Spring 2010

Phonological word-form learning

Stephanie Leona Packard
University of Iowa

PHONOLOGICAL WORD-FORM LEARNING

by

Stephanie Leona Packard

A thesis submitted in partial fulfillment
of the requirements for the Master of
Arts degree in Psychology
in the Graduate College of
The University of Iowa

May 2010

Thesis Supervisor: Associate Professor Prahlad Gupta

Graduate College
The University of Iowa
Iowa City, Iowa

CERTIFICATE OF APPROVAL

MASTER'S THESIS

This is to certify that the Master's thesis of

Stephanie Leona Packard

has been approved by the Examining Committee
for the thesis requirement for the Master of Arts
degree in Psychology at the May 2010 graduation.

Thesis Committee: ___________________________________
Prahlad Gupta, Thesis Supervisor

____
Bob McMurray

____
Larissa Samuelson

To Dad

ACKNOWLEDGMENTS

I would like to extend a special thank you Jessi Hattori for recording the disyllabic and Jamie Tisdale for recording the monosyllabic nonword corpora used as stimuli in these experiments. I would also like to thank the many members of the Language and Memory Lab who assisted in data collection and scoring.

ABSTRACT

Seven experiments examined phonological word-form learning (i.e., the learning of novel wordlike sound patterns) after differing types of training. In each case, learning at the end of training was assessed via stem completion ability. Experiment 1 presented participants with eleven epochs of listening and repeating (incidental phonological learning) and found significant stem completion ability. The results of Experiment 2 showed greater stem completion ability after eleven epochs of listening and repeating along with repeated stem completion testing (deliberate phonological learning). Experiment 3 replicated results from Experiments 1 and 2 in a within-subject design and demonstrated that deliberate phonological learning is item-specific and not merely the result of generalized task facilitation. Experiment 4 measured stem completion ability after one hundred epochs of incidental phonological learning and found that it remained lower than after only eleven blocks of deliberate phonological learning in Experiments 2 and 3. Experiments 5, 6, and 7 utilized monosyllabic nonword stimuli, in contrast to the disyllabic nonword stimuli utilized in the first four experiments, and replicated the overall results from Experiments 1, 2, and 3, respectively. Taken together, these results suggest that incidental phonological learning does not yield full mastery of phonological word-forms.

TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

The ability to use language is widely regarded as the most uniquely defining aspect of human cognition. However, the development of language usage is critically dependent on the ability to learn new words. Every word we currently know was at one time unfamiliar or novel to us, and hence like a *nonword* – a possibly, but non-occurring word-like sound pattern, or *word-form*, of the language (Gathercole, 2006). This link provides motivation for studying nonword processing and learning as an entry point into studying our ability as humans to learn words.

In the process of learning a new word, the language system must form an internal representation of the sequence of sounds that comprise the word (its *phonology*), an internal representation of the meaning (its *semantics*), and a link between the two representations (e.g., Saussure, 1916; Desrochers and Begg, 1987). It is important to note here that a phonological word-form representation can exist independent of semantic information just as a semantic representation can exist independent of phonological information. However, a link between the two representations allows one to activate the other. The ability for information to flow from the phonological word-form representation to the semantic representation is termed receptive. In contrast, the ability for information to flow from the semantic representation to the phonological word-form representation is termed expressive. These two directions of information flow are doubly dissociable, such that exposure to phonological knowledge facilitates expressive learning, but not receptive learning, and exposure to semantic knowledge facilitates receptive learning, but not expressive learning (Gupta, 2005).

Creating the phonological word-form representation constitutes *phonological learning*. There are a number of ways in which one can assess phonological learning in an experimental task. One way is to use a receptive recognition task in which participants learn nonword-picture pairs and subsequently are tested on their ability to choose the appropriate picture that was previously paired with a given nonword. Another way to assess phonological learning experimentally is to use an expressive recall task in which participants learn nonword-picture pairs and subsequently are tested on their ability to produce the appropriate nonword that was previously paired with a given picture. However, neither of these tasks is a purely phonological learning assessment in that both require learning the word-form as well as the picture and the link between the two (at least to some extent).

Fortunately, phonological learning can be independent of any semantic information, as various researchers have discussed (Abbs, Gupta, and Khetarpal, 2008; Dell, et al., 2000; Gupta and Cohen, 2002; and Gupta and Dell, 1999). Again, there are a number of ways in which on can train and assess phonological learning in an experimental task. One such training task that has been extensively used is phoneme monitoring (Davis, et al., 2009; Gaskell and Dumay, 2003; Leach and Samuel, 2007; Lindsey and Gaskell, 2009; and Tamminen and Gaskell, 2008), during which participants indicate whether a target phoneme is present or absent in each nonword they hear. A second training task is to merely have participants listen and immediately repeat each nonword they hear (Abbs, Gupta, and Khetarpal, 2008; Gathercole, 2006; Gupta and Cohen, 2002; Gupta and Dell, 1999; and Tamminen and Gaskell, 2008).

In addition, there are a number of ways in which researchers have assessed phonological learning after training. For example, two-alternative forced choice recognition memory tests have been used to show that after training participants are accurate at remembering which nonwords they were previously exposed to (Davis, et al., 2009; Gaskell and Dumay, 2003; Lindsey and Gaskell, 2009; and Tamminen and Gaskell, 2008). A second popular assessment is repetition latency, which is a measure of the duration of time it takes the participant to immediately repeat the nonword they just heard. As a stimulus is learned, not only does immediate repetition accuracy improve, but repetition latency decreases (Davis, et al., 2009; Gupta & Cohen, 2002; and Gupta &

Dell, 1999). The third assessment that is widely used is lexical competition (Davis, et al., 2009; Gaskell and Dumay, 2003; Lindsey and Gaskell, 2009; and Tamminen and Gaskell, 2008). In this case, each trained nonword is phonologically similar to a known, real word (e.g., *cathedruke* and *cathedral*). Evidence of lexical competition is in the form of slowed lexical decision latencies to the pre-existing words compared to a baseline.

Despite the substantive research utilizing these methodologies, both of the training tasks are by design limited to incidental learning (i.e., learning from mere exposure) and all of the assessments are weak or indirect tests of phonological learning. First, research has shown that the effortful retrieval involved in testing enhances memory (Carrier and Pashler, 1992; and Karpicke and Rodiger, 2008). Thus, a training task that includes repeated testing of some sort would most likely lead to better phonological learning than mere exposure. Second, it is not particularly clear how well the nonwords have been learned in order to support performance in the assessments utilized in previous research. In other words, how robust does the newly formed phonological word-form need to be to support recognition, faster processing, or lexical competition?

The current research takes the first step toward answering this question by comparing phonological learning resulting from incidental learning to that from deliberate learning. It is important to clarify here that incidental learning and deliberate learning are not necessarily two opposing entities, but can be though of along a single continuum of factors that make learning more or less deliberate. In order to compare phonological learning across the two types of training fairly, the same assessment will be used to measure learning achieved by the end of each training task.

Stem completion ability is the measure of phonological learning utilized in the current research for a number of reasons. First, it is well established that when given the beginning of a real word (i.e., a stem), language users can retrieve the entire word from long-term memory to complete the stem. Second, stem completion ability is a direct measure of expressive, rather than receptive, phonological learning. Third, it is a purely phonological measure (i.e., it does not require the learning of addition semantic information). Lastly, it does not limit nonword stimuli to those that are phonological neighbors of known, real words.

The goal of this research project is to investigate phonological word-form learning, independent of semantics, after differing types of training. Experiment 1 examines incidental phonological learning, while Experiment 2 examines deliberate phonological learning. Experiment 3 examines both incidental and deliberate phonological learning in a within-subject design in addition to investigating whether deliberate phonological learning is item-specific and not merely the result of generalized task facilitation. Experiment 4 examines extensive incidental phonological learning. Experiments 5, 6, and 7 are direct replications of Experiments 1, 2, and 3, respectively, utilizing nonwords of a different syllable length.

LEARNING DISYLLABIC NONWORDS

Experiment 1

The purpose of this experiment is to establish whether incidental phonological learning supports stem completion ability. Incidental phonological learning is operationalized as “listen and repeat” in the experimental task. Phonological learning is assessed with respect to stem completion accuracy at the end of the task. Thus, assessment is of the learning achieved by the end of the task (i.e., after multiple exposures) and not the process of learning over time (i.e., across multiple exposures).

Method

Participants

Twelve members of the University of Iowa community received credit toward their Elementary Psychology course for their participation. All were native speakers of English and reported having normal hearing and normal or corrected-to-normal vision.

Experimental Task

The experimental task consisted of eleven epochs. The first ten epochs were comprised of an exposure phase, while the final epoch was comprised of an exposure phase followed by a test phase. During the exposure phases, the participant’s task was to listen and then repeat each nonword aloud immediately after its presentation (*immediate repetition*). During the test phase, the participant’s task was to say the entire nonword aloud when given only the beginning of the nonword (*stem completion*). Thus, immediate repetition accuracy was assessed across epochs, while stem completion accuracy was assessed only in the final epoch. In addition, all stimuli occurred in each of the eleven epochs (*repeating items*).

Stimuli

Auditory stimuli were disyllabic nonwords recorded by a female native speaker of American English. Possible phonemes were restricted to those used in the American English language and the combination of phonemes into syllables and syllables into word-forms were limited to those that are legal in the language. Thus, all nonwords were possible, but non-occurring word-forms. In addition, the vast majority of the nonwords consisted of a CV CVC syllable structure. The only deviation from this syllable structure came in the form of r-colored vowels, resulting in some nonwords with a CVC CVC syllable structure.

The resulting corpus of 200 nonwords was recorded and processed – 8 of which were designated to be practice items and 16 of which were designated to be target or repeating items for all subsequent experiments. A cue for the stem completion test was also recorded and processed for each nonword. The cue consisted of the first syllable of the nonword. For instance, if the nonword was /t∧ dok/, the stem completion cue would be /t∧/.

All stimuli were recorded within a carrier sentence to control for some of the variations in natural speech. Multiple instances of each stimulus were recorded and the clearest exemplar was chosen for processing. Once a selected stimulus was spliced out of the carrier sentence, the average intensity was scaled to 65dB.

Stimuli Lists

Stimuli lists for each of the eleven exposure phases and the single test phase were generated by randomly ordering the sixteen repeating nonwords and stem completion cues, respectively. This randomization procedure was done twice, resulting in two versions of the task that differed only in the order in which the stimuli were presented.

<u>Procedure</u>

Participants were seated a comfortable distance from a computer monitor with the keyboard and mouse off to the side for the experimenter to use. Auditory stimuli were presented over headphones and participants' responses were digitally recorded via a desktop microphone.

Throughout the experiment, the appearance of a central cross on the computer screen was used to cue the participant for their response. The cross appeared immediately after the offset of each nonword in the exposure phases and each stem completion cue in the test phases. During exposure phases, participants were given approximately 2500ms for immediate repetition before the next nonword was presented. During test phases, participants were given unlimited time to make their response. This was implemented with a key press or mouse click by the experimenter to end a given test trial. Participants were verbally encouraged by the experimenter to make their best guess on any item for which their response was initially "I don't know."

Participants were instructed at the beginning of the experiment that they will hear a number of nonwords one at a time through the headphones and each time the cross appears on the computer screen, their task is to repeat the nonword aloud as quickly and accurately as possible. The experimenter provided clarification as needed. In addition, participants completed one epoch comprised of eight practice trials (exposure phase only, no test phase) for familiarization with the task and were provided with a second opportunity to ask any questions. At the beginning of each exposure phase, the following instructions were displayed as a reminder: "please repeat these nonwords as quickly and as accurately as you can".

Directly preceding the stem completion test at the end of the task, participants were instructed that they will hear the first part of one of the nonwords they just repeated and their task is to say the entire nonword aloud. In addition, participants were provided with an example of a stem completion cue and appropriate response. Again, the experimenter provided clarification as needed. At the beginning of the test phase, the following instructions were displayed as a reminder: “now you will be tested on these nonwords”. Furthermore, each stem completion test trial began with the following prompt: “please say the nonword that begins with…”.

Scoring

Accuracy in immediate repetition and stem completion was scored by three procedures. For all scoring procedures, any trial on which the participant self-corrected, only the participants’ final response was scored. In the first scoring procedure, the experimenter scored each item as correct or incorrect during the experimental session (*online scoring*). Online scoring was binary, such that for an item to be scored as correct it must contain all of the correct phonemes in the correct sequence, and thus represents holistic accuracy. Since experimenters can differ in their threshold for considering an item holistically correct and scoring items during the experimental session is constrained (e.g., items must be scored immediately and cannot be replayed), experimental sessions were digitally recorded to enable more rigorous scoring at the level of individual phonemes. In the second scoring procedure, each item was transcribed from the digital recording and subsequently each phoneme was scored as correct or incorrect (*phoneme scoring*). Phoneme scoring was binary at the level of individual phonemes, but represents the proportion of correct phonemes in the correct sequence at the level of item (i.e., nonword). The third scoring procedure utilized the transcriptions of each item, but was binary, such that for an item to be scored as correct it must contain all of the correct phonemes in the correct sequence, and thus represents holistic accuracy (*holistic scoring*).

Results

Immediate Repetition Accuracy

Online scoring immediate repetition accuracy across epochs was assessed with a one-way repeated measures ANOVA, which revealed a significant effect of epoch ($F(10, 110) = 2.0755$, $p < .05$). Across participants, average online scoring immediate repetition accuracy was above 90% correct for each epoch, ranging from approximately 90% correct to approximately 93% correct, with the exception of the first epoch ($M \approx 86.97\%$). Furthermore, Tukey post-hoc tests revealed a significant difference only between the first epoch and the second epoch ($p < .05$) and the first epoch and the nineth epoch ($p < .05$).

Phoneme scoring immediate repetition accuracy across epochs was also assessed with a one-way repeated measures ANOVA, which revealed a significant effect of epoch ($F(10, 110) = 1.9182$, $p < .05$). Across participants, average phoneme scoring immediate repetition accuracy was above 90% correct for each epoch, ranging from approximately 90% correct to approximately 92% correct. Furthermore, Tukey post-hoc tests revealed no significant differences between epochs ($p > .05$ for each).

Holistic scoring immediate repetition accuracy across epochs was assessed with a one-way repeated measures ANOVA, which revealed no significant effect ($p > .05$). Across participants, average holistic scoring immediate repetition accuracy for each epoch ranged from approximately 77% correct to approximately 84% correct.

Stem Completion Accuracy

Online scoring stem completion accuracy in the eleventh epoch (Figure 1) was assessed with a one sample t-test, which revealed a significant difference from zero ($t(11) = 3.0225$, $p < .05$). However, across participants, average online scoring stem completion accuracy in the eleventh epoch was only approximately 7% correct.

Phoneme scoring stem completion accuracy in the eleventh epoch (Figure 2) was assessed with a one sample t-test, which revealed no significant difference from fifty percent ($p > .05$). Furthermore, across participants, average phoneme scoring stem completion accuracy in the eleventh epoch was only approximately 54% correct.

