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Word Learning by Preschoolers with SLI: Effect of Phonotactic Probability and Object Familiarity

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Abstract

Purpose—This study investigated whether previous findings of a low phonotactic probability/ unfamiliar object word learning advantage in preschoolers could be replicated, whether this advantage would be apparent at different 'stages' of word learning, and whether findings would differ for preschoolers with specific language impairment (SLI) and typical development (TD).

Method—One hundred fourteen children participated: 40 with SLI, 39 with TD matched for age and gender, and 35 with TD matched for expressive vocabulary and gender. Comprehension and production were assessed during word learning and at post-test for words that varied in phonotactic probability and object familiarity.

Results—Across groups, comprehension performance increased significantly from days 1–3, but there was no significant word/object type effect. Production performance increased significantly for days 1–4 for all groups and there was a clear *low phonotactic probability/unfamiliar object* advantage during word learning, but not at post-test.

Conclusions—Results help to establish that preschoolers with TD and SLI show a low phonotactic probability/unfamiliar object production advantage during word learning that is not restricted to the first few exposures to words, but continues over time. This study illustrates how the interaction of phonological characteristics in nascent and extant words can affect word learning.

A growing number of researchers are evaluating the effect that phonotactic probability and neighborhood density have on word learning by young children. Phonotactic probability is the likelihood that a particular sound sequence will occur within a language. Neighborhood density is indexed by the number of stored words in the lexicon that differ by only one phoneme from a particular word. These word form characteristics, along with the semantic representations they refer to and the links between representations, are an important area of study in children with specific language impairment (SLI) because many children with SLI demonstrate word learning problems that have been attributed to difficulty creating, storing, and linking phonological and semantic representations. For a detailed review of these findings and the different methods used in word learning studies to date, see the meta-analysis recently published by Kan and Windsor (2010).

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It is challenging to study the impact of phonotactic probability and neighborhood density on word learning because they are correlated (Storkel, 2004; Vitevitch, Luce, Pisoni, & Auer, 1999), making it difficult to separate their effects. Further, results vary depending on whether comprehension or production of new words is measured. Add to this the likelihood that phonotactic probability and neighborhood density have different effects on earlier and later stages of word learning and that different characteristics may have more prominent effects at different developmental levels, and the picture becomes quite complicated.

Nevertheless, an interesting but changing picture of the effect of phonotactic probability and neighborhood density on word learning by preschoolers is emerging. We know that word learning is an ongoing process that is initiated when a child encounters a word for the first time and, if all goes well, creates initial phonological and semantic representation and links between them. In many studies this is referred to as ‘fast mapping’ (Carey & Bartlett, 1978). With additional exposures the phonological (single sounds in the word), lexical (whole-word form) and semantic representations (meaning) are strengthened. This extended process is referred to as word learning or ‘slow mapping’ (Carey, 1978). Evidence suggests that fast mapping and word learning are part of a learning continuum (Capone & McGregor, 2005; Horst, McMurray & Samuelson, 2006), but also that they represent distinct processes that may be differentially affected by word form characteristics (Hoover, Storkel & Hogan, 2010; Storkel & Lee, 2011) and by the semantic characteristics of referents or actions that children learn to name (Alt, Plante & Creusere, 2004; Alt and Plante, 2006; Gray & Brinkley, 2011; Horst, Scott, & Pollard, 2010; Storkel & Adlof, 2009).

Word Form Representations

Early studies of word learning by preschoolers suggested that words with higher phonotactic probability (aka common words) were learned better than words with lower phonotactic probability (aka rare words), although phonotactic probability was manipulated in conjunction with neighborhood density in these studies. For example, Storkel (2001) studied referent identification, form identification, and picture naming following 1, 4, and 7 exposures to noun nonwords varying in phonotactic probability in 3–6 year olds with typical development (TD). Significant main effects for phonotactic probability were found across all three measures, with a higher proportion of correct responses for higher than lower phonotactic probability nonwords; however, post hoc analyses of naming performance indicated that the higher vs. lower phonotactic probability advantage was only significant at 1 week post exposure. Storkel (2003) used the same methods as Storkel (2001), except that preschoolers learned names for actions (verbs) rather than referents (nouns). No main effect was found for phonotactic probability for referent identification or form identification; however, a significant main effect for phonotactic probability was found for picture naming, with a higher proportion of nonwords with higher than lower phonotactic probability produced correctly. It was not clear whether there was a higher vs. lower phonotactic probability advantage at each time point. Finally, Storkel and Maekawa (2005) compared homonym and novel word learning for names of unusual objects in 3–5 year olds with TD using words with higher or lower phonotactic probability. As in previous studies, learning was assessed after 1, 4, and 7 exposures, then again 1 week later, on referent identification and picture naming tasks. The main effect of phonotactic probability was significant (in a four-way ANOVA that included both referent identification and picture naming), with children providing more correct responses to higher than lower phonotactic probability words.

