Rapid Learning of Morphological Paradigms

Sara Finley (sara.finley@waldorf.edu)
Department of Psychology, Waldorf College
Forest City, IA, 50436, USA

Elizabeth Wiemers (wiemerse@net.elmhurst.edu)
Department of Psychology, Elmhurst College
Elmhurst, IL, 60126, USA

Abstract

The present study presents a novel paradigm for testing the ability for adults to rapidly learn novel morphological categories in the wake of irrelevant information: specifically number markings intermixed with irrelevant gender cues. Using an artificial language learning paradigm, participants were exposed to picture-sound pairs in which pictures of animals varied by number (singular, dual and plural), but with irrelevant gender information intermixed with the exposure items (masculine, feminine and neuter). Auditory stimuli were presented in CVCVCV forms (e.g., [zovabu]) in which the first two syllables denoted the animal (e.g., [zova] for snail) and the final syllable denoted number. (e.g., [bu] for single). Results revealed that participants were able to learn which category the suffix endings referred to, based on a two-alternative forced-choice generalization task. Implications for the learning of complex paradigms are discussed.

Keywords: statistical learning, number, morphology.

Introduction

Languages are governed by complex sets of rules in which sentences are formed through a systematic combination of words. The rule-governed nature of sentences relies heavily on the use of morphological rules and syntactic categories. Words of the same syntactic categories (e.g., nouns and verbs) share similarities beyond meaning. For example, while verbs typically describe actions, in English verbs frequently follow a noun and precede a prepositional phrase (as in *The dog sat on the carpet*). In addition, syntactic categories share morphological properties, such as tense, gender and number. These morphological indicators are often present as prefixes or suffixes. The specific phonological form of these morphemes appears to be arbitrary in many languages, as in the use of /-s/ as plural in English. However, there is some evidence that languages with complex systems of gender and number morphology such as French, German, and Hebrew may show signs of systematicity within subcategories (Brooks, Braine, Catalano, and Brody, 1993). In this paper we explore how adults are able to learn complex systems of morphology, and whether learners are sensitive to differences in the arbitrariness of morphological patterns.

This study specifically looks at learning of morphologically complex words. Morphemes are parts of words that do not break down into smaller segments with meanings. For example, the word *flying* contains two morphemes: *fly* and *–ing*. Morphology plays an important role in language learning (as well as in learning linguistic categories) because morphology involves both the form of the morpheme (e.g., *-ing*) as well as its meaning (i.e., progressive). Because morphological forms are often bound – attached to the stems of each word in the category, learners must be able to recognize morphemes within complex words. In order to learn the morphology of one's language, the learner must be able to separate words in terms of their morphological parts. This ability is referred to as morpheme segmentation.

Because all morphemes involve form and meaning, there is a question as to when both aspects of the morpheme are learned. Given that infants are exposed to complex words in speech before they know the meaning of many words, it is likely that infants are able to segment morphological information without semantics. Studies have shown that by 15 months, infants can use distributional cues to learn non-adjacent dependencies, which are necessary for learning syntactic categories (Gomez & Maye, 2005), and by 18 months, can begin to acquire categories (Mintz, Newport, & Bever, 2002). Gomez and Gerken (2000) suggest that some learning of categories occurs at the very earliest stages of life. These studies suggest that morpheme segmentation can occur without knowledge of the specific meaning of the words. In addition, these results also suggest the possibility that early learners are equipped with biases to learn linguistic systems using distributional cues. Because languages tend to show broad similarities with respect to the nature of complex morphological rules, it is possible that languages evolved to accommodate biases within the learner.

The nature of learning biases in young infants raises the question as to why there are differences between child and adult language learners. Any theory of learning biases, innate or otherwise, must explain how biases change (and remain the same) over time, in order to explain why children and adults show differences in language learning strategies (Newport, 1990). One hypothesis is that adults have lost the abilities for acquisition that children have (MacWhinney, 1983), but in some cases of artificial language learning, adults outperform children. Specifically, Braine, Brody, and Brooks (1990) showed higher rates of learning for adults

compared to children when learning novel suffix endings. Another hypothesis suggests adults have learned new methods for acquisition that override the initial learning biases (McWhinney, 1983).