Holistic scoring stem completion accuracy in the eleventh epoch (Figure 3) was assessed with a one sample t-test, which revealed a significant difference from zero ($t(11) = 3.0844$, $p < .05$). However, across participants, average online scoring stem completion accuracy in the eleventh epoch was only approximately 8% correct.

Discussion

The goal of this experiment is to establish whether incidental phonological learning supports stem completion ability and results indicate that it does. Phoneme scoring results in the final epoch indicate that when participants were given the stem, they were able to produce the entire nonword with some accuracy, on average correctly producing 3 of the phonemes. However, this is approximately equivalent to correctly reproducing only the stem for each nonword. Furthermore, holistic and online scoring results in the final epoch indicate that when given the stem, participants were able to produce only a few of the nonwords without any errors, on average only 1-2 of the 16 nonwords.

In addition, immediate repetition accuracy across epochs was relatively high, which is to be expected given that the task and stimuli are not particularly difficult. Phoneme scoring results indicate that participants were able to reproduce stimuli with a high degree of accuracy, on average erring on only 0-1 phoneme in a given nonword. Holistic scoring results indicate that participants were able to reproduce the majority of stimuli without any errors, on average erring on only 3-4 of the 16 nonwords. Online scoring results indicate an even lower error rate, approximately 1-2 of the nonwords. This discrepancy is likely due to slight differences in each experimenter’s threshold for considering an item holistically correct and the fact that scoring items during the experimental session is constrained (e.g., items must be scored immediately and cannot be replayed).

Experiment 2

The purpose of this experiment is to establish whether deliberate phonological learning supports stem completion ability and whether it leads to greater stem completion ability than incidental phonological learning. Deliberate phonological learning is operationalized as a combination of "listen and repeat" and repeatedly testing stem completion ability in the experimental task. In this case, phonological learning is assessed with respect to stem completion accuracy throughout the task. Thus, assessment is both of the learning achieved by the end of the task (i.e., after multiple exposures) and the process of learning over time (i.e., across multiple exposures).

Method

Participants

Twelve members of the University of Iowa community received credit toward their Elementary Psychology course for their participation. All were native speakers of English and reported having normal hearing and normal or corrected-to-normal vision.

Experimental Task

As in Experiment 1, the experimental task consisted of eleven epochs; however, in the current experiment each epoch was comprised of an exposure phase followed by a test phase. Thus, both immediate repetition accuracy and stem completion accuracy were assessed across epochs. As in Experiment 1, all stimuli were repeating items that occurred in each of the eleven epochs.

Stimuli

The auditory stimuli were identical to those utilized in Experiment 1. More specifically, the same exact practice items and repeating items were utilized.

Stimuli Lists

Stimuli lists for all of the exposure phases and the test phase in the eleventh epoch were identical to those in Experiment 1. More specifically, the order in which the stimuli were presented was exactly the same for both of the two versions. Stimuli lists for the test phases in the first ten epochs were generated by randomly ordering the stem completion cues. This randomization procedure was done once for each of the two versions.

Procedure

The procedure was identical to that of Experiment 1 with the following few exceptions. First, participants received all instructions at the beginning of the experiment, including that presentation and testing procedures will repeat. Second, the practice epoch was comprised of an exposure phase followed by a test phase. Third, to account for the time-delay in Experiment 1 during which participants read the instructions for the stem completion test, participants were instructed to read a short passage about Herman Ebbinghaus and answer a question about its content.

Scoring

The scoring procedures were identical to those of Experiment 1. In short, online scoring represents holistic accuracy scored during the experimental session, phoneme scoring represents the proportion of correct phonemes in the correct sequence, and holistic scoring represents holistic accuracy based on the transcriptions of individual phonemes.

Results

Immediate Repetition Accuracy

Online scoring immediate repetition accuracy across epochs was assessed with a one-way repeated measures ANOVA, which revealed no significant effect ($p > .05$). Across participants, average online scoring immediate repetition accuracy was above 90% correct for each epoch, ranging from approximately 90% correct to approximately 95% correct.

Phoneme scoring immediate repetition accuracy across epochs was also assessed with a one-way repeated measures ANOVA, which revealed no significant effect ($p > .05$). Across participants, average phoneme scoring immediate repetition accuracy was above 95% correct for each epoch, ranging from approximately 97% correct to approximately 99% correct.

Holistic scoring immediate repetition accuracy across epochs was assessed with a one-way repeated measures ANOVA, which revealed no significant effect ($p > .05$). Across participants, average holistic scoring immediate repetition accuracy was above 90% correct for each epoch, ranging from approximately 92% correct to approximately 96% correct.

Stem Completion Accuracy

Online scoring stem completion accuracy across epochs (Figure 4) was assessed with a one-way repeated measures ANOVA, which revealed a significant effect ($F(10, 110) = 12.324$, $p < .05$). Across participants, average online scoring stem completion accuracy increased from approximately 3% correct in the first epoch to approximately 28% correct in the eleventh epoch.

Phoneme scoring stem completion accuracy across epochs (Figure 5) was assessed with a one-way repeated measures ANOVA, which revealed a significant effect ($F(10, 110) = 15.419$, $p < .05$). Across participants, average phoneme scoring stem completion accuracy increased from approximately 51% correct in the first epoch to approximately 67% correct in the eleventh epoch.

Holistic scoring stem completion accuracy across epochs (Figure 6) was assessed with a one-way repeated measures ANOVA, which revealed a significant effect ($F(10, 110) = 11.974$, $p < .05$). Across participants, average holistic scoring stem completion accuracy increased from approximately 3% correct in the first epoch to approximately 28% correct in the eleventh epoch.

Discussion

The goal of this experiment is to establish whether deliberate phonological learning supports stem completion ability and whether it leads to greater stem completion ability than incidental phonological learning, and results indicate that it does. Phoneme scoring results indicate that when participants were given the stem, they were able to produce the entire nonword with some accuracy, on average correctly producing 3 of the phonemes in the first epoch and 4 of the phonemes in the final epcoh. However, this is only slightly better than correctly reproducing only the stem for each nonword. Perhaps more informative, holistic and online scoring results indicate that when given the stem, participants were able to produce very few, if any, of the nonwords without any errors in the first epoch, on average only 0-1 of the 16 nonwords; however, they were able to produce on average 4-5 of the 16 nonwords without any errors in the final epoch.

In addition, immediate repetition accuracy across epochs was relatively high, which is to be expected given that the task and stimuli are not particularly difficult. Phoneme scoring results indicate that participants were able to reproduce stimuli with a high degree of accuracy, on average erring on only 0-1 phoneme in a given nonword. Holistic and online scoring results indicate that participants were able to reproduce the majority of stimuli without any errors, on average erring on only 1-2 of the 16 nonwords.

Experiment 3

The purpose of this experiment is two-fold: 1) to establish that deliberate phonological learning leads to greater stem completion ability than incidental phonological learning in a within subjects design, and 2) to establish whether such phonological learning is item-specific or reflects task facilitation of general stem completion ability. As in Experiment 1, incidental phonological learning is operationalized as "listen and repeat" in the experimental task and phonological learning is assessed with respect to stem completion ability at the end of the task. As in Experiment 2, deliberate phonological learning is operationalized as a combination of "listen and repeat" and repeatedly testing stem completion ability in the experimental task and phonological learning is assessed with respect to stem completion accuracy throughout the task.

Method

Participants

Twelve members of the University of Iowa community received credit toward their Elementary Psychology course for their participation. All were native speakers of English and reported having normal hearing and normal or corrected-to-normal vision.

Experimental Task

As in Experiment 2, the experimental task consisted of eleven epochs, which were each comprised of an exposure phase followed by a test phase. However, whether stimuli occurred in each epoch was crossed with whether stimuli were cued and subsequently tested, resulting in four stimuli conditions: (1) *repeating cued*, (2) *repeating uncued*, (3) *unique cued*, and (4) *unique uncued*. More specifically, stimuli in the repeating conditions were items that occurred in the exposure phase of every epoch (a total of eleven times across the entire experiment); whereas, stimuli in the unique conditions were items that occurred in the exposure phase of exactly one epoch (a total of one time across the entire experiment). Stimuli in the cued (and subsequently tested) conditions were items that were tested in the same epoch in which they were included in the exposure phase; whereas, stimuli in the uncued (and subsequently not tested) conditions were items that were never tested. In the test phase of the final epoch, all stimuli were tested, regardless of stimuli condition.

Stimuli

The auditory stimuli were identical to those utilized in Experiments 1 and 2 with a single exception. The same exact practice items and repeating items were utilized; however, the previously unutilized 176 nonwords in the corpus were designated to be unique items.

Stimuli Lists

Prior to creating stimuli lists, half of the sixteen repeating items were randomly assigned to the repeating cued condition, while the other half were assigned to the repeating uncued condition. This assignment procedure was done three times, resulting in three versions of item assignment. An additional three versions were created by simply flipping the condition assignments. Thus, across the six versions, each item occurred in the repeating cued condition three times and in the repeating uncued condition three times. In addition, sixteen of the unique items were randomly assigned to each of the eleven epochs. Within each epoch, half of the sixteen unique items were randomly assigned to the unique cued condition, while the other half were assigned to the unique uncued condition. This assignment procedure was done six times, resulting in six versions of item assignment. Overall, this resulted in a total of thirty-two stimuli per epoch: eight repeating cued, eight repeating uncued, eight unique cued, and eight unique uncued.

Stimuli lists for each of the eleven exposure phases and the test phase in the eleventh epoch were generated by randomly ordering the thirty-two nonwords and stem completion cues, respectively. Stimuli lists for the test phases in the first ten epochs were generated by randomly ordering the stem completion cues for the eight repeating cued and eight unique cued stimuli. This randomization procedure was done once for each of the six versions.

Procedure

The procedure was identical to that of Experiment 2 with a single exception. The instructions at the beginning of the experiment informed participants that nonwords presented with a green-colored screen would be tested in the following test phase.

Scoring

The scoring procedures were identical to those of Experiments 1 and 2. In short, online scoring represents holistic accuracy scored during the experimental session, phoneme scoring represents the proportion of correct phonemes in the correct sequence, and holistic scoring represents holistic accuracy based on the transcriptions of individual phonemes.

Results

Immediate Repetition Accuracy

Online scoring immediate repetition accuracy for each stimulus condition across epochs was assessed with a two-way repeated measures ANOVA, which revealed no significant main effect of epoch ($p > .05$), no significant main effect of stimulus condition ($p > .05$), and no significant interaction effect ($p > .05$). Across participants, average online scoring immediate repetition accuracy for all stimuli conditions ranged from approximately 88% correct to approximately 99% correct.

Phoneme scoring immediate repetition accuracy for each stimulus condition across epochs was also assessed with a two-way repeated measures ANOVA, which revealed no significant main effect of epoch ($p > .05$), no significant main effect of stimulus condition ($p > .05$), and no significant interaction effect ($p > .05$).Across participants, average phoneme scoring immediate repetition accuracy for all stimuli conditions was above 95% correct for each epoch, ranging from approximately 97% correct to approximately 99% correct.

Holistic scoring immediate repetition accuracy for each stimulus condition across epochs was assessed with a two-way repeated measures ANOVA, which revealed no significant main effect of epoch ($p > .05$), no significant effect of stimulus condition ($p > .05$), and no significant interaction effect ($p > .05$). Across participants, average holistic scoring immediate repetition accuracy for all stimuli conditions ranged from approximately 84% correct to approximately 97% correct.

Stem Completion Accuracy

Online scoring stem completion accuracy for the repeating cued and unique cued stimuli conditions across epochs (Figure 7) was assessed with a two-way repeated measures ANOVA, which revealed a significant main effect of epoch ($F(10, 216) = 17.660$, $p < .05$), a significant main effect of stimulus condition ($F(1, 216) = 21.389$, $p < .05$), and a significant interaction effect ($F(11, 216) = 22.073$, $p < .05$). Across participants, average online scoring stem completion accuracy for the repeating cued stimulus condition increased from approximately 3% correct in the first epoch to approximately 29% correct in the eleventh epoch. In contrast, across participants, average online scoring stem completion accuracy for the unique cued stimulus condition ranged from approximately 0% correct to approximately 8% correct across epochs.

Online scoring stem completion accuracy for each stimulus condition in the eleventh epoch was assessed with a one-way repeated measures ANOVA, which revealed a significant effect ($F(3, 33) = 16.0821$, $p < .05$). Across participants, average online scoring stem completion accuracy in the eleventh epoch was approximately 29% correct for the repeating cued condition, approximately 7% correct for the repeating uncued condition, approximately 3% correct for the unique cued condition, and approximately 0% correct for the unique uncued condition. However, Tukey post-hoc tests revealed a significant difference only between the repeating cued condition and each of the remaining three conditions ($p < .05$ for each).

Phoneme scoring stem completion accuracy for the repeating cued and unique cued stimuli conditions across epochs (Figure 8) was assessed with a two-way repeated measures ANOVA, which revealed a significant main effect of epoch ($F(10, 216) = 16.684$, $p < .05$), a significant main effect of stimulus condition ($F(1, 216) = 33.285$, $p < .05$), and a significant interaction effect ($F(11, 216) = 24.665$, $p < .05$). Across participants, average phoneme scoring stem completion accuracy for the repeating cued stimulus condition increased from approximately 52% correct in the first epoch to approximately 72% correct in the eleventh epoch. In contrast, across participants, average phoneme scoring stem completion accuracy for the unique cued stimulus condition ranged from approximately 49% correct to approximately 55% correct across epochs.

Phoneme scoring stem completion accuracy for each stimulus condition in the eleventh epoch was assessed with a one-way repeated measures ANOVA, which revealed a significant effect ($F(3, 33) = 21.806$, $p < .05$). Across participants, average phoneme scoring stem completion accuracy in the eleventh epoch was approximately 72% correct for the repeating cued condition, approximately 53% correct for the repeating uncued condition, approximately 52% correct for the unique cued condition, and approximately 51% correct for the unique uncued condition. Furthermore, Tukey post-hoc tests revealed a significant difference only between the repeating cued condition and each of the remaining three conditions ($p < .05$ for each).

Holistic scoring stem completion accuracy for the repeating cued and unique cued stimuli conditions across epochs (Figure 9) was assessed with a two-way repeated measures ANOVA, which revealed a significant main effect of epoch ($F(10, 216) = 16.364$, $p < .05$), a significant main effect of stimulus condition ($F(1, 216) = 21.243$, $p < .05$), and a significant interaction effect ($F(11, 216) = 22.799$, $p < .05$). Across participants, average holistic scoring stem completion accuracy for the repeating cued stimulus condition increased from approximately 3% correct in the first epoch to approximately 29% correct in the eleventh epoch. In contrast, across participants, average holistic scoring stem completion accuracy for the unique cued stimulus condition ranged from approximately 0% correct to approximately 6% correct across epochs.

