Implicative organization facilitates morphological learning

SCOTT SEYFARTH, FARRELL ACKERMAN, & ROBERT MALOUF
University of California, San Diego and San Diego State University
sseyfarth@ucsd.edu, fackerman@ucsd.edu, rmalouf@mail.sdsu.edu

In word-based morphology, implicative relationships among related wordforms are used to facilitate the learning of complex morphology (see Blevins, to appear, ch. 7; Ackerman & Malouf 2013). For example, an Italian singular suffix *-a* (*persona)* typically implies a plural suffix *-e* (*persone*), while singular suffix *-o* (*gatto*) implies plural suffix *-i* (*gatti*), and vice versa. On this basis, a learner might correctly predict that a novel singular form *rosa* has the plural form *rose*. However, this perspective on morphological organization is challenged by experimental results in artificial language learning, which find that learners are unable to acquire these relationships unless they are supported by additional phonological cues in the stem (Gerken et al. 2009; Brooks et al. 1993, Frigo & MacDonald 1998). We argue that these results were biased by ecological factors, and that implicative relations alone are sufficient to enhance paradigm learnability.

We first identify four methodological features of prior experiments that restrict general learnability: (1) passive exposure and/or rote repetition, rather than active trial-and-error learning; (2) a requirement to learn both novel lexemes and inflections in a short time; (3) a requirement to infer relations among abstract linguistic labels rather than referents; (4) presentation of labels before their referents, which is known to delay association learning (Ramscar et al. 2010).

We present three novel artificial grammar experiments in which subjects demonstrate knowledge of formal paradigmatic relationships, despite experimental randomization designed to avoid redundant phonological or semantic information that would signal class membership. In Experiment 1, subjects attempted to learn how to inflect familiar nouns for number (singular, dual, plural) in an alien language. Six nouns were randomly selected from a pool of 30 household objects and divided into two classes which had suffix inflections as shown in Figure 1. In each training trial, subjects saw one, two, or many pictures of a noun and tried to guess how the aliens would refer to that set. Subjects were then given feedback and shown the correct answer.

After 90 training trials, subjects were tested on their knowledge. In each testing trial, subjects first saw one, two, or many pictures of a new, previously-unseen object, and were given its label. Subjects were then asked to label a different number of the same noun. In critical trials, the new noun was first presented in a form that reliably predicted the test form (e.g., singular *-taf* implies dual *-guk*). The results showed that subjects successfully took advantage of implicative relationships: when subjects could use two compatible suffixes for the second inflection, performance was significantly better when they were first presented with a predictive inflection than when they were not ($p < 0.001$). Experiments 2-3 tested more complex paradigms with 9 nouns and 3 classes. In these paradigms, performance was better only for bidirectional relationships, where the given and unseen suffixes both implied each other ($p < 0.01$).

Our results indicate that subjects acquired paradigmatic relations without redundant cues. This finding suggests that ecological factors drove previous results, which helps resolve

	class 1	class 2
SG	chair-taf	bed-yez
DU	chair-guk	bed-cav
PL	chair-lem	bed-lem

Experiment 1: (n=33)

class 1	class 2	class 3
chair-taf	bed-yez	table-yez
chair-guk	bed-cav	table-cav
chair-lem	bed-lem	table-nup

Experiment 2: (n=28)

class 1	class 2	class 3
chair-taf	bed-yez	table-seb
chair-guk	bed-cav	table-cav
chair-lem	bed-lem	table-nup

Experiment 3: (n=32)

Figure 1: Five (in Exp. 1), six (Exp. 2), or seven suffixes (Exp. 3) were randomized to avoid phonological patterns.

the apparent mismatch between prior experimental and typological data. Some researchers have argued that enriching word classes with additional syntactic or semantic redundancies could permit acquisition if phonological cues are inadequate (Ouyang, Boroditsky, & Frank 2012; Mintz 2002; Braine 1987). However, our results indicate that learners can acquire useful paradigmatic relations without any additional supporting cues if the potential influence of domain-general learning factors is properly taken into account (Frank & Gibson 2011).

References

ACKERMAN, F., & MALOUF, R. (2013). Morphological Organization: The Low Conditional Entropy Conjecture. *Language*, *89*(3), 429–464. doi:10.1353/lan.2013.0054

BLEVINS, J. (to appear). Word and Paradigm Morphology. Oxford University Press.

BRAINE, M. (1987). What is learned in acquiring word classes: a step toward an acquisition theory. In *Mechanisms of Language Acquisition* (pp. 65–87). Hillsdale, NJ: Lawrence Erlbaum.

BROOKS, P., BRAINE, M., CATALANO, L., & BRODY, R. (1993). Acquisition of gender-like noun subclasses in an artificial language: the contribution of phonological markers to learning. *Journal of Memory and Language*, *32*, 76–95.

FRANK, M. C. & GIBSON, E. (2011). Overcoming memory limitations in rule learning. *Language Learning and Development*, *7*(2), 130–148

FRIGO, L., & MACDONALD, J. (1998). Properties of phonological markers that affect the acquisition of gender-like subclasses. *Journal of Memory and Language, 39,* 218–245.

GERKEN, L., WILSON, R., GÓMEZ, R. L., & NURMSOO, E. (2009). The relation between linguistic analogies and lexical categories. In *Analogy in Grammar: Form and Acquisition*. Oxford University Press.

MINTZ, T. H. (2002). Category induction from distributional cues in an artificial language. *Memory & Cognition*, *30*(5), 678–686.

OUYANG, L., BORODITSKY, L., & FRANK, M. C. (2012). Semantic Coherence Facilitates Distributional Learning of Word Meanings. In *Proceedings of the 34th Annual Conference of the Cognitive Science Society.*

RAMSCAR, M., YARLETT, D., DYE, M., DENNY, K., & THORPE, K. (2010). The effects of feature-label-order and their implications for symbolic learning. *Cognitive Science*, *34*(6), 909–957. doi:10.1111/j.1551-6709.2009.01092.x