

Relative cue weighting in the production and perception of register

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Register describes a phonological contrast with multiple phonetic exponents that usually arises from the transphonologization of onset voicing. *High register* vowels are typically characterized by some combination of high f_0 , higher formants, and a modal voice quality, while *low register* vowels are marked by a combination of lower f_0 , lower formants, and breathy voice quality (Huffman 1976, among many others). However, as with many sound changes, it remains unclear exactly how the shift from voicing to register takes place. If it begins in production, we would expect emerging and waning acoustic cues to respectively remain under- and over-weighted in perception (e.g. Coetzee *et al.* 2018). If it is driven by a shift in perception, some cues should be more or less perceptually salient than expected from their acoustic distribution (e.g. Kleber *et al.* 2012). Finally, if listeners' use of different cues in perception matches their acoustic salience, this may indicate that the change is more or less complete (e.g. Kuang & Cui 2018).

Here, we study the emergence of register in two unrelated languages of Vietnam, Chrau (Austroasiatic) and Chru (Austronesian). As shown in Table 1, register is firmly established in both languages, but signaled by different cues: F1 differences dominate in Chru, while both F1 and voice quality are salient properties in Chrau (Brunelle *et al.* 2019; Tạ *et al.* 2019). The low register preserves optional closure voicing in both languages, but this is more common in Chru than in Chrau (Fig. 1). Moreover, devoiced low register stops are realized with a slightly longer positive VOT than voiceless high register stops in Chrau, resulting in a bimodal distribution in which low register stops can either have a more negative or (slightly more) positive VOT than high register stops. If the cues used in perception can be predicted from production, we expect Chru listeners to rely primarily on F1, and to associate negative VOT with the low register. Chrau listeners should rely on a mix of vowel height and voice quality, but may also treat both negative and longer positive VOTs as low register (as opposed to tokens with a short positive VOT).

We investigated the relative perceptual salience of four acoustic properties (f_0 , F1, voice quality, and VOT) using a forced choice identification paradigm. Two minimal register pairs (using segmental carriers /ta/ and /tu/) were created in each language using the KlattGrid synthesizer in Praat. Three values of f_0 , $H1^*-H2^*$ and F1 were generated at the beginning of each vowel (typical high register, typical low register, intermediate), returning to a base value at mid-vowel. VOT was set to -50, +10 or +20 ms. This yielded 51 stimuli per minimal pair. Native speakers of each language (49 Chrau, 42 Chru) heard all stimuli three times and identified them as high or low register by choosing images representing each member of the minimal pairs.

As seen in Fig. 2, in Chru, responses were mostly predicted based on F1, the most prominent acoustic cue, but negative VOT also induced a strong low register bias. In Chrau, listeners relied primarily on voice quality and F1, and made lesser use of f_0 ; VOT effects were much smaller, but -50 ms and 20 ms stimuli both induced more low register responses. Thus, in both languages, cues used in perception can be largely predicted on the basis of their distributional separation in production, but the role of voicing in Chru suggests that it represents a more conservative system. The fact that F1 is perceptually dominant in Chru is unexpected if voice quality and f_0 are integral components of register at the earliest stages of emergence, as has often been assumed. It instead suggests that the emergence of register may first pass through a stage of redundancy in which

closure voicing remains, but a secondary cue is enhanced (as in Coetzee *et al.*, 2018). A multi-dimensional register system would only develop once voicing becomes negligible, as in Chrau.

Figure 1: VOT distribution in stops, by language and register

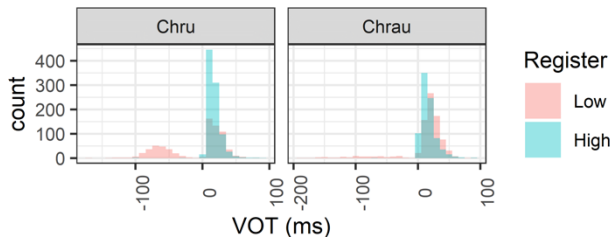
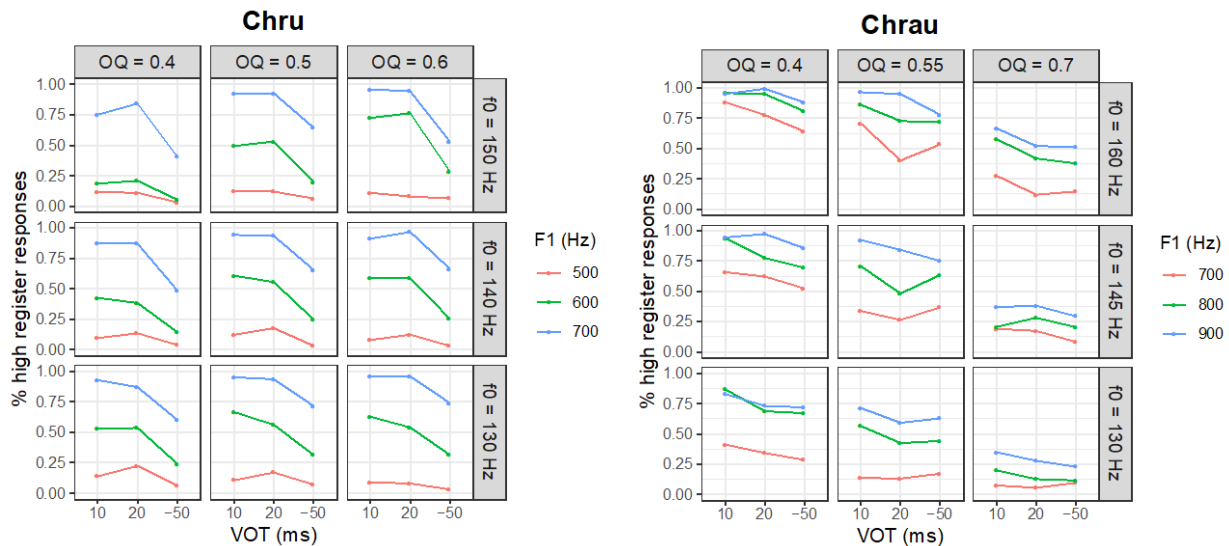


Table 1: Weights (Cohen's *d*) of acoustic cues at vowel onset, by language (non-italics: all vowels; italics: vowel /a/ only to facilitate comparison with Fig. 2)

	f0	F1	H1*-H2*	VOT
Chrau	0.15	1.43	-0.92	0.13
	<i>0.22</i>	<i>1.57</i>	<i>-0.91</i>	<i>0.26</i>
Chru	0.11	2.35	-0.35	0.95
	<i>0.15</i>	<i>2.67</i>	<i>-0.61</i>	<i>1.01</i>

Figure 2: Proportion of high register responses in identification experiment, /a/-vowel stimuli (OQ = KlattSyn glottal opening quotient; greater means breathier. Results are similar for /u/).



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