Holistic scoring stem completion accuracy for each stimulus condition in the eleventh epoch was assessed with a one-way repeated measures ANOVA, which revealed a significant effect ($F(3, 33) = 14.813$, $p < .05$). Across participants, average holistic scoring stem completion accuracy in the eleventh epoch was approximately 29% correct for the repeating cued condition, approximately 6% correct for the repeating uncued condition, approximately 1% correct for the unique cued condition, and approximately 0% correct for the unique uncued condition. However, Tukey post-hoc tests revealed a significant difference only between the repeating cued condition and each of the remaining three conditions ($p < .05$ for each).

Discussion

One goal of this experiment is to establish that deliberate phonological learning leads to greater stem completion ability than incidental phonological learning in a within subjects design and results indicate that it does. Phoneme scoring results indicate that when participants were given the stem of a nonword that occurred in each exposure and test phase (i.e., repeating cued), they were able to produce the entire nonword with increasing accuracy across epochs, on average correctly producing 3 of the phonemes in the first epoch and 4-5 of the phonemes in the final epcoh. In contrast, when participants were given the stem of a nonword in any of the other three stimulus conditions (i.e., unique cued, repeating uncued, and unique uncued) in the final epoch, they were able to produce the entire nonword with some accuracy, on average correctly producing 3 of the phonemes, which is approximately equivalent to reproducing only the stem. Holistic and online scoring results indicate that when given the stem of a nonword that occurred in each exposure and test phase (i.e., repeating cued), participants were able to produce very few, if any, of the nonwords without any errors in the first epoch, on average only 0-1 of the 8 nonwords; however, they were able to produce on average 2-3 of the 8 nonwords without any errors in the final epoch. In contrast, when given the stem of a nonword in any of the other three stimulus conditions (i.e., unique cued, repeating uncued, and unique uncued) in the final epoch, participants were able to produce very few, if any, of the nonwords without any errors, on average only 0-1 of the 8 nonwords per condition.

The second goal of this experiment is to establish whether such phonological learning is item-specific or reflects task facilitation of general stem completion ability and results indicate that deliberate phonological learning is item-specific and does not reflect a general increase in stem completion ability. The results in each of the scoring procedures indicate that stem completion accuracy increased across epochs for nonwords that occurred in each exposure and test phase (i.e., repeating cued), but not nonwords that occurred in a single exposure and test phase (i.e., unique cued). Therefore, it cannot be the case that participants are merely getting better at stem completion in general, but rather that they are getting better at stem completion of a particular set of nonwords (i.e., the ones on which they are being repeatedly tested).

In addition, immediate repetition accuracy for each stimulus condition across epochs was relatively high, which is to be expected given that the task and stimuli are not particularly difficult. Phoneme scoring results indicate that participants were able to reproduce stimuli with a high degree of accuracy, on average erring on only 0-1 phoneme in a given nonword. Holistic and online scoring results indicate that participants were able to reproduce the majority of stimuli without any errors, on average erring on only 0-1 of the nonwords.

Experiment 4

The purpose of this experiment is to establish whether extensive incidental phonological learning leads to greater stem completion ability than the incidental phonological learning in Experiments 1 and 3. As in previous experiments, incidental phonological learning is operationalized as “listen and repeat” in the experimental task and phonological learning is assessed with respect to stem completion ability at the end of the task.

Method

Participants

Five members of the University of Iowa community received payment of $8.00 per hour (a total of $40) for their participation. All were native speakers of English and reported having normal hearing and normal or corrected-to-normal vision.

Experimental Task

The experimental task consisted of two sessions completed on consecutive days. The first session consisted of a total of one hundred epochs that were presented in ten groups of ten epochs, with a short break between each group. The first ninety-nine epochs were comprised of an exposure phase, while the hundredth epoch was comprised of an exposure phase followed by a test phase. The second session consisted of two additional epochs. The first epoch (i.e., epoch 101) was comprised of a test phase, while the second epoch (i.e., epoch 102) was comprised of an exposure phase followed by a test phase. Thus, immediate repetition accuracy was assessed across all except one epoch, while stem completion accuracy was assessed across the final three epochs. In addition, all stimuli occurred in each of the hundred and two epochs.

Stimuli

The auditory stimuli were identical to those utilized in Experiments 1 and 2. More specifically, the same exact practice items and repeating items were utilized.

Stimuli Lists

Stimuli lists for each of the hundred and one exposure phases and the three test phases were generated by randomly ordering the sixteen repeating nonwords and stem completion cues, respectively. This randomization procedure was done once for each of the five participants, resulting in five versions of the task that differed only in the order in which the stimuli were presented.

Procedure

The procedural details were identical to that of Experiment 1 with the following two exceptions. First, the experimenter was not present in the room with the participant during the sessions. Second, the participants returned the following day to complete the second session.

Scoring

The scoring procedures were identical to those of Experiments 1, 2 and 3 with a single exception. Since the experimenter was not present in the room with the participant during the sessions, there is no online scoring. For this experiment, only phoneme scoring, representing the proportion of correct phonemes in the correct sequence, and holistic scoring, representing holistic accuracy based on the transcriptions of individual phonemes, were utilized.

Results

Immediate Repetition Accuracy

Phoneme scoring immediate repetition accuracy across epochs was assessed with a one-way repeated measures ANOVA, which reveals no significant effect ($p > .05$). Across participants, average phoneme scoring immediate repetition accuracy is above 95% correct for each epoch, ranging from approximately 95% correct to approximately 99% correct.

Holistic scoring immediate repetition accuracy across epochs was assessed with a one-way repeated measures ANOVA, which reveals no significant effect ($p > .05$). Across participants, average holistic scoring immediate repetition accuracy for each epoch ranges from approximately 78% correct to approximately 96% correct.

Stem Completion Accuracy

Phoneme scoring stem completion accuracy across the last three epochs (Figure 10) was assessed with a one-way repeated measures ANOVA, which reveals a significant effect ($F(2, 8) = 7.6182$, $p < .05$). Across participants, average phoneme scoring stem completion accuracy is approximately 53% correct after one hundred epochs of immediate repetition, increases to approximately 61% correct at the beginning of the second session (i.e., epoch 101), and increases further to approximately 70% correct following an additional exposure phase. However, Tukey post-hoc tests reveal a significant difference only between the last epoch in the first session (i.e., epoch 100) and the last epoch in the second session (i.e., epoch 102) ($p < .05$).

Holistic scoring stem completion accuracy across the last three epochs (Figure 11) was assessed with a one-way repeated measures ANOVA, which reveals a significant effect ($F(2, 8) = 6.7563$, $p < .05$). Across participants, average holistic scoring stem completion accuracy is approximately 8% correct after one hundred epochs of immediate repetition, increases to approximately 14% correct at the beginning of the second session (i.e., epoch 101), and increases further to approximately 28% correct following an additional exposure phase. However, Tukey post-hoc tests reveal a significant difference only between the last epoch in the first session (i.e., epoch 100) and the last epoch in the second session (i.e., epoch 102) ($p < .05$). Although, there is a marginally significant difference between the first epoch in the second session (i.e., epoch 101) and the last epoch in the second session (i.e., epoch 102) ($p = .0883$).

Discussion

The goal of this experiment is to establish whether extensive incidental phonological learning leads to greater stem completion ability than the incidental phonological learning in Experiments 1 and 3, and results indicate that it does not. After 100 epochs of immediate repetition, phoneme scoring results indicate that when participants were given the stem, they were able to produce the entire nonword with some accuracy, on average correctly producing 3 of the phonemes. However, this is approximately equivalent to correctly reproducing only the stem for each nonword. Furthermore, holistic scoring results in epoch 100 indicate that when given the stem, participants were able to produce only a few of the nonwords without any errors, on average only 1-2 of the 16 nonwords.

However, stem completion ability improves slightly when participants returned for the second session (i.e., epoch 101 stem completion test and epoch 102 immediate repetition and stem completion test). Phoneme scoring results indicate that when participants were given the stem, they were able to produce the entire nonword with some accuracy, on average correctly producing 3-4 of the phonemes in epoch 101 and 4 of the phonemes in the final epoch (i.e., epoch 102). Holistic scoring results indicate that when given the stem, participants were able to produce very few of the nonwords without any errors in epoch 101, on average 2-3 of the 16 nonwords; however, they were able to produce on average 4-5 of the 16 nonwords without any errors in the final epoch (i.e., epoch 102).

In addition, immediate repetition accuracy across epochs was relatively high, which is to be expected given that the task and stimuli are not particularly difficult. Phoneme scoring results indicate that participants were able to reproduce stimuli with a high degree of accuracy, on average erring on only 0-1 phoneme in a given nonword. Holistic scoring results indicate that participants were able to reproduce the majority of stimuli without any errors, on average erring on 1-3 of the 16 nonwords.

Interim Discussion

Taken together, the results of these four experiments suggest that incidental learning does not yield full mastery of phonological word-forms. For all three scoring procedures, immediate repetition accuracy was relatively high across all four experiments, indicating that this measure was not particularly affected by any differences between incidental and deliberate learning. However, stem completion accuracy was differentially affected by incidental and deliberate learning. The pattern of results across these four experiments indicates that repeated exposure and testing improve stem completion ability above baseline performance while repeated exposure alone does not. Even after 100 epochs of immediate repetition exposure, stem completion ability is no different from that of a single immediate repetition exposure. Further research is needed to determine what factors in particular account for this benefit from deliberate learning. The current experiments cannot distinguish between a few possible factors, including knowing which items are to be learned and whether the stem completion testing affects learning directly and/or whether it affects processing during subsequent exposure.

Stem completion ability does improve above baseline in the second session after intensive training (i.e., the next day); however, further research is needed to determine what factor(s) account for this improvement. The current experiment confounds a number of possible factors, such as the passage of time, possible consolidation during sleep, and potential effects of the single stem completion test at the end of the first session.

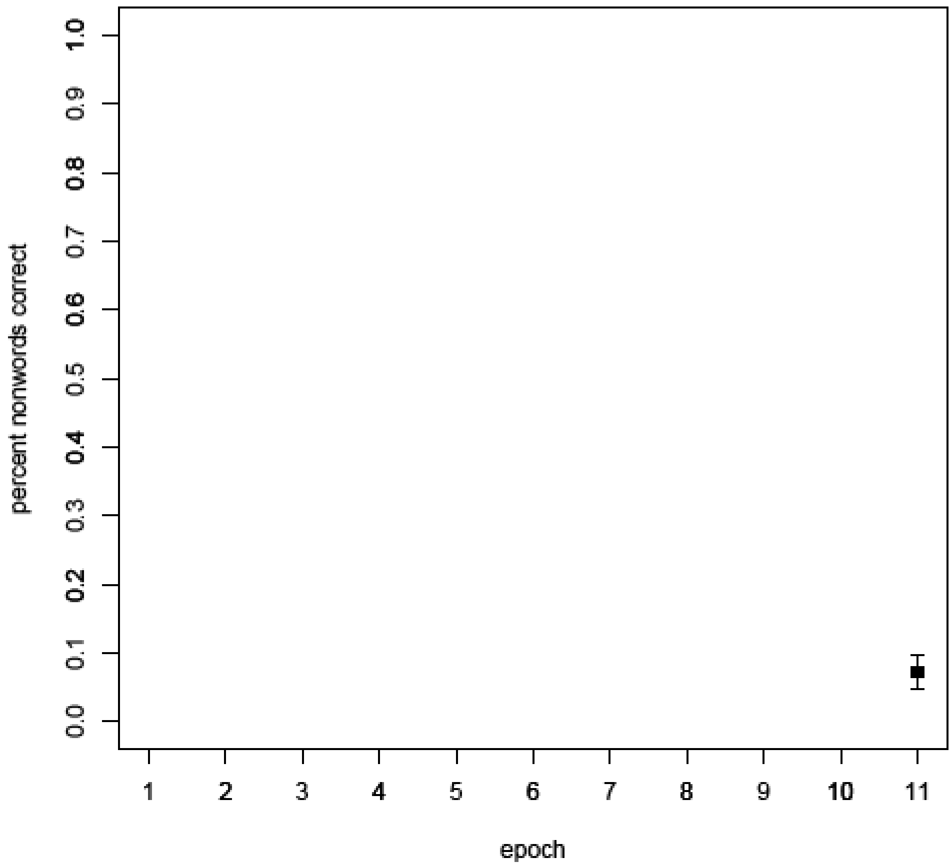

Figure 1. Experiment 1: Online scoring stem completion accuracy across epochs.

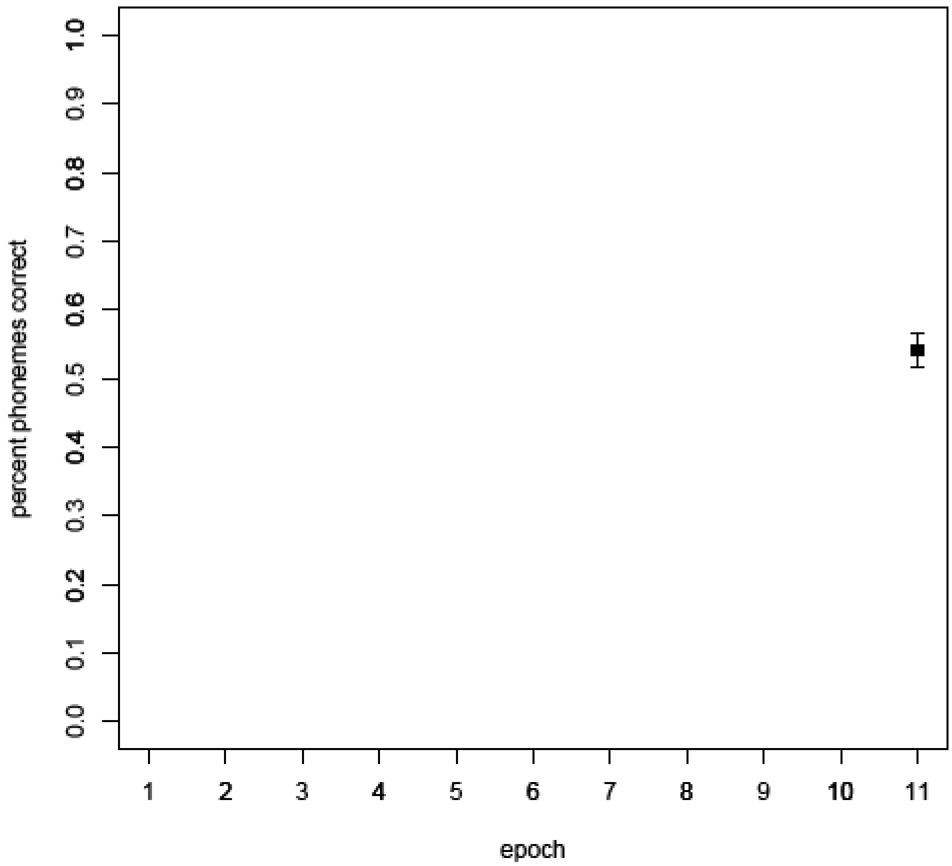

Figure 2. Experiment 1: Phoneme scoring stem completion accuracy across epochs.