Together these studies indicated an overall learning advantage for higher than lower phonotactic probability words, primarily on naming tasks; however, this advantage may have been due to larger differences one week after word learning ended than at earlier time points. It is also important to point out that with only seven exposures, these studies may be more similar to fast mapping than word learning studies reported in the literature (see Kan & Windsor, 2010 for a discussion).

In contrast to these earlier studies, more recent reports evaluating the impact of phonotactic probability in preschoolers with TD suggest that phonotactic probability may not affect fast mapping comprehension or production (Gray & Brinkley, 2011) and that *low* phonotactic probability (rare) words are learned better than high phonotactic probability (common) words when referent identification (comprehension) is assessed immediately following word learning (Gray & Brinkley, 2011; Storkel & Lee, 2011) and at a one-week follow up (Storkel & Lee, 2011). Similarly, low phonotactic probability words were learned better than high phonotactic probability words when naming (production) was assessed in 5-year-olds (Hoover, Storkel, & Hogan, 2010) and groups of preschoolers immediately following word learning (Gray & Brinkley, 2011), but not until one week later for 3- and 4-year olds (Hoover, Storkel, & Hogan, 2010). Interestingly, this *low* phonotactic probability advantage was also found in a study investigating word learning in adults (Storkel, Armbruster, & Hogan, 2006) and in infants who demonstrated earlier learning of words with low vs. higher phonotactic probability (Storkel, 2009).

When Storkel, Armbruster and Hogan (2006) first encountered a *low* phonotactic probability word learning advantage in adults, they suggested that the advantage might be unique to word learning because their findings contrasted with a high phonotactic probability advantage found in adult studies of word recognition, production and recall. They hypothesized that phonotactic probability plays an important role in ‘triggering’ new word learning such that low phonotactic probability words ‘stand apart’ from known words, helping people realize that they have encountered a new word. They situated their low phonotactic probability advantage findings for adults, and subsequently for preschoolers (Hoover, Storkel & Hogan, 2010), in the adult word learning work of Leach and Samuel (2007), who proposed two word learning processes for adding words to the mental lexicon – ‘lexical configuration’ and ‘lexical engagement.’ According to Leach and Samuel, lexical configuration includes factual knowledge associated with a word (e.g. sounds, semantics, spelling and syntactic role) and lexical engagement is the dynamic interaction between the newly learned word and other lexical and sublexical entries already stored in the lexicon. From Storkel’s perspective (e.g. Storkel, 2011), it is important to differentiate these word learning processes because phonotactic probability and neighborhood density may interact differently with each process. It is not clear that differentiating these processes could resolve the discriminant earlier and later phonotactic probability research findings, but it points to the necessity of carefully describing what we measure in word learning and raises the interesting possibility of testing this kind of word learning model experimentally.

Because of their word learning difficulties, it is possible that children with SLI might be affected differently by phonotactic probability and neighborhood density than children with TD; however, our recent study with a preschool SLI group showed the same low over high word learning advantage for both comprehension and production in word learning (Gray & Brinkley, 2011), suggesting that word form characteristics did not differentially affect children with SLI and TD. Because the Gray and Brinkley study is the only one to date to examine the effect of phonotactic probability on word learning by children with SLI, the current study represents an important opportunity to replicate those findings.

