**Substantive bias and variation in the acquisition of /n/~/l/ alternation**

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The substantive bias hypothesis predicts that phonetically natural or motivated patterns are preferred by learners (Wilson 2016), while experimental evidence for substantive bias has been varied. No agreement has been made as to the reasons behind the relative weakness of substantive bias (Moreton & Pater, 2012b). This study aims to find out why the effect of substantive bias has been weak or not systematic in phonological learning studies. A few possible explanations have been already proposed (Baer-Henney et al., 2015; Greenwood, 2016; Glewwe, 2019; Lysvik, 2020; Do & Havenhill, 2021). We note that an overarching idea across previous proposals lies on patterns' *(un)certainty*: substantive bias effects are stronger when learning occurs under the conditions exhibiting uncertainty. This goes with psychological evidence beyond linguistics showing that cognitive biases affect people's judgments more in the contexts with high level of uncertainty (e.g. Kahneman & Tversky, 1972). Against this background, we hypothesize that the substantive bias effect emerges more from *variation learning* in phonology, which provides higher uncertainty to learners than categorical learning. We test the learning of /n/ to /l/ alternation before high front vowels and before other vowels and compared them in categorical and variable learning conditions. The experimental results from Hong Kong Cantonese (HKC) speakers suggest that the learning is substantively biased only when the alternation was shown in variation, confirming our prediction.

Articulatory and acoustic similarities suggest that the change from initial /n/ to /l/ before non-high front vowels is phonetically motivated, while the change from initial /n/ to /l/ before high front vowels is not (Fant, 1960; Ladefoged & Maddieson, 1996). Note that in HKC, the initial /l/ has almost completely replaced /n/ in all phonological contexts in production, while /n/ and /l/ are distinguishable in perception (Matthews & Yip, 2011; Ng, 2017). Thus, to learn the context-specific /n/ to /l/ alternation patterns in this study, participants have to revise a context free rule in their L1 to context-sensitive rules. We designed four languages (see Table 1): a categorical natural language (CNL), a categorical unnatural language (CUL), a variable natural language (VNL), and a variable unnatural language (VUL), varying phonological contexts and the proportions of the alternation. 107 native speakers of HKC (age 18 or older) learned the alternation shown in singular ~ plural pairs within an alien language (see Table 2). To make the /n/ ~ /l/ alternation learning implicit, the items also showed height-conditioned rounding harmony among vowels. The singular form was $C_1V_1C_2$ik or $C_1V_1C_2$uk. All the phonemes were attested in HKC. For fillers, the initial consonant remained unchanged. In the training phase (48 target items; 48 fillers), participants saw the visual stimuli and heard the corresponding audio files of the singular and the plural forms. In the two-alternative forced choice task (32 target items; 16 fillers), there were 8 unseen target items with /ɔ/ and /a:/ as new $V_1$. For target items, the two options showed either initial /n/ or /l/, with the correct suffix (height rounding harmony). For fillers, the two options exhibited either rounding harmony or disharmony, with no consonant alternation. After the test, participants took an AXB test to distinguish initial /n/ and /l/ occurring before /i, y, u, ɛ, ɔ, a:/, from which we filtered out the participants showing bad distinction between the two phonemes.

As the results in Figure 1 show, the overall /n/ to /l/ alternation rates between the two

categorical languages (CNL vs. CUL) were not significantly different. For the two variable languages (VNL vs. VUL), VNL showed higher alternation rates compared to VUL, suggesting higher likelihood of generalizing alternation when the dominant pattern is phonetically motivated. Such tendency was seen systematically in independent analyses conducted for the seen and unseen items. In categorical learning, a binary logistic regression showed a strong bias against alternation ($\beta$ = -1.0391 $p < .01$), and it also showed no effect of Languages, Vowel Context or their interactions. In variation learning, however, a binary logistic regression revealed that the alternation rate was significantly lower for VUL in comparison with VNL ($\beta$ = -1.0312, $p < .01$), which was clearly different from categorical pattern learning. Crucially, it was *uncertainty,* i.e., variation, that made the phonetic motivation relevant to learning, thus participants who learned the dominant natural language were more likely to generalize the learned alternation pattern to new items. The findings suggest that the substantive bias effect is not global, but it is activated under certain circumstances. This study found that uncertainty is one of the contexts that could trigger the effects of substantive bias, suggesting the shape and distribution of input could influence the effect of substantive bias.

| | Phonetically motivated | Phonetically unmotivated |
|---|---|---|
| Categorical pattern | **CNL**<br>n → l/__ u, ɛ, ɔ, a:<br>n → n/__ i, y | **CUL**<br>n → l/__i, y<br>n → n/__ u, ɛ, ɔ, a: |
| Variable pattern | **VNL**<br>n → l/__ u, ɛ, ɔ, a: (67%) with n → n/__ u, ɛ, ɔ, a: (33%)<br>n → l / __ i, y (33%) with n → n/__i, y (67%) | **VUL**<br>n → l/__i, y (67%) with n → n/__i, y (33%)<br>n → l/__ u, ɛ, ɔ, a: (33%) with n → n/__ u, ɛ, ɔ, a: (67%) |

Table 1. The four artificial languages

| | | $C_1$ | $V_1$ | $C_2$ | | |
|---|---|---|---|---|---|---|
| Singular | Target | n | i, y, u, ɛ, ɔ, a: | p, $p^h$, t, $t^h$, k, ts, $ts^h$, s | ik | uk |
| | Filler | s, k, $k^h$ | | | | |
| Plural | Target | n, l | | | ik-i | uk-y |
| | Filler | s, k, $k^h$ | | | | |

Table 2. Stimuli

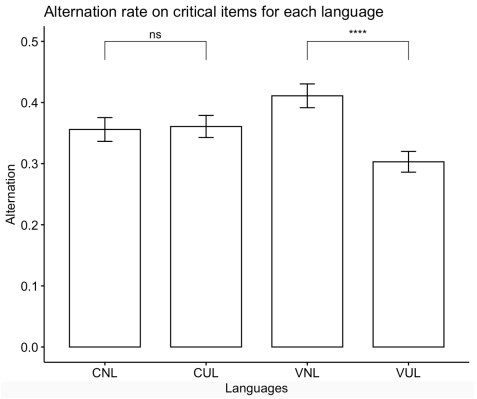


Figure 1. Alternation rates on target items for each language

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