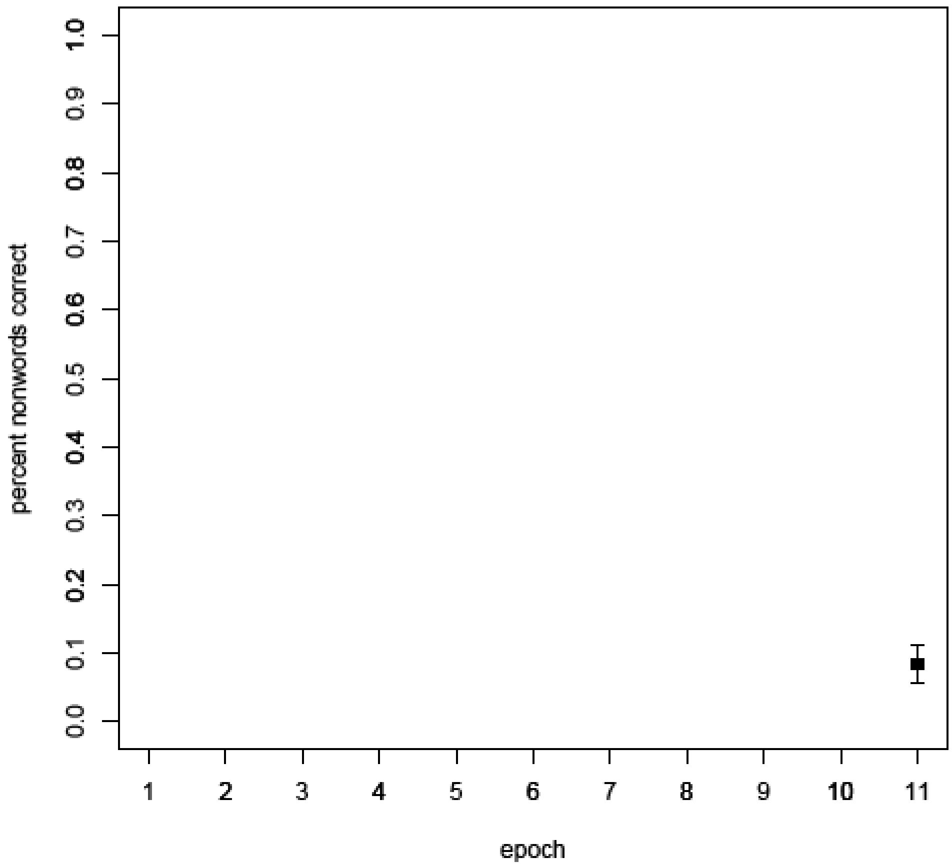

Figure 3. Experiment 1: Holistic scoring stem completion accuracy across epochs.

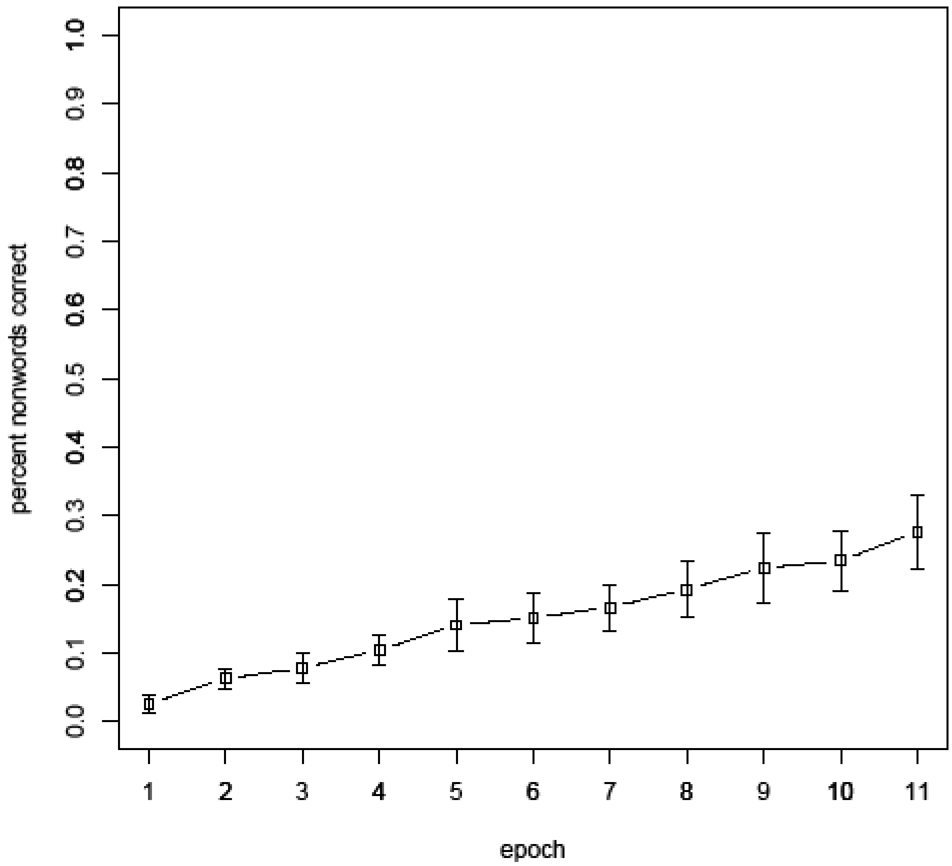

Figure 4. Experiment 2: Online scoring stem completion accuracy across epochs.

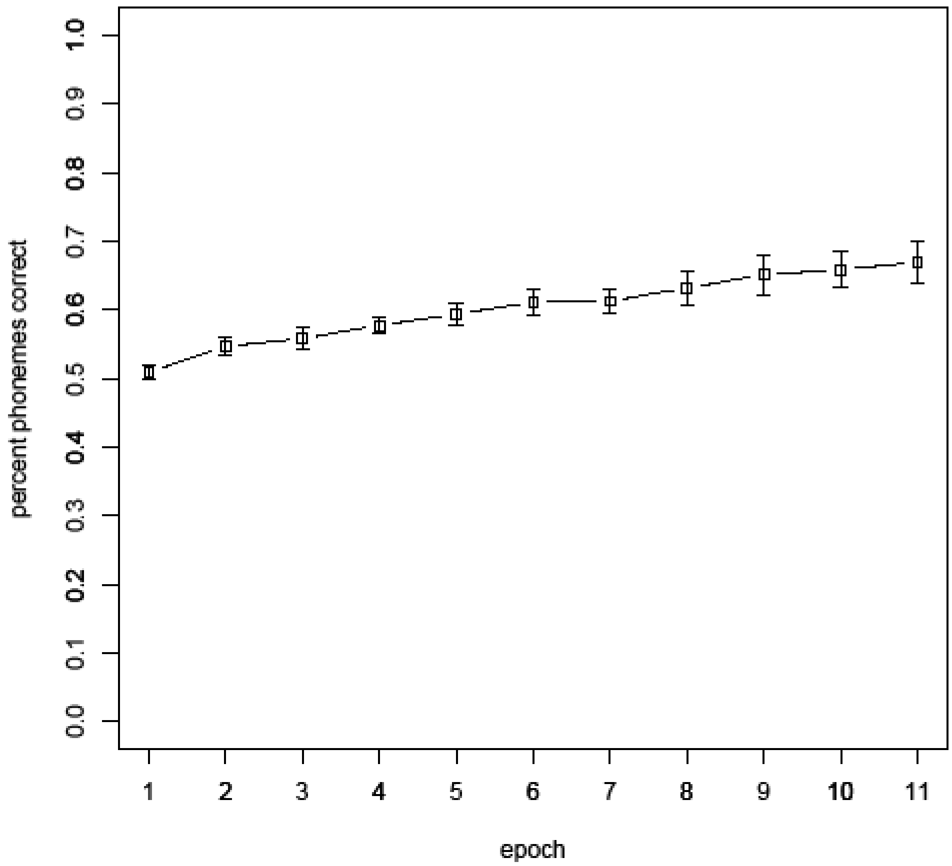

Figure 5. Experiment 2: Phoneme scoring stem completion accuracy across epochs.

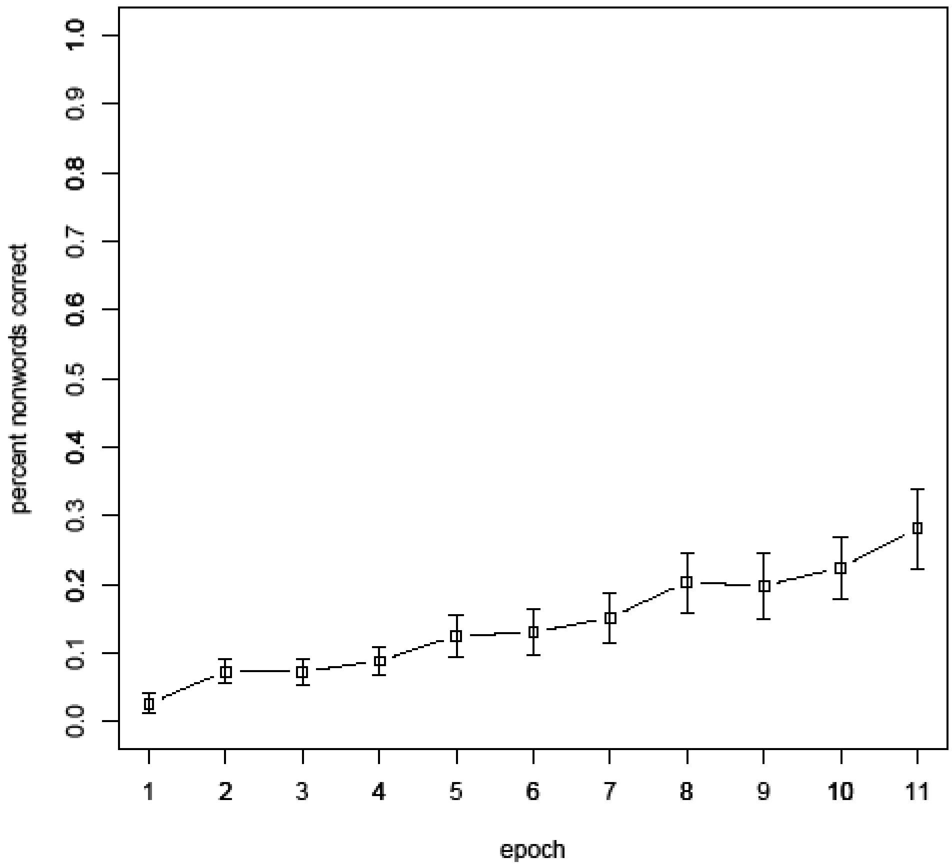

Figure 6. Experiment 2: Holistic scoring stem completion accuracy across epochs.

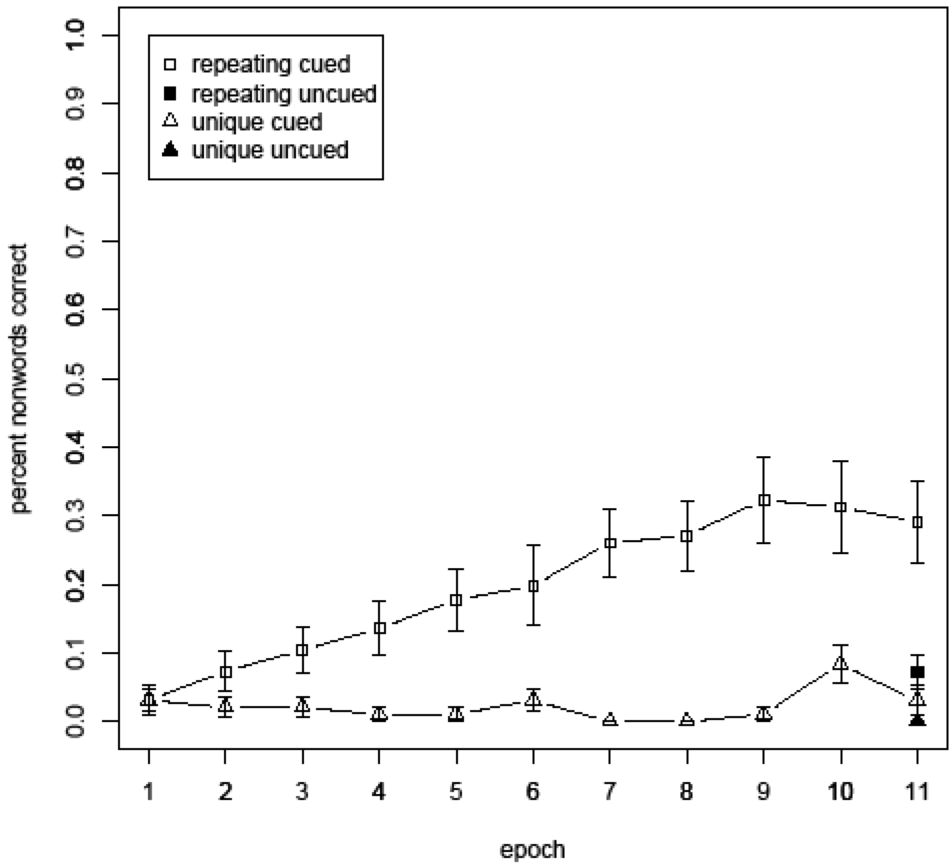

Figure 7. Experiment 3: Online scoring stem completion accuracy across epochs.

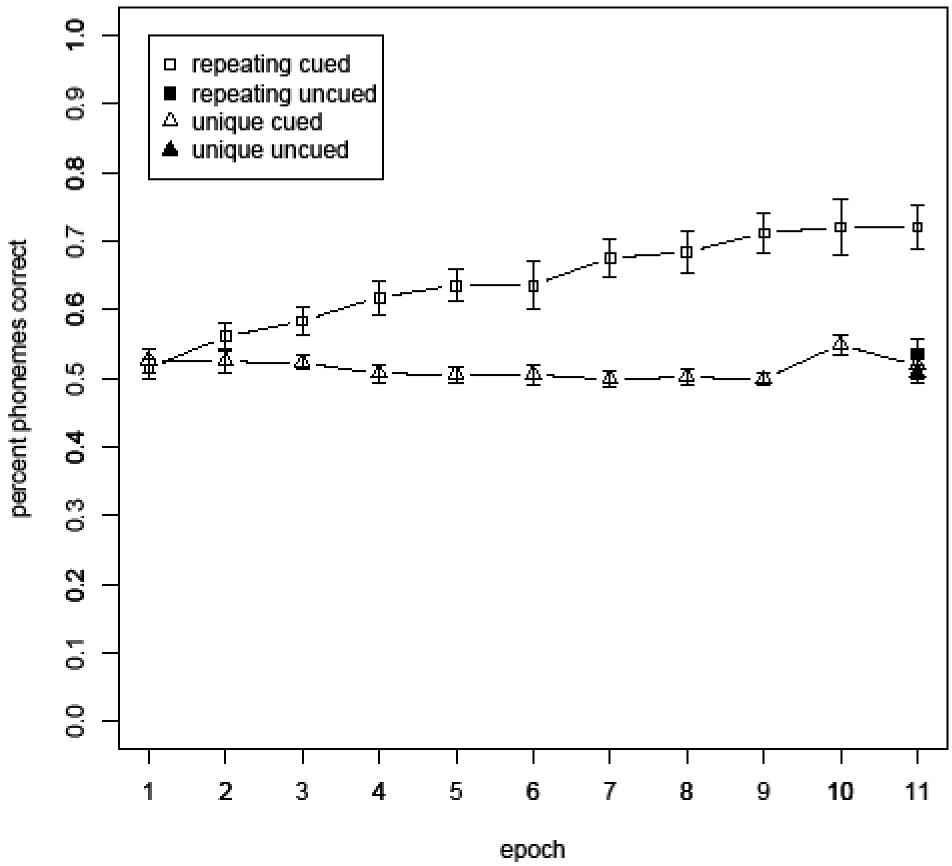

Figure 8. Experiment 3: Phoneme scoring stem completion accuracy across epochs.