Semantic Representations

Just as word form characteristics impact word learning, so do the semantic characteristics of the referents children are learning to name. An earlier study by Gray (2005) found that if children already had a stored semantic representation for a word (e.g. dog), it appeared easier to learn a new phonological word form and to link it to the stored semantic representation (e.g. dalmation) than to learn both a new word form and semantic representation. However, that study did not control or manipulate phonotactic probability and a later study by Gray and Brinkley (2011) found that words with low segments naming unfamiliar objects (children had no stored name for the object) were comprehended and produced better than words with high phonotactic probability segments naming familiar objects (children already had a name for the object), although the effect for phonotactic probability was more pronounced than object familiarity. These results suggested that competition between stored and newly learned *word forms* negatively impacted word learning, and that word form and semantic representations potentially interact to influence word form learning. No effect of phonotactic probability or object familiarity was found for fast mapping in that study.

In a manipulation of semantic representations a study by Storkel and Maekawa (2005) investigated whether having a stored word form affected the ability to learn a *new semantic representation* for a word. In that study of preschoolers, homonyms of familiar words were easier to learn than novel words, presumably because learning a homonym only required the establishment of a new semantic representation for the word, but learning a novel word required establishment of new phonological and semantic representations.

Storkel and Adlof's (2009) recent word learning experiment illustrated the negative effect that stored semantic representations can have on word learning. They found that it was easier for children with TD to identify (comprehend) and name objects from small vs. large semantic sets. They hypothesized that when children saw objects similar to ones they were learning to name (large semantic set), competing semantic representations were activated and this created competition between the new semantic representation and previously stored representations.

Together word learning studies focused on word form representations and semantic representations highlight the need to attend to not only word form characteristics when studying word learning, but also semantic characteristics and the links between different types of representations.

Purpose

Given the diverse findings on the effects of phonotactic probability and neighborhood density in young children with TD and the lack of studies examining effects of these word form and semantic characteristics on word learning by preschoolers with SLI, the purpose of this study was to hold neighborhood density constant (no neighbors) while manipulating phonotactic probability and object familiarity. This study was a methodological replication of the Gray and Brinkley (2011) study, except that word encoding cues were not used. This provided the opportunity to replicate the low phonotactic probability/unfamiliar word advantage found in our earlier study of children with TD and SLI using words with low neighborhood density sequences, and to replicate the low phonotactic probability advantage found by Storkel and Lee (2011) in their study of children with TD that used mid density words.

Because word learning was studied across four days with a post-task assessment on the fifth day, this permitted us to evaluate whether word form (phonotactic probability) and semantic characteristics (object familiarity) appeared to differentially influence the processes of ‘triggering’ (Storkel, 2011) and ‘configuration’ (Samuel & Leach, 2007) in children. If low phonotactic probability is important for triggering we would expect to see a low phonotactic probability advantage on the first of four word learning days when the words would stand

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out as a mismatch to other known words. This should be supported by the low neighborhood density of all words since none of them had lexical neighbors. Storkel (2011) hypothesized that a high phonotactic probability advantage should emerge during lexical configuration because words with high phonotactic probability sounds sequences are ‘maximally activated’ when the word is heard, and this provides support for working memory retention, resulting in enhanced storage in long-term memory. Configuration would also be helped by high neighborhood density, but that was not possible in this study because all words were low neighborhood density. If high phonotactic probability promotes configuration, we would expect to see this effect in days 2–3 of the study, resulting in a word/object type × time interaction with the advantage shifting from low to high phonotactic probability over time. It is not clear whether phonotactic probability affects engagement, which is assessed by measuring the impact that newly learned words have on other stored words in the lexicon. Based on our previous results, given the same level of phonotactic probability, we expected that words naming familiar objects would be harder to learn than words naming unfamiliar objects because the latter presented no lexical competition.

Method

Overview

This word learning study was part of a larger study of children’s vocabulary and semantic knowledge. Three groups of children participated – preschoolers with SLI (SLI group), preschoolers with TD matched individually to preschoolers with SLI by age (±3 months) and gender (AM group), and preschoolers with TD matched individually to preschoolers with SLI by raw vocabulary scores on the Expressive Vocabulary Test (EVT; Williams, 1997) (± 1SD) and gender (VM group). During word learning the same four names were taught each day for four days. Word learning comprehension and production were probed each day. Two objects children learned to name were familiar – they already knew names for them - and two were unfamiliar. Two words contained high-frequency sublexical sequences and two contained low-frequency sublexical sequences.

