3) produced an articulatory distinction only; and one participant (sf2) produced both acoustic and articulatory distinctions between the targeted vowels in a way that was not perceived by native speakers of

English. It is also worth mentioning that, except for Korean participant km1, when these participants exhibited a covert contrast, their vowels were perceived as either [i] or [ɛ], rather than [ɪ] or [æ], neither of which occurs in their native language.

	Duration	F1	F2	Tongue height
CORRECT TENSE vs. WRONG LAX	sf1, sf2, sm1	sm1	sf1	sf2
WRONG TENSE vs. CORRECT LAX	km1			
CORRECT LOW vs. WRONG MID				
WRONG LOW vs. CORRECT MID				kf3

Table 1. The L2 participants who exhibited the production of a covert contrast for each measurement.

Figure 1 shows an example tongue contour for WRONG LOW and CORRECT MID from one participant (kf3) who produced a covert contrast. Although the listeners heard no distinction between the vowels, kf3 had the anterior part of the tongue (area of interest indicated with an arrow) significantly lower when the intended target was the low vowel, which suggested a covert contrast.

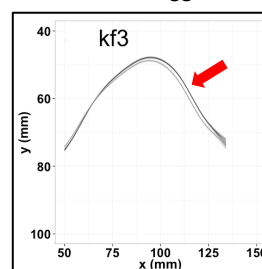


Figure 1. Example tongue contour for WRONG LOW (light gray lines) vs. CORRECT MID (dark gray lines).

**Discussion:** Some of our L2 participants produced a reliable distinction between English vowels that were perceived identical on the surface, suggesting covert contrast. We wish to argue that covert contrast represents an intermediate stage on the way to the learner fully acquiring the phonemic difference in question. A piece of evidence supporting this claim is that there seems to be a tendency for our participants to produce fewer acoustic and articulatory distinctions for vowels for which they make a covert contrast. This suggests that L2 participants who produce a covert contrast will progress to a stage of overt contrast by increasing the acoustic and articulatory differences between the vowels. Overall, our findings not only bring research on L2 pronunciation patterns in line with the findings of research on L1 acquisition and disordered speech, but also expand the idea of covert contrast to include reliable articulatory differences.

## References

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