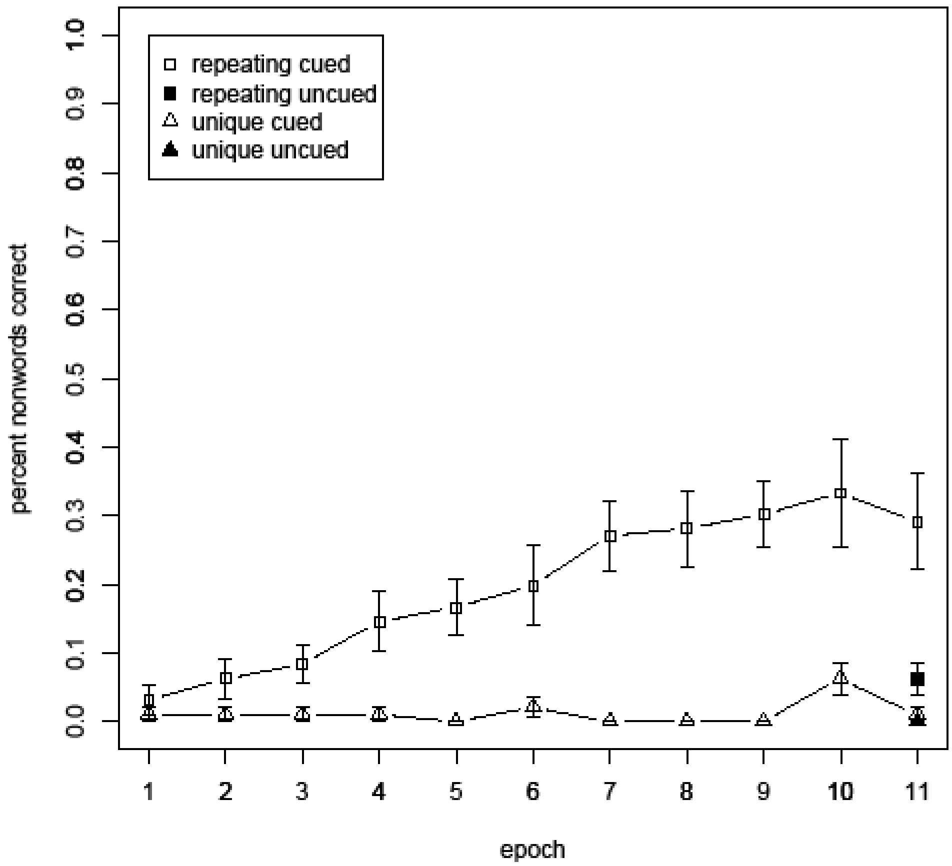

Figure 9. Experiment 3: Holistic scoring stem completion accuracy across epochs.

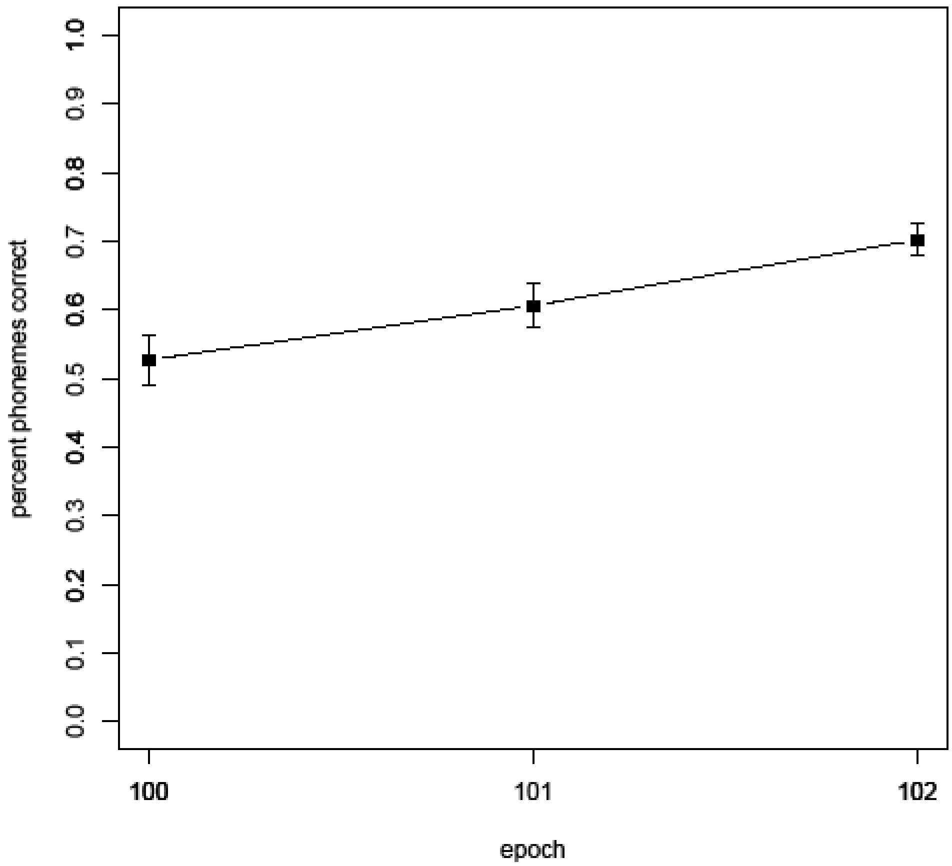

Figure 10. Experiment 4: Phoneme scoring stem completion accuracy across epochs.

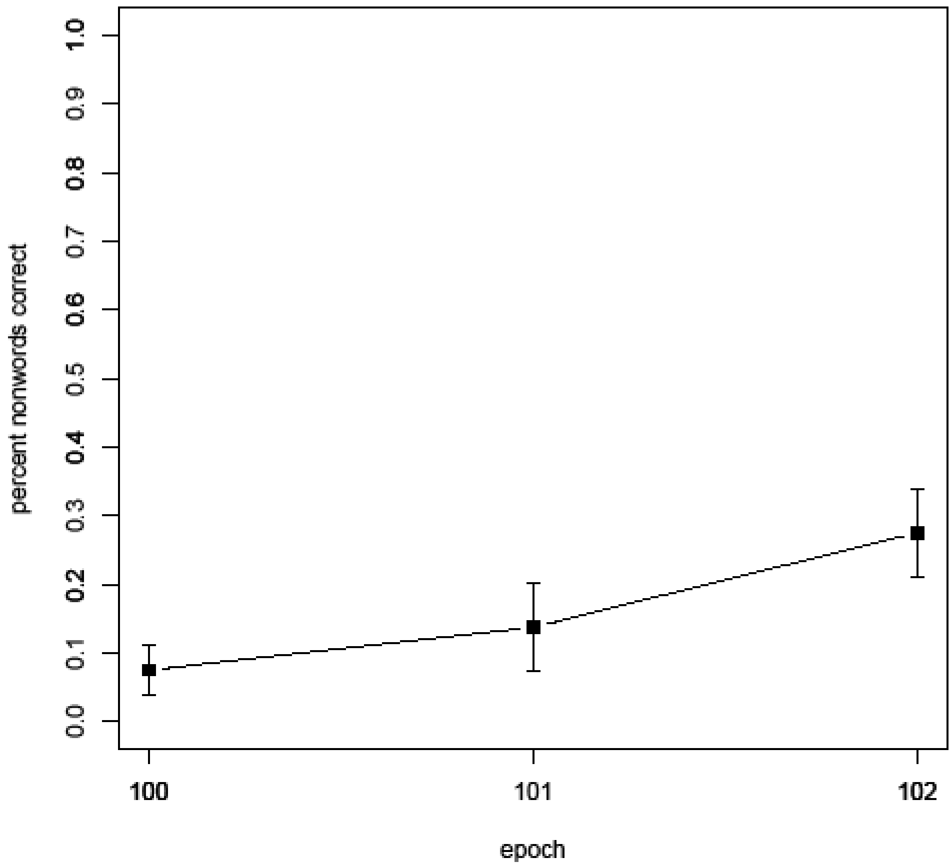

Figure 11. Experiment 4: Holistic scoring stem completion accuracy across epochs.

LEARNING MONOSYLLABIC NONWORDS

Experiment 5

The purpose of this experiment is to replicate Experiment 1 utilizing monosyllabic nonwords. More specifically, the goal is to establish whether incidental phonological learning supports stem completion ability. As in the previous experiments, incidental phonological learning is operationalized as “listen and repeat” in the experimental task and phonological learning is assessed with respect to stem completion ability at the end of the task.

Method

Participants

Twelve members of the University of Iowa community received either payment of $8.00 or credit toward their Elementary Psychology course for their participation. All were native speakers of English and reported having normal hearing and normal or corrected-to-normal vision.

Experimental Task

The experimental task was identical to that of Experiment 1. In short, the first ten epochs were comprised of an exposure phase, while the final epoch was comprised of an exposure phase followed by a test phase. Thus, immediate repetition accuracy was assessed across epochs, while stem completion accuracy was assessed only in the final epoch. In addition, all stimuli were repeating items that occurred in each of the eleven epochs.

Stimuli

Auditory stimuli were monosyllabic nonwords recorded by a male native speaker of American English. Possible phonemes were restricted to those used in the American

English language and the combination of phonemes into word-forms was limited to those that are legal in the language. Thus, all nonwords were possible, but non-occurring word-forms. In addition, the vast majority of the nonwords consisted of a CVC syllable structure in which the phoneme in the word-final position was a stop consonant (i.e., /p/, /b/, /d/, /g/, /t/, or /k/). The two deviations from this syllable structure came in the form of r-colored vowels and in the form of pluralized nonwords, both resulting in some nonwords with a CVCC syllable structure.

The resulting corpus of 346 nonwords was recorded and processed – 10 of which were designated to be practice items and 16 of which were designated to be target or repeating items for all subsequent experiments. A cue for the stem completion test was also recorded and processed for each nonword. The cue consisted of the beginning of the nonword, specifically until the onset of the stop consonant. For instance, if the nonword was /nɛp/, the stem completion cue would be /nɛ/.

All stimuli were recorded within a carrier sentence to control for some of the variations in natural speech. Multiple instances of each stimulus were recorded and the clearest exemplar was chosen for processing. Once a selected stimulus was spliced out of the carrier sentence, the average intensity was scaled to 65dB.

Stimuli Lists

Stimuli lists were generated in an identical manner to those in Experiment 1.

Procedure

The procedure was identical to that of Experiment 1.

Scoring

The scoring procedures were identical to those of Experiments 1, 2 and 3. In short, online scoring represents holistic accuracy scored during the experimental session, phoneme scoring represents the proportion of correct phonemes in the correct sequence, and holistic scoring represents holistic accuracy based on the transcriptions of individual phonemes.

Results

Immediate Repetition Accuracy

Online scoring immediate repetition accuracy across epochs was assessed with a one-way repeated measures ANOVA, which revealed no significant effect ($p > .05$). Across participants, average online scoring immediate repetition accuracy was above 95% correct for each epoch, ranging from approximately 96% correct to approximately 98% correct.

Phoneme scoring immediate repetition accuracy across epochs was also assessed with a one-way repeated measures ANOVA, which revealed no significant effect ($p > .05$). Across participants, average phoneme scoring immediate repetition accuracy was above 95% correct for each epoch, ranging from approximately 96% correct to approximately 98% correct.

Holistic scoring immediate repetition accuracy across epochs was assessed with a one-way repeated measures ANOVA, which revealed no significant effect ($p > .05$). Across participants, average holistic scoring immediate repetition accuracy for each epoch ranged from approximately 95% correct to approximately 98% correct.

Stem Completion Accuracy

Online scoring stem completion accuracy in the eleventh epoch (Figure 12) was assessed with a one sample t-test, which revealed a significant difference from zero ($t(11) = 8.685$, $p < .05$). Across participants, average online scoring stem completion accuracy in the eleventh epoch was approximately 50% correct.

Phoneme scoring stem completion accuracy in the eleventh epoch (Figure 13) was assessed with a one sample t-test, which revealed a significant difference from fifty percent ($t(11) = 3.6855$, $p < .05$). Across participants, average phoneme scoring stem completion accuracy in the eleventh epoch was approximately 65% correct.

Holistic scoring stem completion accuracy in the eleventh epoch (Figure 14) was assessed with a one sample t-test, which revealed a significant difference from zero ($t(11) = 8.3302$, $p < .05$). Across participants, average online scoring stem completion accuracy in the eleventh epoch was 47% correct.

Discussion

The goal of this experiment is to replicate Experiment 1 by establishing that incidental phonological learning supports stem completion ability utilizing monosyllabic nonwords and results indicate that it does. Phoneme scoring results in the final epoch indicate that when participants are given the stem, they were able to produce the entire nonword with some accuracy, on average correctly producing 2 of the phonemes. However, this is approximately equivalent to correctly reproducing only the stem for each nonword. Furthermore, holistic and online scoring results in the final epoch indicate that when given the stem, participants were able to produce many of the nonwords without any errors, on average7- 8 of the 16 nonwords.

In addition, immediate repetition accuracy across epochs was relatively high, which is to be expected given that the task and stimuli are not particularly difficult. Phoneme scoring results indicate that participants were able to reproduce stimuli with a high degree of accuracy, on average erring on only 0-1 phoneme in a given nonword. Holistic and online scoring results indicate that participants were able to reproduce the majority of stimuli without any errors, on average erring on only 0-1 of the 16 nonwords.

Experiment 6

The purpose of this experiment is to replicate Experiment 2 utilizing monosyllabic nonwords. More specifically, the goals are to establish whether deliberate phonological learning supports stem completion ability and whether it leads to greater stem completion ability than incidental phonological learning. As in the previous experiments, deliberate phonological learning is operationalized as a combination of "listen and repeat" and repeatedly testing stem completion ability in the experimental task.

Method

Participants

Twelve members of the University of Iowa community received either payment of $8.00 or credit toward their Elementary Psychology course for their participation. All were native speakers of English and reported having normal hearing and normal or corrected-to-normal vision.