While there are clear differences between children and adults, there is evidence that adults still show biases towards certain morphemes. For example, several studies have shown that children learn suffixes more quickly than adults, and adults learn prefixes more quickly than children (Frigo & McDonald, 1998; MacWhinney, 1983), but research has also shown that adults can parse suffixes with no additional distributional cues (Finley, 2010). In addition, Finley and Newport (in prep) showed that adult learners are biased against typologically infrequent morphological patterns such as infixation. By studying when adults are able to learn patterns that deviate from their native language (and when they cannot), we can better understand the biases that exist for language learning, as well as to better understand how adults can better achieve native-like competence in learning a second language. If adults show biases for particular patterns that are common, but against patterns that are rare or unattested in natural language, it suggests that biases about language learning persist into adulthood that may help to shape how languages across the world are structured.

The present study focuses on how morphological patterns are learned when the pattern itself differs from the native language, and there is information in the input that is irrelevant to the morphological parsing. The question is whether adults can easily ignore the irrelevant parsing, and learn a morphological pattern that is similar to the native language (English) but differs in important respects. For example, number marking of nouns in English follows a singular-plural distinction in which singular nouns are unmarked, but plural nouns are marked with a suffix. There are also languages that have a three-way number marking system in which singular, dual and plural are marked each with a specific suffix, as in Slovene (Greenberg, 2006). This type of system poses a specific challenge for an adult learner because the participant may enter the experiment with the assumption that number marking works exactly like English, but will have to undo these assumptions in order to learn that all numbers are marked and that there is a distinction between 'two' and 'plural' that is not found in English.

Previous research has explored how adults and children learn novel category patterns. The bulk of these studies focused on the statistical properties of the items themselves, such as the frequency of presentation, the role of immediate feedback (Braine, et al., 1990), similarity of words belonging to each class (Brooks, Braine, Catalano, & Brody, 1993) and the density and overlap between subcategories (Reeder, Newport, & Aslin, 2013; Reeder, Newport, & Aslin, 2009, 2010). Finley and Newport (2010; 2011) focused on the statistical cues that allow for morpheme segmentation without semantic information. In addition, it has been shown that providing visual word cues can enhance speech segmentation of a novel language (Cunillera, Laine, Camara, & Rodriguez-Fornells, 2010).

The present paper extends previous research by focusing specifically on morphological paradigms that relate to a specific system of form-meaning combinations that can extend to novel words as in a *wug* test (Berko, 1958). While Finley and Newport (2010, 2011) focused on learning a novel language in which all words were systematically marked by a morpheme, the morphemes had no meaning associated with them, and so it was not clear how the morphemes worked together to form a morphological system, or paradigm. A morphological paradigm is a set of morphemes that marks specific classes (e.g., three suffixes, each marking a different number, /-bu/ 'singular', /-ke/ 'dual', /-mi/ 'plural'). In this study, we test the role of distributional information in learning novel morphological systems, thus extending Finley and Newport (2010, 2011) to include morphologically complex systems where both form and meaning are required to learn the language. In order to understand what aspects of the system participants learn, we measured generalization to novel items. This involved measuring responses to test items that appeared in the set of training words in addition to a new set of test words.

In addition, the present study explored whether learners can cope with irrelevant cues when learning a novel pattern. For example, when exposed to a novel label, the learner must weigh many possibilities, many of which are not part of the intention of the speaker (Medina, Snedecker, Trueswell, & Gleitman, 2011). The same is true in learning novel morphological patterns. If the word ending has a specific morphological meaning (e.g., /-ing/ in English /running/ as opposed to /-ing/ in /string/), the learner must discern whether (and when) this ending has semantic significance, and what (if any) that semantic significance is.

In the present study, participants were exposed to a novel language in which all words were nouns that marked number (singular, plural and dual). However, gender information was provided for the nouns, simulating the problem of ambiguity in learning novel instances in a controlled manner.

Methods

The present study used an artificial language that contained a large number of stem words and fewer suffixes, mirroring the fact that many natural languages have many more open class morphemes (stems) than closed class morphemes (affixes). Participants were exposed to a miniature language with nouns marked for number, in the form of picture-word pairings. Following exposure, participants were provided with a test in order to determine whether the participant was able to discriminate between the different suffixes and their appropriate meanings.

