# Revisiting the phonological learnability of *NonFinalR: A large-scale experimental study

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***Summary:*** *NonFinalR has been viewed as a phonologically natural constraint, which bans a rising contour tone in non-(phrase-)final positions. It is presumably driven by the avoidance of articulating a long rising f0 contour in phonetically reduced non-final syllables [1,2]. Its phonological learnability has been previously verified in experimental studies [3], but an alternative low-level phonetic explanation remains. The current study compared the learnability of *NonFinalR and constraints banning other non-final tones in a Web-based, large-scale artificial grammar learning (AGL) experiment. We found a lasting effect of unconscious learning only for *NonFinalR, which again supports the role of articulatory substances on the abstract level of phonology.

***Background:*** In the previous AGL study [3], adult speakers of L1 Taiwan Mandarin were briefly exposed to disyllabic input created with four tones: H(igh), R(ising), L(ow), and F(alling). The input complied with *NonFinalR or *NonFinalH, but the speakers were biased to extend only *NonFinalR to auditory acceptability judgments of novel forms. The intrinsic learnability difference between the two constraints could be attributed to substance-based phonology, in which *NonFinalR, but not *NonFinalH, is phonologically computable with the ease of articulation. However, native speakers of a tone language with rich contour tones might be more sensitive to f0 contours on the perceptual level [4]. An alternative low-level perception-based account is that the participants in [3] could detect non-final rising f0 contours more easily than non-final high-level pitches in the auditory acceptability judgment task. That is, they could correctly accept/reject novel forms simply because they were more *explicitly* aware of non-final rising f0 contours that did not appear during the exposure phase. In this study, we attempted to disassociate the role of low-level perceptual salience and *unconscious* substance-based phonology in the inductive bias favoring *NonFinalR. In our AGL experiment, we compared the learnability of *NonFinalR with *NonFinalH, *NonFinalL, and *NonFinalF. The low-level perceptual account predicts a better performance for identifying test items violating *NonFinalR and *NonFinalF for L1 Taiwan Mandarin speakers' higher sensitivity to non-final tonal contours in an auditory judgment task. The phonological account assumes the critical role of articulatory difficulties in phonology and predicts a better judgment performance only for *NonFinalR learners. *NonFinalH and *NonFinalL are not expected to be learned successfully in both accounts (see Table 1).

***Method:*** A Web-based AGL experiment was run in ENIGMA [5] on 251 online adult participants speaking L1 Taiwan Mandarin. The learners were first exposed to 120 CV.CV sequences produced with a di-tonal sequence composed of the four tones: H, R, L, and F, excluding L-L for its violation of Third-tone sandhi. Learners were randomly assigned to learn one of the four constraints or to a Control condition as the baseline, in which the four tones were evenly distributed across both syllables. Both immediately and at least 24 hours after the passive listening phase, all learners were asked to judge the acceptability of 75 novel CV.CV items with all possible di-tonal sequences except L-L. After each judgment, learners had to provide a binary confidence rating on the judgment (Yes vs. No) as an awareness measure. An above-baseline performance for unconfident judgments across the immediate and delayed tests represents strong evidence for *unconscious* judgmental knowledge of abstract tonal constraints [6].

***Results:*** An initial analysis of 27,655 valid judgments suggests successful learning of all four target tonal constraints, and the effect persisted into the delayed judgment task; *all non-control learners* could distinguish test items based on their constraint violation more correctly than the control peers (Figure 1). However, if the analysis was limited to the 9,478 judgments rated subjectively as unconfident by the participants, *only* *NonFinalR learners were significantly different from Control learners in discriminating test items based on their constraint violation in both judgment tasks (Figure 2; Group × Violation: $\beta = -0.112$, $se = 0.053$, $z = -2.141$, $p = .03$). This above-baseline performance with unconfident judgments by *NonFinalR learners is consistent with previous findings and a phonological account that weighs in the articulatory factor.

**Table 1.** Predictions on the learnability of constraints banning non-final H, R, L, or F based on low-level perception-based (phonetic) account and substance-based phonological account

| Tonal Constraints | Low-level Phonetics | Substance-based Phonology |
|---|---|---|
| *NonFinalH | ✖ | ✖ |
| *NonFinalR | ✓ | ✓ |
| *NonFinalL | ✖ | ✖ |
| *NonFinalF | ✓ | ✖ |

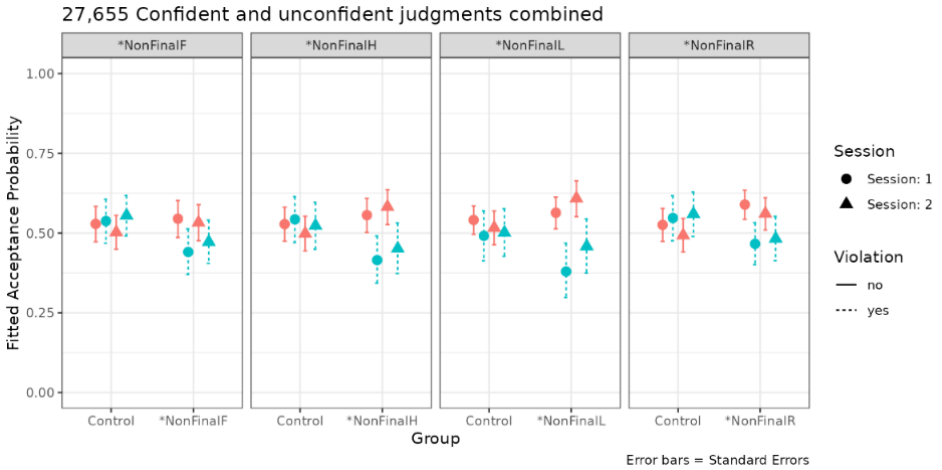


**Fig. 1.** Comparisons of acceptance probability by target constraint violation between Control and each of the four target groups in mixed-effects logistic regression modeling

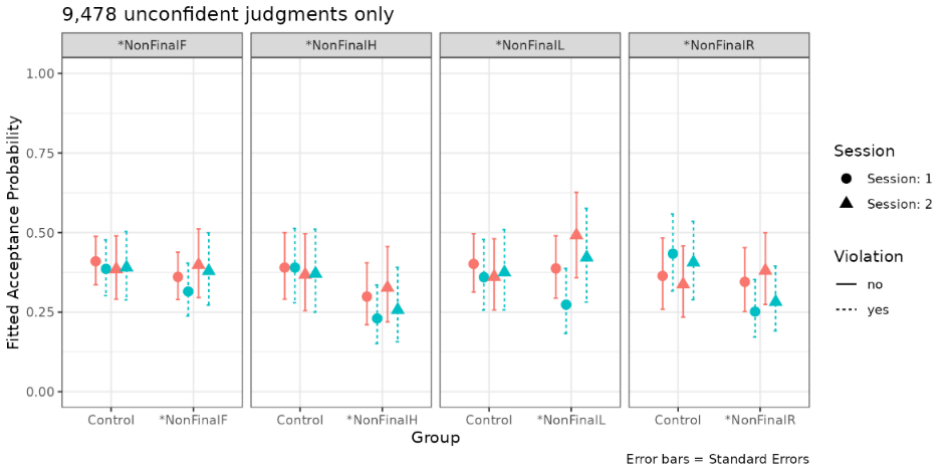


**Fig. 2.** Comparisons of acceptance probability without confidence by *NonFinalR violation between the Control and *NonFinalR groups in mixed-effects logistic regression modeling (Accept ~ Group × Violation × Session + (1 + Group | Item) + (1 + Violation + Session | Subject))

**References**


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