Experimental Task

The experimental task was identical to that of Experiment 2. In short, each epoch was comprised of an exposure phase followed by a test phase. Thus, both immediate repetition accuracy and stem completion accuracy were assessed across epochs. In addition, all stimuli were repeating items that occurred in each of the eleven epochs.

Stimuli

The auditory stimuli were identical to those utilized in Experiment 5. More specifically, the same exact practice items and repeating items were utilized.

Stimuli Lists

The stimuli lists were generated in an identical manner to that of Experiment 2.

Procedure

The procedure was identical to that of Experiment 2.

Scoring

The scoring procedures were identical to those of Experiments 1, 2, 3, and 5. In short, online scoring represents holistic accuracy scored during the experimental session, phoneme scoring represents the proportion of correct phonemes in the correct sequence, and holistic scoring represents holistic accuracy based on the transcriptions of individual phonemes.

Results

Immediate Repetition Accuracy

Online scoring immediate repetition accuracy across epochs was assessed with a one-way repeated measures ANOVA, which revealed no significant effect ($p > .05$). Across participants, average online scoring immediate repetition accuracy was above 90% correct for each epoch, ranging from approximately 94% correct to approximately 96% correct.

Phoneme scoring immediate repetition accuracy across epochs was also assessed with a one-way repeated measures ANOVA, which revealed no significant effect ($p > .05$). Across participants, average phoneme scoring immediate repetition accuracy was above 95% correct for each epoch, ranging from approximately 97% correct to approximately 99% correct.

Holistic scoring immediate repetition accuracy across epochs was assessed with a one-way repeated measures ANOVA, which revealed no significant effect ($p >. 05$). Across participants, average holistic scoring immediate repetition accuracy was above 95% correct for each epoch, ranging from approximately 95% correct to approximately 97% correct.

<u>Stem Completion Accuracy</u>

Online scoring stem completion accuracy across epochs (Figure 15) was assessed with a one-way repeated measures ANOVA, which revealed a significant effect ($F(10, 110) = 17.9401$, $p < .05$). Across participants, average online scoring stem completion accuracy increased from approximately 29% correct in the first epoch to approximately 72% correct in the eleventh epoch.

Phoneme scoring stem completion accuracy across epochs (Figure 16) was assessed with a one-way repeated measures ANOVA, which revealed a significant effect ($F(10, 110) = 16.540$, $p < .05$). Across participants, average phoneme scoring stem completion accuracy increased from approximately 60% correct in the first epoch to approximately 85% correct in the eleventh epoch.

Holistic scoring stem completion accuracy across epochs (Figure 17) was assessed with a one-way repeated measures ANOVA, which revealed a significant effect ($F(10\ 110) = 18.7541$, $p < .05$). Across participants, average holistic scoring stem completion accuracy increased from approximately 30% correct in the first epoch to approximately 75% correct in the eleventh epoch.

Discussion

The goal of this experiment is to replicate Experiment 2 by establishing that deliberate phonological learning supports stem completion ability and that it leads to greater stem completion ability than incidental phonological learning utilizing monosyllabic nonwords, and results indicate that it does. Phoneme scoring results indicate that when participants were given the stem, they were able to produce the entire nonword with some accuracy, on average correctly producing 2 of the phonemes in the first epoch and 2-3 of the phonemes in the final epoch. However, this is only slightly better than correctly reproducting only the stem for each nonword. Perhaps more informative, holistic and online scoring results indicate that when given the stem, participants were able to produce some of the nonwords without any errors in the first epoch, on average 4-5 of the 16 nonwords; however, they were able to produce on average 11-12 of the 16 nonwords without any errors in the final epoch.

In addition, immediate repetition accuracy across epochs was relatively high, which is to be expected given that the task and stimuli are not particularly difficult. Phoneme scoring results indicate that participants were able to reproduce stimuli with a high degree of accuracy, on average erring on only 0-1 phoneme in a given nonword. Holistic and online scoring results indicate that participants were able to reproduce the majority of stimuli without any errors, on average erring on only 0-1 of the 16 nonwords.

Experiment 7

The purpose of this experiment is to replicate Experiment 3 utilizing monosyllabic nonwords. More specifically, the goals are to establish that deliberate phonological learning leads to greater stem completion ability than incidental phonological learning in a within subjects design and to establish whether such phonological learning is item-specific or reflects task facilitation of general stem completion ability. As in the previous experiments, incidental phonological learning is operationalized as “listen and repeat” in the experimental task and phonological learning is assessed with respect to stem completion ability at the end of the task. And, deliberate phonological learning is operationalized as a combination of “listen and repeat” and repeatedly testing stem completion ability in the experimental task and phonological learning is assessed with respect to stem completion accuracy throughout the task.

Method

Participants

Twelve members of the University of Iowa community received credit toward their Elementary Psychology course for their participation. All were native speakers of English and reported having normal hearing and normal or corrected-to-normal vision.

Experimental Task

The experimental task was identical to that of Experiment 3. In short, the experimental task consisted of eleven epochs, which were each comprised of an exposure phase followed by a test phase. Stimuli were presented in one of the following four conditions: repeating cued, repeating uncued, unique cued, unique uncued. However, in the test phase of the final epoch, all stimuli were tested, regardless of stimuli condition.

Stimuli

The auditory stimuli were identical to those utilized in Experiments 5 and 6 with a single exception. The same exact practice items and repeating items were utilized; however, the previously unutilized 320 nonwords in the corpus were designated to be unique items.

Stimuli Lists

The stimuli lists were generated in an identical manner to that of Experiment 3.

Procedure

The procedure was identical to that of Experiment 3.

Scoring

The scoring procedures were identical to those of Experiments 1, 2, 3, 5, and 6. In short, online scoring represents holistic accuracy scored during the experimental session, phoneme scoring represents the proportion of correct phonemes in the correct sequence, and holistic scoring represents holistic accuracy based on the transcriptions of individual phonemes.

Results

Immediate Repetition Accuracy

Online scoring immediate repetition accuracy for each stimulus condition across epochs was assessed with a two-way repeated measures ANOVA, which revealed a significant main effect of epoch ($F(10, 473) = 2.5133$, $p < .05$), a significant main effect of stimulus condition ($F(3, 473) = 7.3068$, $p < .05$), and no significant interaction effect ($p > .05$). However, across participants, average online scoring immediate repetition accuracy for all stimuli conditions is above 95% correct, ranging from approximately 95% correct to approximately 99% correct.

Phoneme scoring immediate repetition accuracy for each stimulus condition across epochs was also assessed with a two-way repeated measures ANOVA, which revealed a significant main effect of epoch ($F(10, 461) = 2.1827$, $p< .05$), a significant main effect of stimulus condition ($F(3, 461) = 6.6385$, $p < .05$), and no significant interaction effect ($p > .05$). However, across participants, average phoneme scoring immediate repetition accuracy for all stimuli conditions was above 90% correct for each epoch, ranging from approximately 91% correct to approximately 99% correct.

Holistic scoring immediate repetition accuracy for each stimulus condition across epochs was assessed with a two-way repeated measures ANOVA, which reveled a significant man effect of epoch ($F(10, 461) = 2.1294$, $p < .05$), a significant main effect of stimulus condition ($F(3, 461) = 6.4360$, $p < .05$), and no significant interaction effect ($p > .05$). Across participants, average holistic scoring immediate repetition accuracy for all stimuli conditions ranged from approximately 84% correct to approximately 99% correct.

Stem Completion Accuracy

Online scoring stem completion accuracy for the repeating cued and unique cued stimuli conditions across epochs (Figure 18) was assessed with a two-way repeated measures ANOVA, which revealed a significant main effect of epoch ($F(10, 216) = 5.0002$, $p < .05$), a significant main effect of stimulus condition ($F(1, 216) = 60.375$, $p < .05$), and a significant interaction effect ($F(11, 216) = 7.8727$, $p < .05$). Across participants, average online scoring stem completion accuracy for the repeating cued stimulus condition increased from approximately 39% correct in the first epoch to approximately 68% correct in the eleventh epoch. In contrast, across participants, average online scoring stem completion accuracy for the unique cued stimulus condition ranged from approximately 20% correct to approximately 35% correct across epochs.

Online scoring stem completion accuracy for each stimulus condition in the eleventh epoch was assessed with a one-way repeated measures ANOVA, which revealed a significant effect ($F(3, 33) = 20.824$, $p < .05$). Across participants, average online scoring stem completion accuracy in the eleventh epoch was approximately 68% correct for the repeating cued condition, approximately 45% correct for the repeating uncued condition, approximately 23% correct for the unique cued condition, and approximately 24% correct for the unique uncued condition. Furthermore, Tukey post-hoc tests revealed a significant difference between the repeating cued condition and each of the remaining three conditions ($p < .05$ for each) and between the repeating uncued condition and each of the remaining two conditions ($p < .05$ for each).

Phoneme scoring stem completion accuracy for the repeating cued and unique cued stimuli conditions across epochs (Figure 19) was assessed with a two-way repeated measures ANOVA, which revealed a significant main effect of epoch ($F(10, 216) = 2.1593$, $p < .05$), a significant main effect of stimulus condition ($F(1, 216) = 66.8315$, $p < .05$), and a significant interaction effect ($F(11, 216) = 2.4880$, $p < .05$).Across participants, average phoneme scoring stem completion accuracy for the repeating cued stimulus condition increased from approximately 66% correct in the first epoch to approximately 83% correct in the eleventh epoch. In contrast, across participants, average phoneme scoring stem completion accuracy for the unique cued stimulus condition ranged from approximately 56% correct to approximately 64% correct across epochs.

Phoneme scoring stem completion accuracy for each stimulus condition in the eleventh epoch was assessed with a one-way repeated measures ANOVA, which revealed a significant effect ($F(3, 33) = 14.3720$, $p < .05$). Across participants, average phoneme scoring stem completion accuracy in the eleventh epoch was approximately 83% correct for the repeating cued condition, approximately 70% correct for the repeating uncued condition, approximately 60% correct for the unique cued condition, and approximately 58% correct for the unique uncued condition. Furthermore, Tukey post-hoc tests revealed a significant difference between the repeating cued condition and each of the remaining three conditions ($p < .05$ for each) and between the repeating uncued condition and the unique uncued condition ($p < .05$).

Holistic scoring stem completion accuracy for the repeating cued and unique cued stimuli conditions across epoch (Figure 20) was assessed with a two-way repeated measures ANOVA, which revealed a significant main effect of epoch ($F(10, 216) = 2.6784$, $p < .05$), a significant main effect of stimulus condition ($F(1, 216) = 78.7885$, $p < .05$), and a significant interaction effect ($F(11, 216) = 3.2093$). Across participants, average holistic scoring stem completion accuracy for the repeating cued stimulus condition increased from approximately 39% correct in the first epoch to approximately 70% correct in the final epoch. In contrast, across participants, average phoneme scoring stem completion accuracy for the unique cued stimulus condition ranged from approximately 25% correct to approximately 39% correct across epochs.

Holistic scoring stem completion accuracy for each stimulus condition in the eleventh epoch was assessed with a one-way repeated measures ANOVA, which revealed a significant effect ($F(3, 33) = 19.0584$, $p < .05$). Across participants, average holistic scoring stem completion accuracy in the eleventh epoch was approximately 70% correct for the repeating cued condition, approximately 47% correct for the repeating uncued condition, approximately 28% correct for the unique cued condition, and approximarely 27% correct for the unique uncued condition. Furthermore, Tukey post-hoc tests revealed a significant difference between the repeating cued condition and each of the remaining three conditions ($p < .05$ for each) and between the repeating uncued condition and each of the remaining two conditions ($p < .05$ for each).

Discussion

One goal of this experiment is to replicate Experiment 3 by establishing that deliberate phonological learning leads to greater stem completion ability than incidental phonological learning in a within subjects design utilizing monosyllabic nonwords and results indicate that it does. Phoneme scoring results indicate that when participants were given the stem of a nonword that occurred in each exposure and test phase (i.e., repeating cued), they were able to produce the entire nonword with increasing accuracy across epochs, on average correctly producing 2 of the phonemes in the first epoch and 2-3 of the phonemes in the final epcoh. In contrast, when participants were given the stem of a nonword in any of the other three stimulus conditions (i.e., unique cued, repeating uncued, and unique uncued) in the final epoch, they were able to produce the entire nonword with some accuracy, on average correctly producing 1-2 of the phonemes, which is approximately equivalent to reproducing only the stem. Holistic and online scoring results indicate that when given the stem of a nonword that occurred in each exposure and test phase (i.e., repeating cued), participants were able to produce some of the nonwords without any errors in the first epoch, on average 3 of the 8 nonwords; however, they were able to produce on average 5-6 of the 8 nonwords without any errors in the final epoch. When participants were given the stem of a nonword that occurred in each exposure phase, but only the final test phase (i.e., repeating uncued), they were able to produce some of the nonwords without any errors in the final epoch, on average 3-4 of the 8 nonwords. In contrast, when given the stem of a nonword in either of unique stimulus conditions (i.e., unique cued and unique uncued) in the final epoch, participants were able to produce very few of the nonwords without any errors, on average only 2 of the 8 nonwords per condition.

The second goal of this experiment is to replicate Experiment 3 by establishing that such phonological learning is item-specific utilizing monosyllabic nonwords and results indicate that it is. The results in each of the scoring procedures indicate that stem completion accuracy increased across epochs for nonwords that occurred in each exposure and test phase (i.e., repeating cued), but not nonwords that occurred in a single exposure and test phase (i.e., unique cued). Therefore, it cannot be the case that participants are merely getting better at stem completion in general, but rather that they are getting better at stem completion of a particular set of nonwords (i.e., the ones on which they are being repeatedly tested).

In addition, immediate repetition accuracy for each stimulus condition across epochs was relatively high, which is to be expected given that the task and stimuli are not particularly difficult. Phoneme scoring results indicate that participants were able to reproduce stimuli with a high degree of accuracy, on average erring on only 0-1 phoneme in a given nonword. Holistic and online scoring results indicate that participants were able to reproduce the majority of stimuli without any errors, on average erring on only 0-1 of the nonwords.

Interim Discussion

Taken together, the results of these additional three experiments support the notion that incidental learning does not yield full mastery of phonological word-forms. The pattern of results across these three experiments directly replicates that across the experiments from the previous section with a single exception. Specifically, for all three scoring procedures, immediate repetition accuracy was relatively high across all three additional experiments, indicating again that this measure was not particularly affected by any differences between incidental and deliberate learning. In addition, stem completion accuracy was differentially affected by incidental and deliberate learning.