Participants

All thirteen participants were adult native English speakers recruited from Elmhurst College and the surrounding community. Each participant was given a $10

gift card for participating. Some participants may have previously participated in an artificial grammar learning experiment, however no participant had been exposed to the stimuli used during the present experiment.

Design

The experiment was designed to test the ability of adult learners to integrate learning form and meaning when the form is arbitrary. A miniature language was developed for the study that contained only words with stems and suffixes. Stems of the words were paired with a type of animal (e.g., /befa/ denotes a ladybug). Each suffix corresponded to the number of animals. The suffix /-bu/ denoted 'singular' (e.g., /befabu/ 'one ladybug'), the suffix /-ke/ denoted 'dual', (e.g., /befake/ 'two ladybugs'), and the suffix /-mi/ denoted 'plural' (e.g.. /befami/ 'more than two ladybugs').

Exposure to the language was created via picture-word pairings in which the sound of the word was paired with a picture of the appropriate number of animals. The gender of the animal varied randomly throughout, and served as irrelevant information. The gender of the animal was denoted using a bowtie for males, purses for females and no marking for unmarked gender. Examples of the picture-sound pairings can be found in Table 1.

Table 1: Examples of Picture-Naming Pairings.

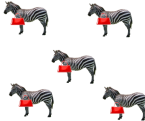| Sound	Picture
ganubu	
ganuke	
fegeke	
fegemi	

All stems were of the form CVCV and all suffixes were of the form CV (/-bu/, /-ke/ and /-mi/), where C is a consonant and V is a vowel. All words were therefore CVCVCV. Consonants were all from the set [b, d, g, k, m, n, p, s, t, v, z] and vowels were from the set [a, e, i, o, u]. No words overlapped with English words, and each consonant and vowel was presented equally often in each position.

Training consisted of 12 stems (each corresponding to a different animal), combined with two of the three suffixes, creating 24 total training items. Each stem and each suffix appeared with equal frequency across the 24 training items. Exposure consisted of repeating the 24 training items eight times. While each sound could be paired with three different pictures (e.g., if /ganubu/ signified a single giraffe, the appropriate picture would be for any gender: female, male and neuter), the same picture was used for each picture-word pairing for all eight cycles of the training stimuli. The irrelevant information (e.g., gender markings on the training pictures) was distributed throughout the training items.

Participants were tested on their knowledge of the language as well as their ability to generalize the suffix information to novel stem forms using a two-alternative forced-choice test. In the test, participants matched two spoken words to a single picture. Participants were told one of the words would be from the language they had been listening to and the other word would not be from the language. Participants chose which of two words correctly corresponded to the picture shown. There were twelve items in three different test conditions, described in more detail below, with examples in Tables 2-4.

Familiar Stem-Familiar Picture The first type of test item specifically tested the learner's ability to match a picture seen in training to its corresponding word. Participants heard two words with the same bi-syllabic stem. One word was heard during training, and the other word was a word not heard in training but contained the same stem as the 'correct' test item. If the participant was able to match the picture to the correct suffix, it demonstrates that the participant had learned the suffix-picture pairings. Because the two options contained the same stems, the options were highly similar, and could thus not rely on the stem to make the correct response.

Table 2: Familiar Stem-Familiar Picture Test Items

Correct Item	Decoy Item	Picture
befabu	befake	
sufemi	sufebu	
ganuke	ganumi	

Familiar Stem-Novel Picture The second type of test item probed the learner's ability to generalize the suffixes to the items that were not heard in training. For every stem, there were three possible suffix pairings, but only two were heard

in training. In this test condition, the picture shown corresponded to the stem+suffix pairing that was not heard in training, and the decoy item was a stem+suffix item that was heard during training. Both options had the same stem, meaning that participants had to rely on the suffix to choose the correct response. Because the decoy item was familiar to the participant, if participants chose the item that was most familiar, they would be incorrect. Examples of these test items can be found in Table 3, below.

Table 3: Familiar Stem-Novel Picture Test Items

Correct Item	Decoy Item	Picture
befake	befami	
sufebu	sufemi	
ganumi	ganubu	

Novel Word-Novel Picture The third type of test item probed the learner's ability to generalize to novel stem items. This served as a comprehension version of a *wug* test. Participants heard two stem+suffix combinations, in which the stems were identical in both conditions. The picture shown corresponded to one of the suffixes. Participants could only rely on knowledge of the suffix to get these items correct, as the participants had not seen these stem items in training.