Participants

One hundred fourteen children participated: 40 with SLI, 39 with TD matched for age and gender, and 35 with TD matched for expressive vocabulary and gender. Children were between the ages of 3;2 (years; months) and 5;8 and spoke English as their primary language according to parent report. No child was bilingual. Six children in each of the three groups were of Hispanic ethnicity. The SLI group included children of Asian (1), African American (1), white (25), more than one (12) and unknown (1) races. The AM group included children of American Indian (2), Asian (2), African American (3), white (28), more than one (3), and unknown (1) races. The VM group included children from Asian (1), African American (2), white (22), more than one (9), and unknown (1) races. Table 1 provides additional descriptive information about the three participant groups. Parents consented to their child’s participation in the study per university Internal Review Board requirements for human subjects’ protection.

The SLI group was recruited from local public and private preschools and the TD groups from public and private preschools and daycare centers. To be included in the study children with SLI were required to qualify for special education services for language impairment at their school. In Arizona children must score more than 1.5 *SDs* below the mean on two norm-referenced language tests to qualify for these services. All children met the following criteria as determined by an ASHA certified speech-language pathologist:

1. Hearing within normal limits bilaterally (25 dB HL) at 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz (American National Standards Institution [ANSI], 1989).

2. Normal nonverbal intelligence as indicated by a standard score of 75 or above on the Nonverbal scale of the K-ABC-II (Kaufman & Kaufman, 2004).
3. For children with SLI, no evidence of serious neurological problems or developmental disorder other than language, articulation, or phonological problems, as reported by the parent and teacher.
4. Adequate speech intelligibility for applying the scoring procedures.
5. For the AM and VM groups, normal speech, language, motor, and cognitive development as reported by parent and teacher.

Additional tests were administered by a certified speech-language pathologist to describe the speech and language skills of all participants. These included the Peabody Picture Vocabulary Test—3rd Edition (PPVT-III; Dunn & Dunn, 1997); the EVT; the Structured Photographic Expressive Language Test—3rd Edition (SPELT-III; Dawson & Eyer, 2003) or the Structured Photographic Expressive Language Test—Preschool Second Edition (SPELT-P2; Dawson, Stout, Eyer, Tattersall, Fonkalsrud & Croley, 2005) depending on the age of the child; the Antonyms, Sentence Completion and Paragraph Comprehension subtests of the Comprehensive Assessment of Spoken Language (CASL; Carrow-Woolfolk, 1999), and the Bankson-Bernthal Test of Phonology (BBTOP; Bankson & Bernthal, 1990). Scores and between-group comparisons are reported in Table 1. To calculate scoring reliability, 10% of the assessments were scored by a second speech-language pathologist (SLP). Average point-to-point scoring agreement on the standardized assessments was 97.53% (range 88.13–100%).

Dollaghan and Campbell's (1998) 16-item nonword-repetition task was administered to assess short-term phonological memory. Nonwords were presented using a laptop computer via headphones with an attached microphone. Children's repetitions were recorded into digital audio files. Trained research assistants listened to the audio files, transcribed children's productions, and calculated the percent phonemes correct for each child. Distortions and sound additions were scored as correct - substitutions and omitted phonemes were scored as errors. To calculate nonword scoring reliability 22% of the children's files – about 1/3 from each group - were double scored by a second research assistant. The mean point-to-point agreement for the percent phonemes correct for each word was 98% (range: 84.4–100%).

Assessment results indicated that the AM and VM groups scored significantly higher than the SLI group on all speech, language, nonverbal cognitive and short-term phonological memory measures except the Paragraph Comprehension subtest of the CASL and the Antonyms subtest of the CASL (see Table 1). Despite these group differences, the SLI group mean was within 1 SD of the normative mean on all tests except the BBTOP and the SPELT-2. This suggests that the SLI group demonstrated expressive language impairment and speech sound disorders as indexed by the BBTOP, but receptive language and receptive and expressive vocabularies within the normal range.