However, results from Experiment 3 indicate that repeated exposure and testing improve stem completion ability above baseline performance while repeated exposure alone does not. Recall that the repeating uncued condition yielded the same low level of stem completion ability as the unique baseline conditions. In contrast, results from Experiment 7 demonstrate that the repeating uncued condition yielded a greater level of stem completion ability than the unique baseline conditions. This apparent discrepancy can be explained on the basis of a difference in stimulus difficulty. Overall stem completion performance is higher in the experiments with monosyllabic nonwords than that in the experiments with disyllabic nonwords. In both sets of experiments, the task is to produce the entire nonword given only the stem; however, the stem consists of a different proportion of the give nonword across syllable lengths. Specifically, the stem consists of approximately 2/3 of the monosyllabic nonwords, whereas, the stem consists of approximately 1/2 of the disyllabic nonwords.

Related to this difference in stimulus difficulty, stem completion performance in the unique baseline condition (i.e., unique cued) with monosyllabic nonwords actually trends downward across epochs, albeit non-significantly. However, in the final epoch, stem completion performance in the repeating uncued condition remains at the level of performance in the unique baseline condition in the first epoch. Thus, the decreasing trend in performance across epochs leads to a difference in stem completion ability between these conditions in the final epoch. In contrast, stem completion performance in the unique baseline condition (i.e., unique cued) with disyllabic nonwords is at floor across epochs, thus resulting in no difference in stem completion ability between these conditions in the final epoch.

Again, further research is needed to determine what factors in particular account for this benefit from deliberate learning. The current experiments cannot distinguish between a few possible factors, including knowing which items are to be learned and whether the stem completion testing affects learning directly and/or whether it affects processing during subsequent exposure.

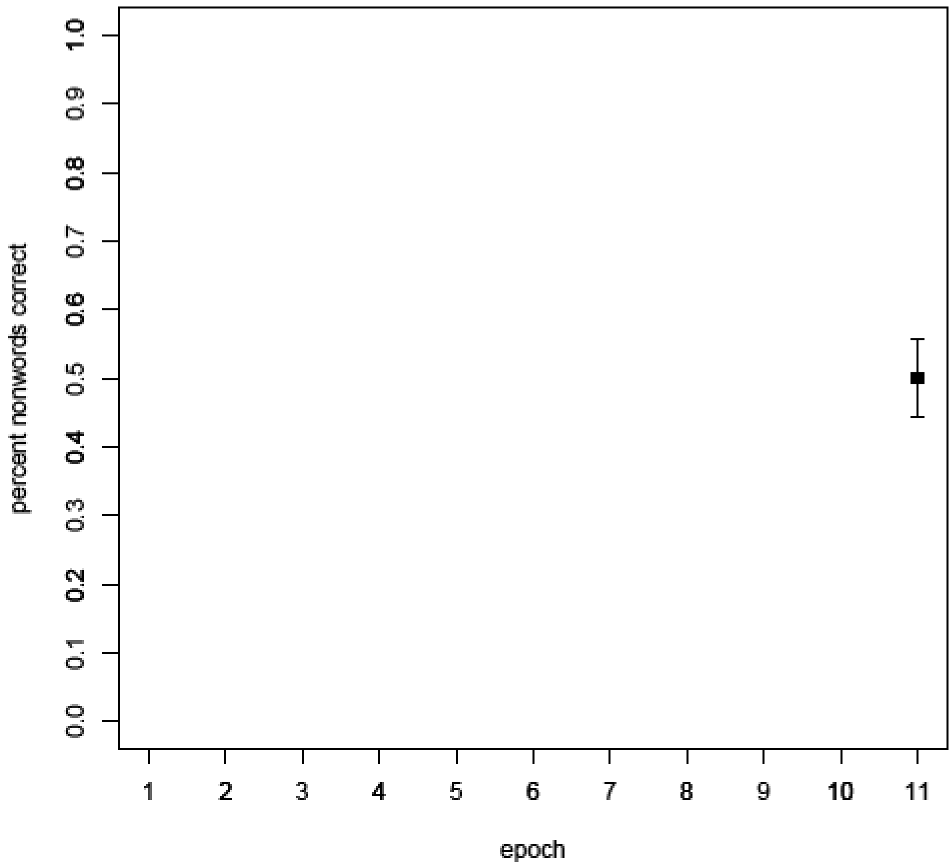

Figure 12. Experiment 5: Online scoring stem completion accuracy across epochs.

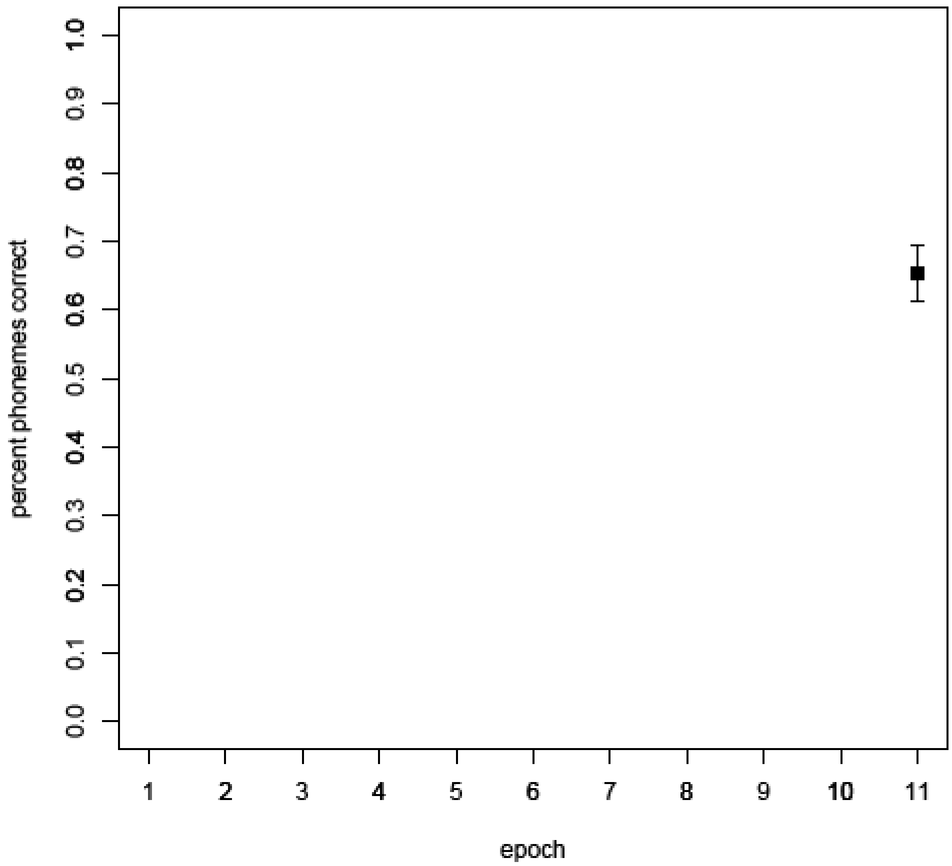

Figure 13. Experiment 5: Phoneme scoring stem completion accuracy across epochs.

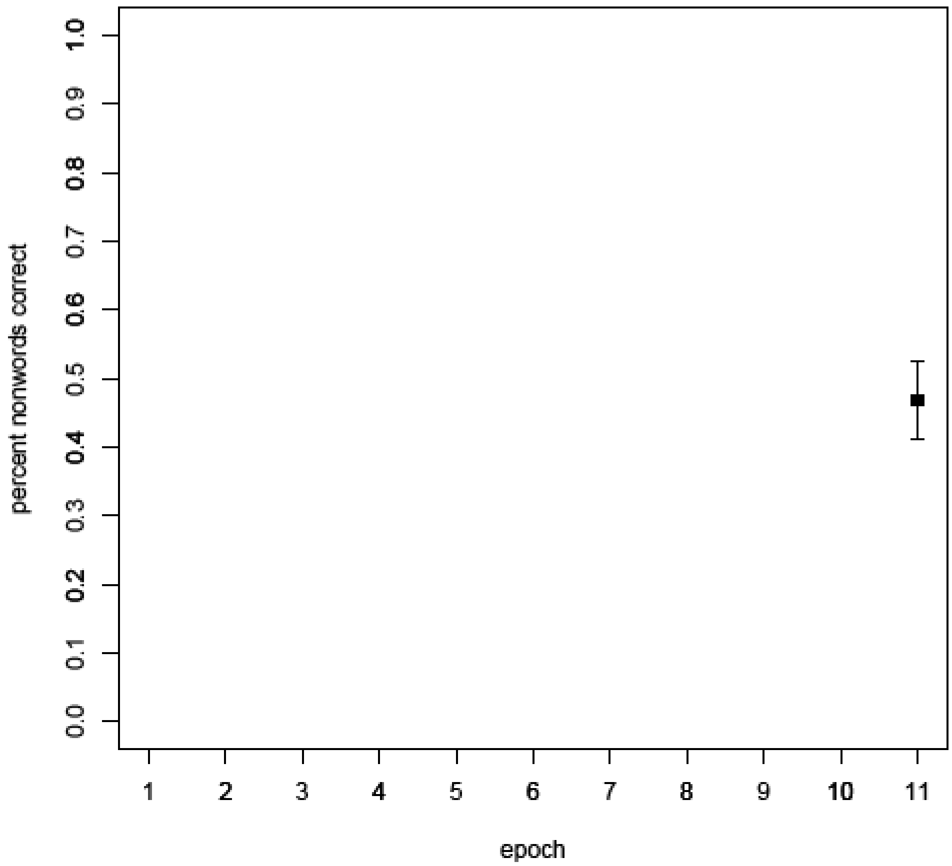

Figure 14. Experiment 5: Holistic scoring stem completion accuracy across epochs.

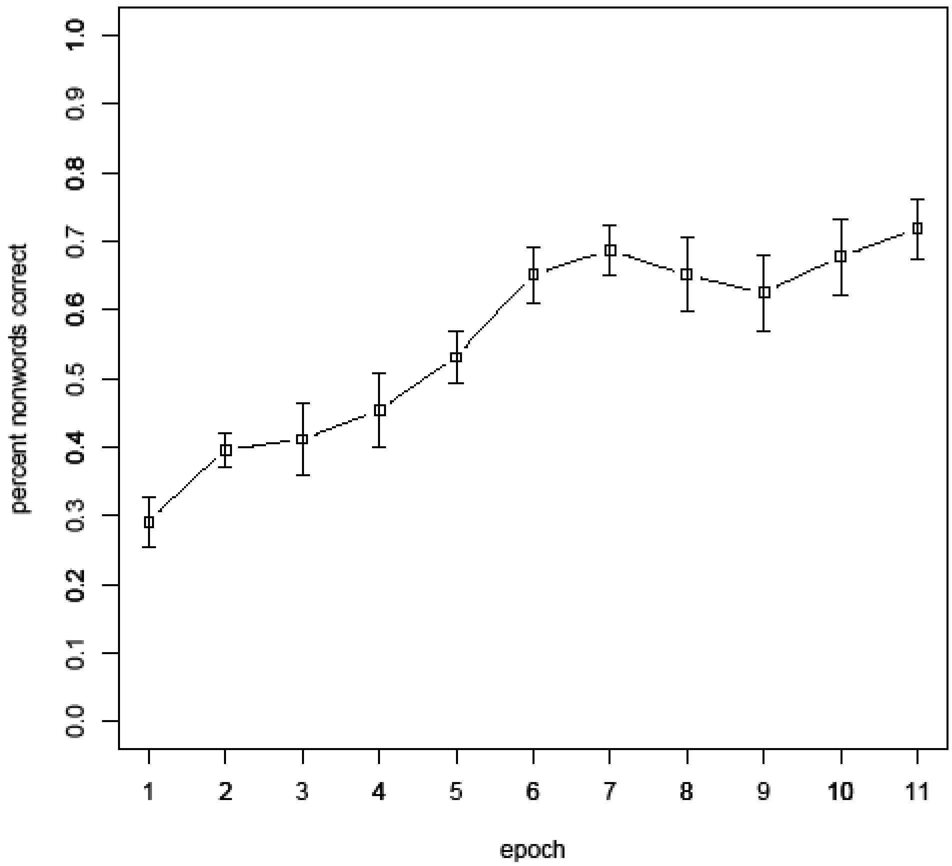

Figure 15. Experiment 6: Online scoring stem completion accuracy across epochs.

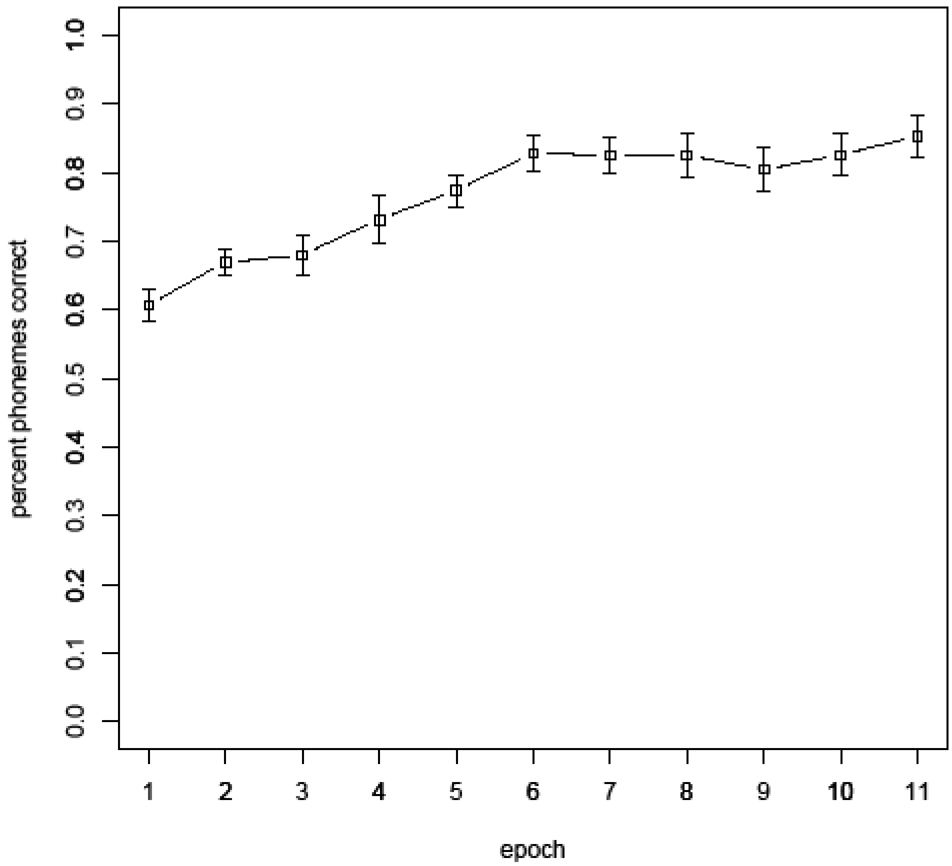

Figure 16. Experiment 6: Phoneme scoring stem completion accuracy across epochs.