Table 4: Novel Word-Novel Picture Test Items

| Correct Item	Decoy Item	Picture
pumubu	pumumi	
pazimi	pazike	
koveke	kovebu	

There were 12 tokens of each of the three test sets of test items. These items were presented in a random, mixed fashion. The 12 items in each test condition were balanced such that the correct response was singular, plural and dual an equal number of times (four). The items were also balanced such that all possible suffix combinations were heard an equal number of times (e.g., in a test trial where /bede**mi**/ is pit against /bede**ke**/, the two suffix options are /ke/ and /mi/. This suffix combination occurred equally often as /ke/ vs. /bu/ and /mi/ vs. /bu/).

All stimuli were recorded by an adult female native speaker of English in a sound attenuated booth at 12,000 Hz (though participants were allowed to adjust headphones to a comfortable volume during the experiment). Stress was placed on the first syllable using standard English pronunciation, with the exception that no vowels were reduced, meaning all syllables contained partial stress (as English reduces unstressed syllables). All stimuli items were normalized for intensity (set at 70dB) using Praat (Boersma & Weenink, 2005). All phases of the experiment were run in Psyscope X (Cohen, MacWhinney, Flatt, & Provost, 1993). Participants were given both written and verbal instructions. The entire experiment took approximately 20 minutes.
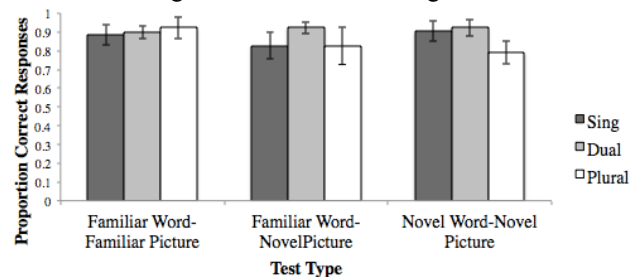
Results

Proportion of correct responses for all three test items are given in Figure 1. We compared each test item to 50% chance via three separate one-sample t-tests. All three test items were significantly above chance; the Familiar Stem-Familiar Picture test items had a mean of 0.88, $t(12)=7.91$, $p<0.001$, the Familiar Stem-Novel Picture test items had a mean of 0.85, $t(12)=75.69$, $p<0.001$ and the Novel Word-Novel Picture test items had a mean of 0.88, $t(12)=7.37$, $p<0.001$, suggesting that the participants learned the suffixation pattern.

Figure 1: Test Item Results.
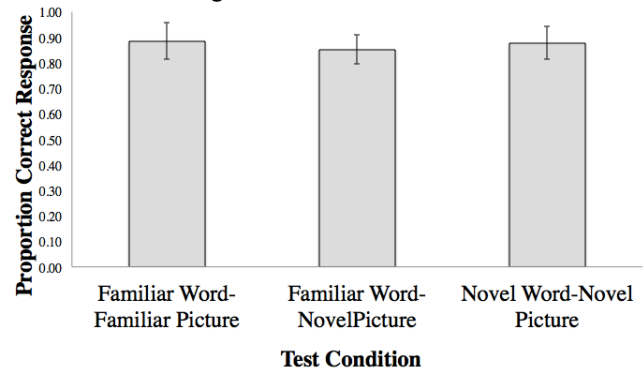
Because the novel language contained contrasts and markings for number (singular-dual-plural) that are not found in English, we divided responses by number marking, to ensure that all three number markings were learned by participants. These are presented in Figure 2.

Figure 2: Number-Marking Results.

445

We compared the results via a 3x3 within-subjects ANOVA. There were no main effects for Test Type, ($F(2, 24)$= 1.29, p = 0.29), Number Type ($F(2, 24)$= 1.79, p = 0.19), and no Interaction ($F(4, 48)$= 1.71, p = 0.16). This suggests that all three number markings were learned equally well.

