Gradient and categorical effects in native and non-native nasal-rhotic coordination
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Languages are known to differ in their patterns of consonant-to-consonant coordination (Gafos, 2002, inter alia). Acquisition of a second language (L2) therefore involves learning these language-specific coordination patterns and the corresponding coarticulation/assimilation processes within and across words (Cebrian, 2000; Zsiga, 2003; Oh, 2008; Davidson, 2010). For example, English word-final /n/ overlaps with the following word-initial /ɹ/, resulting in gradient assimilation in retroflexion (posteriority). This can be observed using electropalatography (EPG), as shown in Figure 1a. In the present work, we seek to determine whether L2 learners of English acquire this gradient assimilatory pattern – a task that involves both learning to appropriately produce the target phoneme contrasts (/ɹ/ and /n/; see Figure 1b) and to temporally coordinate them with each other in sequences.

To this end, we investigated how advanced L2 learners of English (EN) – native speakers of French (FR), Japanese (JP), and Spanish (SP) – produce cross-word /n/ + /ɹ/ sequences. The 4 languages of interest differ in their phonetic realizations of syllable-initial rhotics: a uvular fricative /ʁ/ in FR, an alveolar trill /r/ in SP, and a (post-)alveolar flap /ɽ/ in JP. Both JP and SP show categorical patterns of coda nasal place assimilation. In contrast, assimilation in FR is gradient, or even absent in nasal + rhotic sequences (references omitted due to space limits). In terms of L1-shaped patterns of L2 assimilation, we therefore predict that a failure to acquire English gradient patterns would involve a transfer of categorical assimilation (L1 JP and SP) or little to no gradient assimilation (FR), even if the speakers learn to produce English-like rhotics in pre-vocalic contexts.

We employed EPG, a method that tracks the contact of the tongue with an artificial palate, custom-made for each participant. 12 participants – 3 each of L1 FR, JP, and SP as well as 3 North American EN controls – were asked to read phrases with (i) /n/ + /ɹ/ and /n/ (as a control) sequences (common ransom, common napkin) and (ii) vowel + /ɹ/ and /n/ sequences (extra ransom, extra napkin). The materials were produced 9 times in the carrier sentence That’s a(n) ____, randomized and interspersed with other stimuli. The nasal interval was annotated based on acoustics, and tongue-palate contact measurements were extracted at 3 points in time. The dependent variable adopted here is the Centre of Gravity of contact (CoG; Gibbon & Nicolaidis, 1999), which is high for the anterior /n/ and low for the posterior /ɹ/ (see Figure 1b). Preceding /ɹ/, the nasal would be expected to show gradient changes in CoG towards the articulation of the rhotic, but a stable articulation before /n/ (see Figure 1a).

To determine whether the learners had acquired the target rhotic contrast, we first examined the realization of the two consonants in vowel + rhotic/nasal sequences. As shown in Figure 2a, all language groups produced /ɹ/ and /n/ distinctly as measured by CoG. However, a few tokens of the JP-produced /ɹ/ were realized as alveolar flaps, while SP-produced /ɹ/’s were considerably more anterior, being approximant-like adaptations of the trill. Turning to the coda nasal, all language groups but FR adapted it to approximate the rhotic in CoG (Figure 2b): /n/ was significantly more posterior before /ɹ/ than before /n/, although not as retracted as the following rhotic. An examination of the temporal profiles of the JP and SP speakers, however, revealed no gradient changes in /n/ before /ɹ/; these learners had apparently transferred their L1 assimilation patterns. The near-lack of /n/ assimilation for FR speakers can be attributed to the minimal overlap in sequences and occasional [ə]-insertions attested in the present data.

Overall, the results show that, although our learners (with the exception of Spanish speakers) had essentially acquired the English rhotic articulation, they had not fully mastered the target C-C coordination patterns. This is consistent with findings of previous acoustic studies of L2 timing and coarticulation (Zsiga, 2003; Oh, 2008), highlighting the difficulty of acquiring gradient phonetic phenomena.
Figure 1. (a) Sample EPG frames over time for English /n/ in 2 contexts; (b) average linguopalatal contact profiles for /ɹ/ and /n/ (9 tokens) produced by a native English speaker; black = 100% contact; white = 0% contact; the first 3 rows correspond to the alveolar region.

Figure 2. Mean CoG (place) for (a) post-vocalic /ɹ/ and /n/ (midpoint) and (b) /n/ preceding /ɹ/ and /n/ (at the 2/3 point through the nasal) by language group.

Selected references