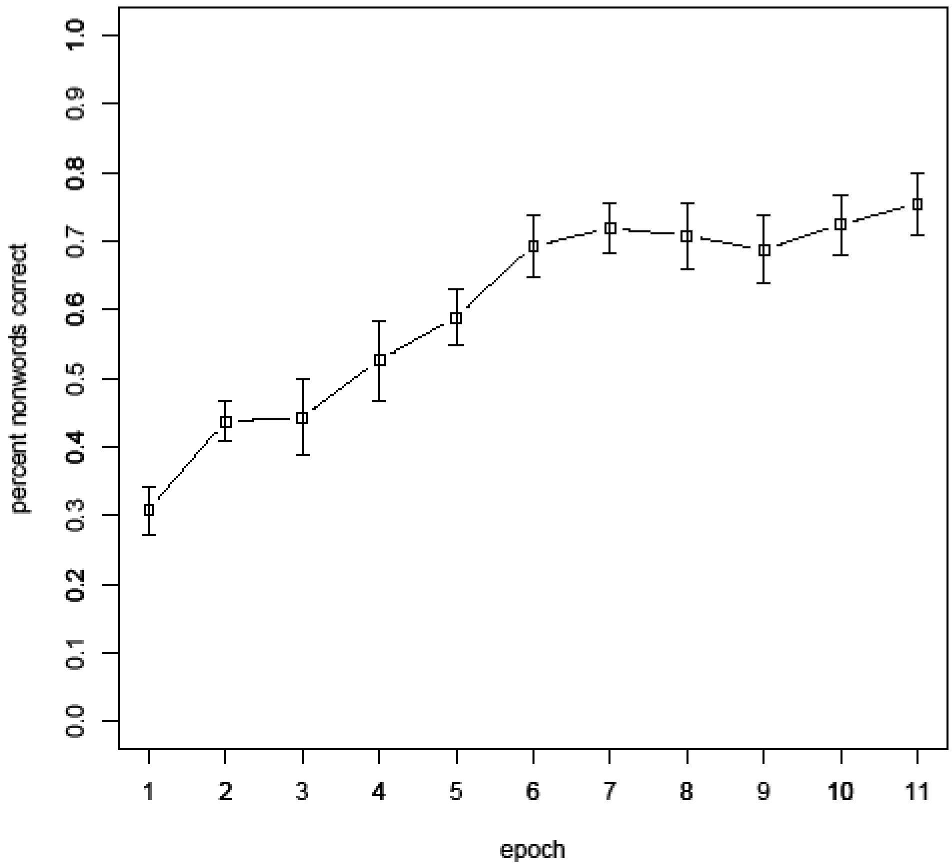

Figure 17. Experiment 6: Holistic scoring stem completion accuracy across epochs.

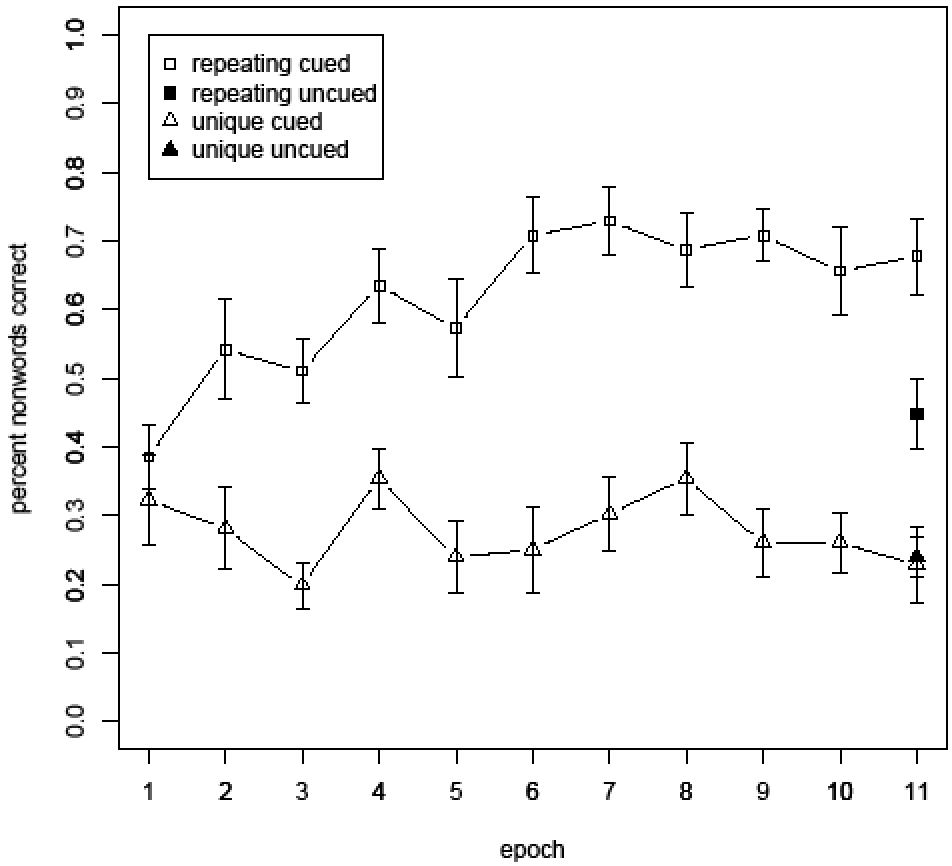

Figure 18. Experiment 7: Online scoring stem completion accuracy across epochs.

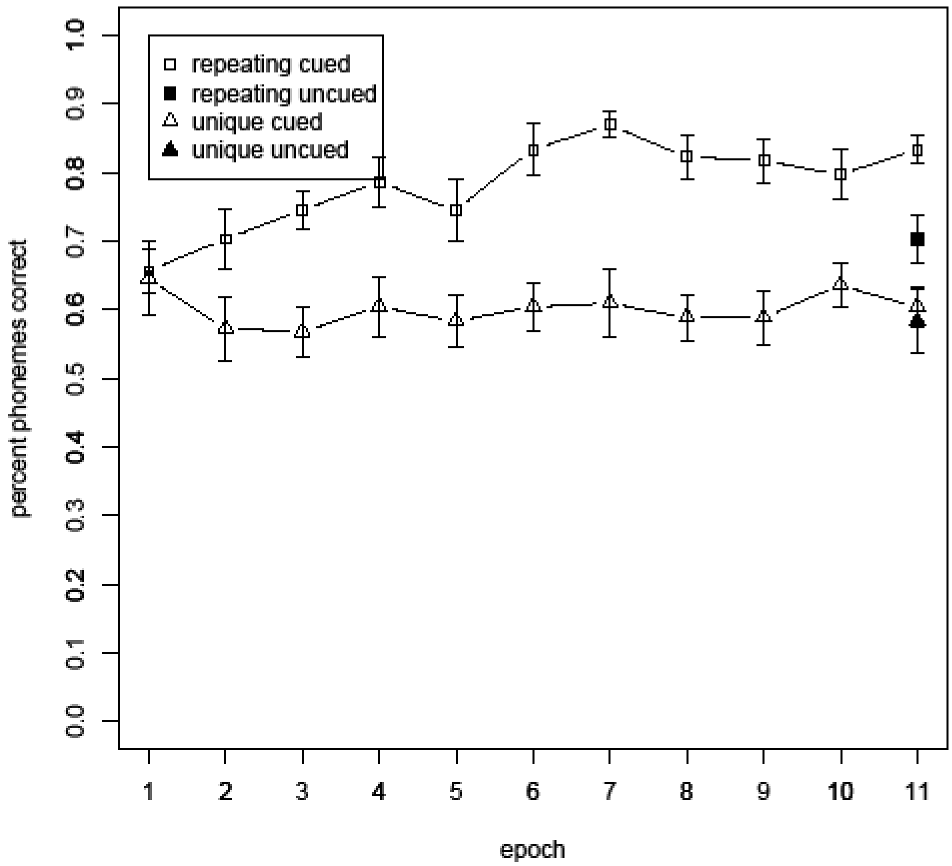

Figure 19. Experiment 7: Phoneme scoring stem completion accuracy across epochs.

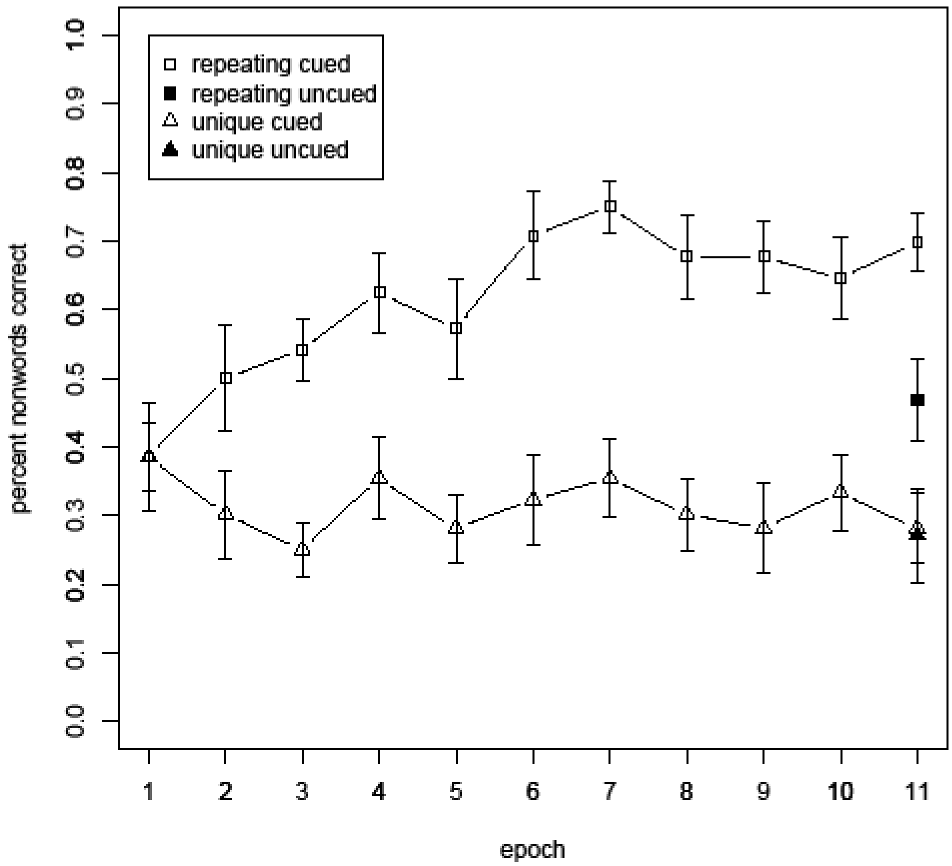

Figure 20. Experiment 7: Holistic scoring stem completion accuracy across epochs.

GENERAL DISCUSSION

The goal of this research project is to investigate phonological word-form learning, independent of semantics, after differing types of training. Overall, the current results suggest that incidental learning does not yield full mastery of phonological word-forms. It is surprising that extensive incidental learning did not improve performance given the vast amount of research on learning from brief exposure. For example, Saffran, Aslin, and Newport (1996) provide strong evidence that infants as young as 8-months-old can learn to segment words after only 2 minutes of exposure. In addition, brief auditory exposure is sufficient for learning phonotactic constraints in both adults (Onishi, Chambers, and Fisher, 2002) and infants (Chambers, Onishi, and Fisher, 2003). This seems to suggest that although incidental learning is sufficient for many other types of information, it is not sufficient for phonological word-form learning.

The finding that phonological learning resulting from deliberate learning is greater than that from incidental learning has implications for accounts of phonological learning as well as future research. For starters, theories of phonological learning need to account for this difference. In addition, it seems to be established that newly learned word-forms do not engage in lexical competition immediately after training, but only after sleep (presumably involving consolidation processes) (Davis, et al., 2009; Gaskell and Dumay, 2003; and Tamminen and Gaskell, 2008). However, since training in these experiments was limited to incidental learning, it is possible that this only accounts for half of the story. Furthermore, there is some evidence of newly learned word-forms engaging in lexical competition after training that included stem completion without sleep (Lindsay and Gaskell, 2009).

REFERENCES

Abbs, B., Gupta, P., and Khetarpal, N. (2008). Does overt repetition facilitate word learning? The role of overt repetition in word learning with and without semantics. *Applied Psycholinguistics, 29*: 627-667.

Carrier, M. and Pashler, H. (1992). The influence of retrieval on retention. *Memory & Cognition, 20*: 633-642.

Chambers, K. E, Onishi, K. H., and Fisher, C. (2003). Infants learn phonotactic regularities from brief auditory experience. *Cognition, 87*:B69-B77.

Davis, M. H., Di Betta, A. M., Macdonald, M. J. E., and Gaskell, M. G. (2008). Learning and consolidation of novel spoken words. *Journal of Cognitive Neuroscience, 21*:803-820.

Dell, G.S., Reed, K.D., Adams, D.R. and Meyer, A.S. (2000). Speech errors, phonotactic constraints, and implicit learning: A study of the role of experience in language production. *Journal of Experimental Psychology: Learning, Memory and Cognition, 26*:1355-1367.

Desrochers, A., and Begg, I. (1987). A theoretical account of encoding and retrieval processes in the use of imagery-based mnemonic techniques: The special case of the keyword method. In M. A. McDaniel, and M. Pressley (Eds.), *Imagery and related mnemonic processes*. Berlin: Springer-Verlag.

Gaskell, M. G., and Dumay, N. (2003). Lexical competition and the acquisition of novel words. *Cognition, 89*:105-132.

Gathercole, S.E. (2006). Nonword repetition and word learning: The nature of the relationship. *Applied Psycholinguistics, 27*:513-543.

Gupta, P. (2005). What's in a word? A functional analysis for word learning. *Perspectives on Language Learning and Education, 12*:4-8.

Gupta, P. and Cohen, N.J. (2002). Theoretical and computational analysis of skill learning, repetition priming, and procedural memory. *Psychological Review, 109*:401-448.

Gupta, P., and Dell, G. S. (1999). The emergence of language from serial order and procedural memory. In B. MacWhinney (Ed.), *The emergence of language*, 28th Carnegie Mellon Symposium on Cognition. Mahwah, NJ: Lawrence Erlbaum.

Karpicke, J. D. and Rodiger, H. L. (2008). The critical importance of retrieval for learning. *Science, 319*: 966-968.

Leach, L. and Samuel, A. G. (2007). Lexical configuration and lexical engagement: When adults learn new words. *Cognitive Psychology, 55*:306-535.

Lindsay, S. and Gaskell, M. G. (2009). Spaced learning and the lexical integration of novel words. In N.A. Taatgen and H. van Rijn (Eds.), *Proceedings of the 31st Annual Conference of the Cognitive Science Society*. (pp. 2517-2522). Austin, TX: Cognitive Science Society.

Onishi, K.H., Chambers, K.E., and Fisher, C. (2002). Learning phonotactic constraints from brief auditory experience. *Cognition, 83*:B13-B23.

Saffran, J. R., Aslin, R. N. & Newport, E. L. (1996). Statistical learning by 8-month-old infants. *Science. 274*, 1926-1928.

Saussure, F. de. (1916). *Cours de linguistique generale*. Paris: Payot.

Tamminen, J. and Gaskell, M. G. (2008). Newly learned spoken words show long-term lexical competition effects. *The Quarterly Journal of Experimental Psychology, 61*:361-371.