We hypothesized that the difference between dual and plural may be the most difficult to learn because dual and plural are not distinguished in English. We therefore performed planned comparisons between dual and plural test items. There were no differences between dual and plural test items for either the Familiar Word-Familiar Picture, $t(12)$=0.32, p=0.75, or the Familiar Word-Novel Picture, $t(12)$=1.10, p=0.29 test items. There was a significant difference between the dual and the plural test items for the Novel Word-Novel Picture test items, $t(12)$=2.50, p=0.028. This suggests that if there is a difference in the difficulty of learning novel number markings, that this is most likely to appear during generalization to novel stems.

The learning rates were relatively robust across participants. Of the 13 participants, only two had overall means less than 80% (50% and 41.67% respectively). For these two participants, the difference in number was most pronounced. These participants were most accurate on dual test items (70.83% correct), around chance for singular items (45.83% correct) and below chance for plural items (20.83% correct). Because so few participants scored below 80% correct, no inferential statistics can be made. However, these results may indicate that those who have difficulty learning novel morphological systems may only have trouble with specific number markers.

Discussion

The results of the present study provide important insights into how novel complex morphological systems are learned. First, consistent endings along with consistent number cues allowed the vast majority of participants to infer that the final suffix referred to number, and that this final suffix applied to novel items, both for stems heard during exposure, as well as novel items not heard during exposure. Second, this ability is very robust in adults. Of the thirteen participants, only two showed means below 80% suggesting that these relatively complex patterns are learned with ease, without any feedback from the learning paradigm. Third, the number markings in the present experiment differed from those found in English: all different numbers were marked (as opposed to only plural in English), and a distinction was created between dual and plural (as opposed to only plural in English).

The stimuli in the present experiment included irrelevant cues to gender, which the participants were able to rule out. Because both gender and number cues were provided, the paradigm allows for future research to study both gender and number markings simultaneously. It also demonstrates that learners are able to cue into the relevant aspects of novel data, and ignore irrelevant aspects.

The results showed relatively few differences between test items that probed for knowledge of the different number markings, despite the fact that the dual number marking was novel to the English speakers. This suggests that learners are adaptable to novel number markings. Interestingly, the two participants who showed poor performance overall, seemed to show differential responses to different number categories, suggesting that problems in learning novel morphology may be specific to a specific morpheme, rather than the entire morphological paradigm. Because these trends can only be made for two participants, more research is needed to understand why some learners have difficulty learning novel morphological structures, while others have little difficulty.

The present study presented a novel paradigm for exploring how adults are able to learn novel morphological systems. The results demonstrated that adults are able to rapidly and robustly learn novel number marking systems despite irrelevant gender cues. The present paradigm provides a tool for future research to explore how complex systems of form and meaning are learned and generalized to novel items. The present paradigm allows the experimenter to control for how much information is relevant to the morphological system and how much is irrelevant.

The paradigm specifically allows the researcher to explore novel questions about how complex morphological systems are learned. In many languages, the same phonological unit is used to mark multiple morphemes. For example, /-s/ is used in English to mark both plural as well as third person singular, present tense verbs. In German, /der/ is used to mark nominative singular case, as well as plural genitive case. In these instances, the learner must sort out when each morpheme is used. The present paradigm may help to sort out what aspects of the morphological paradigm are most helpful to learning a complex paradigm. Future research will explore how phonological regularities and semantic consistency contribute to learning a novel morphological paradigm.

The present study makes use of adult participants. While studying children is often ideal when examining language learning, adult studies are also extremely useful in terms of understanding how learning biases persist into adulthood. The present paradigm is well suited to adapt to child language studies, allowing future research to easily make adult-children comparisons in learning. However, there are many reasons that using adults in the present study has theoretical importance. Throughout life, novel stimuli are presented in a language no matter how long ago the language was learned. New words come into the language (e.g., as each new generation adds to the list of slang words). Adult studies increase the knowledge about continuing language learning in the first language and learning in general. In addition, studying adults in a second language environment will help to understand the biases that adults use in second language learning, which may provide insight into making adult second language learning easier. In addition, studies of adult second language learning often

reveal deficiencies in learning the morphology of the language (Johnson & Newport, 1989; Newport, 1990). Thus, understanding adult learning biases for morphological learning may have direct implications for understanding these deficits (and possibly finding methods to correct them).

