Testing Greenberg's Universal 18 using an Artificial Language Learning Paradigm

Linguistic theories differ in the extent to which constraints on language learning are claimed to determine the space of possible human grammars. Mainstream generative theories often conceive of language acquisition as governed by a set of learning biases, rules, principles, etc., which play a role in shaping the way languages evolve and change over time, and relatedly, as an explanation for the existence of typological generalizations or universals (Lightfoot 1999; Kirby 1999; Niyogi 2006; Chomsky 1965, among many others). Although the precise nature of the learning biases as well as their role in explaining typological generalizations are frequently debated, direct evidence is lacking. Very little convincing empirical work exists which explicitly tries to uncover biases against learning (or use) of typologically rare or unattested patterns.

This paper presents results from an artificial language learning (ALL) task which addresses the hypothesis that learners are sensitive to the same constraints seen respected by typologically attested patterns. The typological universal targeted in the experiment is Greenberg's Universal 18 (Greenberg 1963), which is concerned with the ordering of adjectives and numerals with respect to nouns they modify. In particular, of the following four logically possible orders, only the first three are attested cross-linguistically (Greenberg 1963; Hurford 2003; Rijkhoff 1998; Hawkins 1983).

1. Adjective-Noun & Numeral-Noun ("harmonic")
2. Noun-Adjective & Noun-Numeral ("harmonic")
3. Noun-Adjective & Numeral-Noun ("dominant")
4. *Adjective-Noun & Noun-Numeral ("recessive")

The ALL methodology used in the present experiment differs from past related work in a number of crucial ways. First, we explicitly compare learning of typologically common and unattested patterns. Second, we use probabilistic variation in the input to compare learners' success at (a) tracking the statistics of the input language and (b) actively producing more probable word combinations. Third, learning is relatively naturalistic; subjects learn semantically meaningful word combinations in a novel artificial language by listening to an "informant", and must comprehend and produce word combinations during the course of learning.

Whereas past work on learning and typological universals has compared learners' ability to generalize a pattern they have learned to new forms (Wilson 2006, Finley and Badecker 2008), we use learning of probabilistic patterns as a measure of comparison. The use of variable grammars in ALL was adopted from traditional probability learning studies by Hudson Kam & Newport (2005) to test the claim that children, but not adult learners, exert a regularizing influence on variation found in their language. Hudson Kam and Newport (2005) found that adults were in fact more likely to match the probabilities found in a target grammar, whereas children were more likely to regularize. Our study alters their method by providing adult subjects with an implicit functional pressure to regularize. We therefore investigate the extent to which learners differentially treat multiple patterns of interest which are variably instantiated in their input. The motivation for incorporating this variability is to allow comparison of subjects' treatment of typologically attested and unattested (or rare) patterns, without expecting subjects to innovate patterns they are not exposed to. Instead we compared learners success at regularizing the majority pattern in their production of word combinations. Under the hypothesis that there is a direct connection between learning, typology, and change, learners should be more willing (or able) to regularize variable rules that are in line with typologically attested patterns as opposed to unattested ones. The study is therefore the first to compare language conditions of interest based both on learners' ability to veridically learn a target pattern, *and* to regularize that pattern under pressure to do so.

Subjects in the experiment learned adjective-noun and numeral-noun combinations in one of 4 novel language conditions. Subjects were tested on their ability to correctly describe pictures they were shown. They were rewarded (by a point system) not only when they used the correct vocabulary items, but when an utterance made in response to a particular picture matched the order used (stochastically generated) by the informant to describe the same picture. Subjects would therefore achieve a higher point

total if they boosted the frequency of the majority order found in the target language. The language conditions along with the order probabilities for each modifier type are shown below.

	(a) *Harmonic*	(b) *Harmonic*	(c) *Dominant*	(d) *Recessive*
Adj-N (N-Adj)	0.3 (0.7)	0.7 (0.3)	0.3 (0.7)	0.7 (0.3)
Num-N (N-Num)	0.3 (0.7)	0.7 (0.3)	0.7 (0.3)	0.3 (0.7)

Results, currently based on data from 10 subjects, showed that in language conditions (a) and (b) subjects were more successful at learning the majority order for each modifier type, likely since English also follows a harmonic pattern. More interestingly, subjects in those conditions were also most likely to regularize the majority pattern. Calculation of the Kullback-Leibler divergence (a measure of the divergence of an observed probability distribution from a target distribution, Kullback and Liebler 1951) of individual subjects' output probabilities from the target for their condition (as shown above) revealed that subjects in those conditions showed a higher divergence from the target than subjects in other conditions, but always in the direction of the target pattern (mean KL divergence 0.134). In other words, their probability of producing the majority pattern was in fact higher than 70%. Differences were also found between subjects' performance in the non-harmonic conditions (c) and (d) –the cross-linguistically unattested pattern. In both conditions, subjects were better at learning the pattern of the modifier whose majority order was parallel to English, but they did not boost their frequency of production of that order as subjects in conditions (a) and (b) were able to do. However, subjects in condition (c) were more likely to achieve a closer match to the target grammar than subjects in condition (d). Overall, subjects in condition (d) showed a higher KL divergence than in condition (c) (mean KL divergence 0.083, compared to 0.055), but in this case in the direction of increased random variation rather than regularization. The results, although preliminary, show that success in the task may in fact be more difficult for subjects learning the unattested pattern. These results also suggest that subjects' ability to regularize the majority pattern in the face of functional pressure is a good measure of the difficulty of the learning condition.

Based on the results of this study, in the case of Greenberg's Universal 18, biases shown by learners may in fact be parallel to those found cross-linguistically. We believe that the methodology used here offers a promising new venue for empirical investigation of the relationship between learning biases and typological universals.

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