Changing Minds Changing Tools: A Learning-Theoretic Approach to Language Acquisition

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For a long time after Chomsky (1959), mainstream linguistic theory denied the possibility that language could be acquired using domain-general learning mechanisms. This consensus began to shift in the 1980s, with the re-emergence of connectionism and the development of usage-based cognitive/functionalist approaches to linguistic theory. The ensuing debate generated a great deal of interest in learning mechanisms for language acquisition (see Kapatsinski, in press b, for a review). While domain-specific mechanisms have been proposed (e.g. Gibson & Wexler, 1994), further research has generally abandoned them due to robustness issues and converged (back) on domain-general mechanisms familiar from other domains. For example, phonologists have turned back from strict ranking of constraints to gradient weighting using domain-general weight updating algorithms (Hayes & Wilson, 2008; Kapatsinski, 2013). At this point, there is no theoretical position that denies the applicability of domain-general learning mechanisms to language.

Many studies have demonstrated the power of domain-general mechanisms in acquiring specific aspects of language and making surprising and surprisingly correct predictions. In particular, much recent research has shown that various phenomena in language acquisition are consistent with the Rescorla-Wagner (1972) model (Ellis, 2006; Kapatsinski, in press a; Olejarczuk et al., in press; Ramscar et al., 2013). This research suggests that language acquisition is learning.

However, the literature on domain-general learning theory is not characterized by consensus around the Rescorla-Wagner model or some alternative to it (e.g. Kruschke, 1992; Miller, 1995; Sutton & Barto, 1998). Alternative learning mechanisms assume different types of experience to be critical for learning a particular aspect of language, and learn different things from the same experience.

Despite calls for a learning-theoretic linguistics (Hayes & Wilson, 2008), relatively little work has explicitly compared the predictions of alternative learning mechanisms for language acquisition or explored the ways in which they may work together in driving language acquisition and constraining language change. This is the aim of research summarized in *Changing minds changing tools* (Kapatsinski, in press, a; see also Harmon et al., in prep; Harmon & Kapatsinski, 2017; Kapatsinski, 2009, 2010, 2013; Kapatsinski & Harmon, 2017; Olejarczuk et al., in press; Olejarczuk & Kapatsinski, submitted).

While we follow a complementary-learning systems approach to learning theory (McClelland et al., 1995), most of our research to date has explored relatively short-term changes in beliefs resulting from brief perceptual experience in the laboratory. In recent work, we have documented that this type of learning is characterized by a great importance of surprise (Kapatsinski, in press, a; Olejarczuk & Kapatsinski, Submitted; Olejarczuk et al., in press). While many learning models following Rescorla and Wagner (1972) have suggested that surprise is crucial for learning, the precise way in which surprise is utilized varies across alternative models. Our research investigates some of the ways surprise is used in language learning.

Kapatsinski (in press, a; pp.103-107) and Olejarczuk and Kapatsinski (Submitted) argue that learners temporarily downweigh their beliefs when they are clearly contradicted by recent experience. This effectively increases the learning rate for unexpected patterns, allowing the learner to rapidly learn the contingencies of the current environment. As a result, when learning is measured as a change from pretest to post-test, unexpected patterns engender more learning than expected ones (e.g. Figure 1). Computational simulations show that the differences between expected and unexpected patterns in our study are greater than one would expect from a Bayesian model. In particular, we see rapid downweighting of previously predictive cues to stress location when the cue-outcome mappings are reversed from the participants' native language experience. In contrast, upweighting of such cues beyond their original levels appears to be comparatively more difficult. The rapid learning of surprising patterns may help explain a persistent mystery in language change: how it is that novel patterns can overtake their entrenched predecessors despite their initially low input frequency. For example, the past tense suffix *–ed* successfully overtook all competing strong verb patterns of old English, despite its initially low frequency in the language.

Harmon et al. (in preparation; see also Kapatsinski, in press a, pp.140-143) show that surprise alone appears to be insufficient to engender downweighting of a predictive cue. In this study, we made use of the fact that phonological contrasts are highly multidimensional, but characterized by one dimension serving as the primary cue (e.g. Kapatsinski et al., 2017). Voicing, the difference between *beer* and *pier* is cued by as many as 16 cues, with VOT serving as primary cue for English speakers. We showed that random pairing of VOT with voicing feedback engenders no downweighting of this primary cue. Instead, it engenders upweighting of a

secondary cue (F0 at the onset of the following vowel), but only if attending to the secondary cue allows the learner to *improve* the accuracy of their predictions during training. If the secondary cue is constant during training, no learning occurs (a null hypothesis confirmed by Bayes Factor analysis), despite the fact that training provides positive evidence that the primary cue is non-predictive. Computational simulations show that this result contradicts the predictions of the Rescorla-Wagner model, which suggests that random cue-outcome pairings should produce rapid downweighting of a predictive cue. Instead, the results are captured by reinforcement learning models (Sutton & Barto, 1998), with two assumptions: 1) participants rapidly divert attention away from non-predictive cues (Kruschke, 1992), and 2) attention to a cue increases the learning rate for associations involving that cue (Rescorla & Wagner, 1972, et seq). Assuming this, diverting attention away from a cue that is no longer predictive facilitates rapid learning about other cues whereas knowledge about the meaning of the primary cue remains unaffected. As argued by Kruschke (1992), this may allow the learner to maintain stable long-term beliefs while rapidly adjusting to the changing environment; in this case, linguistic environment. For example, whereas English speakers use VOT as the main cue to voicing, Korean speakers use F0. Learning to understand a Korean speaker of English therefore requires rapid upweighting of F0. Shifting attention to F0 when VOT is unpredictive allows the listener to adapt while maintaining knowledge about VOT.

Overall, these results challenge single-mechanism theories of learning. Surprise appears to reduce the learner's confidence in their beliefs. In this sense surprise does more than is usually assumed. However, surprise may not by itself be sufficient to lead to a change in behavior, including covert behavior, such as the allocation of attention. Rather, the learner should have evidence that the change will lead to more rewarding behavior. In this sense, surprise is less powerful than often assumed. Behavioral changes in language acquisition may need to be *shaped* (Goldstein et al., 2003; Skinner, 1981). Developing a learning-theoretic account of language acquisition will require elucidating how several domain-general learning mechanisms work together in driving behavioral changes.

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