The present study adds to the growing number of studies that demonstrate that learners are able to make use distributional cues to learn the regular (rule-based) aspects of language. When forms (e.g., suffixes) are paired consistently with a meaning, the learner infers a general rule that can apply to items that have never been seen or heard before. This is done despite additional, irrelevant cues that could potentially disrupt the learning mechanism. The fact that learners are able to sort out which cues are relevant without any direct feedback, demonstrates the enormous inferential power of the human mind.

Acknowledgments

References

Berko, J. (1958). The child's learning of English morphology. *Word, 15*, 150-177.

Boersma, P., & Weenink. (2005). Praat: Doing phonetics by computer.

Braine, M. D. S., Brody, R. E., Brooks, P. J., Sudhalter, V., Ross, J. A., Catalano, L., et al. (1990). Exploring language acquisition in children with a miniature artificial language: Effects of item and pattern frequency, arbitrary subclasses, and correction. *Journal of Memory and Language, 29*, 591-610.

Brooks, P. J., Braine, M. D. S., Catalano, L., & Brody, R. E. (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.

Cohen, J. D., MacWhinney, B., Flatt, M., & Provost, J. (1993). PsyScope: A new graphic interactive environment for designing psychology experiments. *Behavioral Research Methods, Instruments and Computers, 25*, 257-271.

Cunillera, T., Laine, M., Camara, E., & Rodriguez-Fornells, A. (2010). Bridging the gap between speech segmentation and word-to-world mapping: Evidence from an audiovisual statistical learning task. *Journal of Memory and Language, 63*, 295-305.

Finley, S., & Newport, E. (2010). Morpheme segmentation from distributional information. In J. Chandleee, K. Franich, K. Iserman & K. L. (Eds.), *BUCLD 34 Proceedings Supplement, online*. Boston: BUCLD.

Finley, S., & Newport, E. (in prep). Morpheme segmentation in artificial grammar learning.

Finley, S., & Newport, E. N. (2011). Morpheme segmentation in school-aged children. In A. Fine (Ed.), *Rochester working papers in the language sciences*. Cambridge, MA: MIT Press.

Frigo, L., & McDonald, J. L. (1998). Properties of phonological markers that affect the acquisition of gender-like subclasss. *Journal of Memory and Language, 39*, 218-245.

Gomez, R. L., & Gerken, L. (2000). Infant artificial language learning and language acquisition. *Trends in Cognitive Science, 4*(5), 178-186.

Gomez, R. L., & Maye, J. (2005). The developmental trajectory of nonadjacent dependency learning. *Infancy, 7*(2), 183-206.

Greenberg, M. (2006). A short reference grammar of standard Slovene. from http://www.theslovenian.com/articles/2008/greenberg.pdf

Johnson, J. S., & Newport, E. (1989). Critical period effects in second language learning: The influence of maturational state on the acquisition of English as a second language. *Cognitive Psychology, 21*, 60-99.

MacWhinney, B. (1983). Miniature Linguistic Systems as Tests of the Use of Universal Operating Principles in Second-Language Learning by Children and Adults. *Journal of Psycholinguistic Research, 12*(5), 467-478.

Medina, T. N., Snedecker, J., Trueswell, J. C., & Gleitman, L. R. (2011). How words can and cannot be learned by observation. *Proceedings of the National Academy of Sciences, 108*(2), 9014-9019.

Mintz, T., Newport, E., & Bever, T. G. (2002). The distributional structure of grammatical categories in speech to young children. *Cognitive Science, 26*, 393-424.

Newport, E. (1990). Maturational constraints on language learning. *Cognitive Science, 14*, 11-28.

Reeder, P., Newport, E., & Aslin, R. (2013). From shared context to syntactic categories: The role of distributional information in learning linguistic form-classes. *Cognitive Psychology, 66*, 30-54.

Reeder, P., Newport, E., & Aslin, R. N. (2009). The role of distributional information in linguistic category formation. In S. Ohlsson & R. Catrambone (Eds.), *Proceedings of the 32nd Annual Conference of the Cognitive Science Society* (Vol. 32, pp. 2063-2068). Austin, TX: Cognitive Science Society.

Reeder, P., Newport, E., & Aslin, R. N. (2010). Novel words in novel contexts: The role of distributional information in form-class category learning. In S. Ohlsson & R. Catrambone (Eds.), *Proceedings of the 32nd Annual Conference of the Cognitive Science Society*. Austin, TX: Cognitive Science Society.