Inductive learning of (non-)iterative consonant harmony

Recent studies have established many parallels between the typology of phonological patterns and the range of inductive biases exhibited in the laboratory (Moreton and Pater, 2012; Finley, 2017). We will present the results of an ongoing artificial grammar learning experiment which, to our knowledge, is the first to examine issues related to iterativity in the learning of consonant harmony. Our findings suggest that, despite the fact that nearly all attested consonant harmony processes iterate to multiple targets (Hansson, 2010), learners in this study are not necessarily biased in this way. We discuss the theoretical implications of these results, particularly as they relate to the Agreement by Correspondence framework (Rose and Walker, 2004; Bennett, 2015).

Consonant harmony is a type of phonological pattern in which two non-adjacent consonants are required to agree in some way. In Koorete, for example, sibilants are required to agree in anteriority (across a single vowel). As shown in (1a-b), this process results in the causative suffix /-us/ surfacing as [-uʃ] when there is a root-final [–ant] sibilant. As shown in (1c), this process is iterative, affecting additional suffixes like /-esːe/ (3mSg.juss).

(1) Koorete sibilant harmony (data from Hayward, 1982; Hansson, 2010)

a. /goː**tʃ**-us-/	[goː**tʃ**-u**ʃ**-]	'cause to pull'	
b. /dʒa**ʃ**-u**s**-/	[dʒa**ʃ**-u**ʃ**-]	'cause to fear'	
c. /dʒa**ʃ**-u**s**-e**s**ːe/	[dʒa**ʃ**-u**ʃ**-e**ʃ**ːe]	'let him/them frighten (s.o.)!	(*dʒa**ʃ**-u**ʃ**-e**s**ːe)

Although patterns of consonant harmony are relatively rare cross-linguistically, humans seem to detect them with ease in artificial grammar learning studies. Finley (2011, 2012) shows that participants are able to detect harmony when sibilants are several syllables apart, further arguing that a typological dichotomy related to locality is a reflection of human learning bias (see also McMullin and Hansson, 2019). In this study, we explore whether the apparent cross-linguistic absence of non-iterative consonant harmony can likewise be tied to human learning bias.

The current artificial grammar learning experiment uses a "poverty of the stimulus" paradigm (Wilson, 2006), where participants are first exposed to a subset of stimuli with the relevant harmony pattern and then tested on novel items. All of the stimuli exhibiting harmony followed a pattern of regressive liquid harmony triggered by the addition of suffixes [-li] or [-ru]. At the time of writing, data has been collected for 45 participants (all native speakers of North American English). These participants were randomly assigned to one of three training conditions and exposed to either a short-range harmony pattern with two relevant consonants harmonizing across a single vowel (sHarm group, n=18), an iterative pattern involving three harmonizing consonants (iHarm group, n=15), or no harmony pattern (Control group, n=12). Following the training phase, all participants were tested on harmony in three contexts (short-range, long-range, and iterative) using a 2-Alternative Forced Choice task. The options for short-range and long-range test items consisted of a harmonic option and a disharmonic option, such as *pukori-li* vs. ***pukoli-li*** (short-range) and *kiremu-li* vs. ***kilemu-li*** (long-range). The iterative test items were further divided into two sub-types, as the three liquids can be harmonized in several different ways. The iterative test items labeled 'Iter-2v1' correspond to the trials in which participants choose between two iterations of harmony or only one iteration of harmony (e.g., *boleli*; ***boreri-ru*** vs. *boleri-ru)*. In 'Iter-1v0' trials, participants instead choose between one iteration of harmony or a faithful (disharmonic) option (e.g., *boleli;* ***boleri-ru*** vs. *boleli-ru)*. By training participants on a subset of the harmony pattern in question then testing on three different contexts, we can better understand how learners internalize harmony rules and generalize them to novel items and contexts.

Results were analyzed using a mixed-effects logistic regression. The odds ratios (ORs) extracted from the model are presented in (2) below. Each OR value represents the increased likelihood of participants in each group selecting the *more harmonic* test item for each trial type (i.e., the options shown in boldface in the examples above), relative to the Control group.

(2)

	Test item type			
	Short-range	Long-range	Iter-2v1	Iter-1v0
sHarm vs. Control	**OR=3.77 (p<0.001)**	OR=1.71 (p=0.089)	OR=1.37 (p=0.404)	OR=1.99 (p=0.067)
iHarm vs. Control	**OR=4.90 (p<0.001)**	**OR=2.60 (p=0.004)**	**OR=3.54 (p=0.002)**	OR=1.89 (p=0.108)

Our results reveal that, at the group level, sHarm participants learn the pattern that was presented to them in training (short-range; OR= 3.77), but that they are not significantly more likely than the Control group to select the more harmonic option on any other trial types. That is, although their training did not explicitly demonstrate a non-iterative pattern, learners in the sHarm group seems to act conservatively, applying harmony only to one of the targets in the Iter-2v1 trials. The iHarm group learned to apply harmony iteratively (Iter-2v1: OR= 3.54), and generalized the pattern to both the short-range (OR= 4.90) and long-range (OR= 2.60) contexts.

In the Agreement by Correspondence framework (ABC; Rose and Walker, 2004), agreement is enforced after first establishing surface correspondence relations among the relevant consonant pairs. We will discuss our findings as they relate to three versions of this relation that have been proposed in the literature: *global correspondence*, which establishes a relation among all relevant segments ($C_x \ldots C_x \ldots C_x$, e.g., Bennett, 2015); *local correspondence*, which creates chains of correspondent pairs ($C_x \ldots C_{x/y} \ldots C_y$, e.g., Hansson, 2007); and *headed correspondence*, where there is an asymmetric correspondence between a head and its dependents ($C_D \ldots C_D \ldots C_H$, see Iacoponi, 2015). An analysis of the factorial typologies of relevant constraints for each type of surface correspondence was conducted using OT-Help (Staubs et al., 2010). When taken at face value, the results above are most readily accounted for under global correspondence. In particular, establishing local correspondence chains predicts that harmony will necessarily be iterative, while headed correspondence cannot account for participants' reluctance to apply one iteration of harmony in Iter-1v0 test items. We note, however, that the OR values for these trials are approaching significance for both experimental groups. Further data collection (ongoing), as well as an analysis of variation among individual results may help us to better understand how participants are generalizing, and how they are best accounted for within the ABC framework.

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