The Effects of Awareness, Cue-Outcome Temporal Order, and Offline Consolidation on Learning Non-Native Phonological Cues

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The present study aimed to investigate the learnability of lexical stress patterns—a non-native phonological cue for Turkish speakers—within an artificial language learning paradigm. Learning non-native phonological contrasts has been shown to be challenging when the target cues do not have contrastive functions in the native language [1]. Considering the fixed pattern of lexical stress in Turkish, native Turkish speakers would be expected to develop insensitivity to different stress patterns [2–4]. For this reason, the present study aimed to investigate the factors that could facilitate the acquisition of stress patterns associated with categorical semantic features: the effects of awareness, consolidation, and the temporal order of cues and outcomes on learning stress patterns.

Earlier studies showed that lexical stress patterns can be learned even without explicit awareness of the regularities [5]. However, given the challenging nature of perceiving lexical stress for Turkish participants, we incorporated a visuo-motor response task based on earlier studies, in which motor response tasks facilitated learning of categorical features in auditory [6] and morphological stimuli [7] . To examine the effect of awareness on learning, we included multiple measures: verbal reports, self-confidence ratings, and source attributions.

Participants were exposed to an artificial language composed of two semantic categories: animate and inanimate. Each word, presented only auditorily, was paired with a corresponding picture. Notably, the same word forms were used across both categories, creating segmental overlap in lexical items. However, the two categories were distinguished by their stress patterns: first-syllable stress for animate items, and second-syllable stress for inanimate items. In the training session, stress patterns predicted animacy, whereas this stress-to-semantic mapping was violated in designated violation blocks. Participants completed two-alternative forced-choice judgment tests following the training session. Learning was assessed through the reaction-time costs in violation blocks relative to congruent blocks, as well as accuracy in the judgment tasks.

To explore the role of temporal order, we manipulated the sequence of word and picture presentations, drawing on discrimination learning theory [8]. In the cue-outcome condition, words preceded pictures during training, aligning with the theory's prediction that this order facilitates learning of novel cues by supporting outcome prediction. In the outcome-cue order, pictures were presented before words. Additionally, we examined the role of sleep in consolidation. Sleep has been shown to support the development of automatic and implicit knowledge [9]. Accordingly, participants in the sleep group completed their second training session after a night of sleep, while those in the awake group completed both sessions on the same day. The study employed a 2 (temporal order: cue–outcome vs. outcome–cue) × 2 (consolidation: sleep vs. awake) between-participants design. To analyze the interaction between awareness and sleep-related consolidation, a hint condition was introduced to increase awareness rates; awareness was modeled as an additional predictor and interaction term in the consolidation analyses.

The findings revealed that significant learning relied on explicit awareness of the stress-to-semantic mapping in the artificial language. Contrary to predictions from discrimination learning theory, cue-outcome order did not reliably enhance learning, suggesting that the perceptual difficulty of stress cues may override temporal prediction advantages. Lastly, sleep benefited the proceduralization of the target regularity only for the aware participants; however, this was a within-group effect rather than a significant comparison with awake group. Taken together, these findings implicated the challenging nature of learning lexical stress patterns for speakers of fixed-stress languages and elucidated the mechanisms underlying the acquisition of non-native phonological cues.

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