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Regularity and vowel harmony: Statistical learning and rule abstraction

To what extent does the regularity of a pattern, or rule, affect the way in which it is acquired by speakers of a language? Is there a threshold of regularity below which variation obscures or prevents the formation of a pattern or rule in a speaker's grammar? A wide variety of studies have explored these questions by examining the acquisition, of both adjacent dependencies and non-adjacent dependencies, through artificial language learning tasks. It has been found that adults, young children and infants can quickly acquire awareness of consistent and temporally adjacent dependency patterns of not only speech segments, but also of musical tones (Aslin, Saffran & Newport 1998; Perruchet & Pacton 2006; Saffran, Aslin & Newport 1996; Saffran, Newport, Aslin, Tunick & Barrueco 1997; among many others). In terms of non-adjacent dependency patterns, other research has shown, for example that infants are sensitive to word order regularity exhibited by stimuli (Gomez & Gerken 1999, 2000; Gomez & Maye 2005; among others). Additionally, studies on adults have shown that learning of morphological patterns is affected by regularity of phonological cues present in the base word (Becker 2008; Albright & Hayes 2003).

This paper expands upon this research by examining how regularity affects native English speaking adults' acquisition of a purely phonological non-adjacent dependency: ATR vowel harmony. The results of three experiments are presented. These experiments investigate how phonological regularity affects the extent to which a non-explicit phonological pattern, or rule, can be acquired through the use of an artificial language learning task. By manipulating the degree of regularity of a non-explicit rule of ATR vowel harmony exhibited by the training items in the experiments, this research examines not only how regularity may affect the subjects' acquisition of the vowel harmony rule, but also whether learners' sensitivity to regularity effects is subject to a specific threshold.

Sixty adult native English-speaking subjects (20 per experiment) were trained on sets of artificial language data in which the degree of regularity of a non-explicit rule of ATR vowel harmony was manipulated. In Experiment 1, crucially, all of the words were ATR harmonic. In Experiment 2, 80% of the training words were ATR harmonic, while 20% were disharmonic. In Experiment 3, only 50% of the training words were ATR harmonic, while the other 50% were ATR disharmonic. Subjects in each of these experiments were then required to offer well-formedness judgments on novel words. Half of these novel items were ATR harmonic, conforming to the non-explicit rule exhibited by the training items. The other half of the novel items were ATR disharmonic, in violation of the non-explicit rule exhibited by the training items. During the testing phase of the experiment, subjects were asked to listen to a word and indicate whether it could be a word of the language they listened to in the training phase. Subjects' response time, accuracy, and the percent 'yes' responses were analyzed. Subjects' accuracy was coded as 'correct' if a subject accepted a harmonic test item or rejected a

disharmonic test item. The percent 'yes' dependent variable is simply the number of times a subject accepted an item as a possible word of the language.

Response time analyses of these experiments showed a significant difference, both by-subjects and by-items, in response times between harmonic and disharmonic items for subjects in only Experiments 1 and 2. Subjects' response times in Experiment 3 failed to yield a significant difference to harmonic and disharmonic items. Furthermore, subjects from Experiment 1, where the harmony rule exhibited maximal regularity, yielded the fastest response times, whereas subjects from Experiment 2 were slower and subjects from experiment 3 performed at chance level. Between-subjects analyses of response time indicated a significant difference between each of the three experiments, suggesting that the regularity of the training items influenced subjects' response times.

Subjects' accuracy levels also differed by experiment. Experiment 1 yielded the highest accuracy rates, followed respectively by accuracy rates of Experiments 2 and 3. Accuracy analyses also showed a significant difference between experiments, both by-subjects and by-items. These results suggest that the regularity of the harmony pattern acted as an important role in subjects' accuracy level. Furthermore, there was an unanticipated significant difference in subjects' accuracy rates at accepting harmonic items and rejecting disharmonic items. Specifically, subjects were significantly better at accepting harmonic items than they were at rejecting disharmonic items. This was an interesting and totally unexpected effect. It suggests that while the presence of the harmonic pattern is taken by-subjects as a strong cue, leading them to successfully accept harmonic items, but did not assist them to the same degree in rejecting disharmonic items.

Analyses of subjects' percent 'yes' to items identified a significant difference between experiments as well. Specifically, subjects were significantly more likely to both accept a harmonic item and reject disharmonic items in the experiments in which the harmony pattern was more regular. Simultaneously, subjects were also significantly less likely to accept harmonic items and reject disharmonic items in experiments in which the harmony pattern was less regular. These results suggest that the more systematic or regular the harmony pattern, it is significantly more likely that subjects are to figure out that harmonic words are part of the language. Conversely, the less systematic the harmony, it is more that a disharmonic word would be considered possible.

Altogether, these results suggest that learners are not only sensitive to different degrees of regularity exhibited by a pattern, but, interestingly, that regularity effects can also alter how learners make decisions about what matches a pattern and what does not. These results provide strong support for the hypothesis that speakers abstract the degree of regularity exhibited by a specific language phenomenon in the construction of non-explicit pattern generalizations, or rule abstraction. Furthermore, they suggest that speakers' ability to form a given phonological rule is sensitive to a threshold which occurs somewhere below 80% regularity of a pattern. These results indicate that the regularity of a pattern represents an important source of information for learners and speakers of a language. This has significant

implications for not only formal theories of language, but also for theories about specific speech processes like speech segmentation, lexical access and lexical organization and how regularity may inform or alter these processes.

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