Materials

Objects—Children learned names for objects selected from craft and hardware items. The selection process is described in Gray (2005). Objects that children and adults could name were considered familiar and objects they could not name were considered unfamiliar. Two familiar and two unfamiliar objects were included in the study. Additional common objects were included (e.g., shovel, monkey) to encourage children's participation in production tasks.

Words—Children learned one set of four words selected from a set of twelve two-syllable nonwords developed by Edwards, Beckman and Munson (2004) (see Appendix A). Sets were randomized across children in each group. Two words in each set contained a low-frequency sublexical sequence and two in each set contained a high-frequency sublexical sequence. None of the words had a phonological neighbor, thus they were all low neighborhood density. One high and one low word named a familiar object and one high and one low word named an unfamiliar object. In sum, each word set contained one word from each of the following categories: high phonotactic probability/familiar object, low phonotactic probability/familiar object, high phonotactic probability/unfamiliar object, and low phonotactic probability/unfamiliar object.

Play sets—The children and research assistants played with the target objects and Playmobile™ toys during each word learning session. Three Playmobile™ sets, including a beach, mining, and pirate theme, were counterbalanced across children so that each child played with one Playmobile™ set.

General Procedures

Children completed assessments during the first three days of the study then participated in a variety of vocabulary tasks over a three-week period. The order of participation in these tasks was counterbalanced across the children in each group so that one third completed the word learning study the first week, one third the second week, and one third the third week.

After training completion, research assistants demonstrated competence in administering and scoring the research protocol by obtaining 100% on a fidelity checklist. Master trainers then accompanied each research assistant to the first teaching session with children and scored the session to ensure that procedural fidelity and scoring reliability were 90% or higher. Research assistants were blind to group and were assigned children based on the convenience of where they and the children lived or attended school. Research assistants worked with one to seven children and children worked with one to three research assistants.

The word learning study required five days to complete. Words were taught using the same protocol for four days, then on the fifth day children completed comprehension, recognition, and production post-tests. Each word learning session lasted approximately 30 minutes. Children played with their research assistant in a quiet room at their school or home, where they sat at a child-sized table or on the floor.

Word Learning Procedures

The word learning task was organized into four blocks to assist Research assistants in their intervention delivery. During Block I the research assistant modeled the name of each target object as they handed it to the child, followed by an imitation prompt (e.g., “This is the [target]. .. say [target]”) and feedback (e.g., “Yes, [target word]”). A second model, imitation prompt, and feedback for each production followed. Next, the research assistant administered a comprehension probe for each of the target objects (e.g., “Hand me the [target word]”) followed by immediate feedback regarding the child’s accuracy of response (e.g., “Right, that’s the [target]” or, for an incorrect response, “Here’s the [target]”). Finally, the research assistant administered a production trial for each object (e.g., “What’s this?” or “What are you holding?”) with the same kind of feedback. The procedures for Blocks I, II and III were identical except that words were presented in different orders within each block. All objects were visible at all times. Children received one point for each correct response to a comprehension or production probe, with feedback regarding the accuracy of their responses (e.g., “Yes, that’s a [target word]” or “This is a [target word]”). Block IV differed from Blocks I, II, and III in that each word was modeled only once with only a single comprehension and production probe, plus feedback for each word. To summarize, during each word learning session children completed four comprehension and four production probes. Including imitation prompts, comprehension trials, and feedback, children heard each object name repeated 33 times.

Comprehension probes were scored correct if the child showed the research assistant the correct object. Production probes were scored correct if the child produced all of the target word's phonemes correctly or produced the same phonological variation of the word used in their imitation responses. These phonological variations must have also been observed on the child's productions on the BBTOP. To assess procedural and scoring reliability 20% of the experimental sessions were scored live or via videotape by a second research assistant. The mean point-to-point agreement for procedural fidelity was 98.2% (range 89.4–100%) and for scoring reliability was 98.7% (range 90.6–100%).

Post-Task Assessments

Comprehension, recognition, and production post-task assessments were administered on the fifth study day after four days of word learning. The order of administration was counterbalanced across children in each group. For *comprehension* the research assistant said a target name and children pointed to one of four colored photographs (one target and three foils) arranged in a 2 × 2 array on a page. The target and foil positions varied in relationship to each other. One foil depicted a play object present each day during word-learning, one depicted another target object, and one depicted an object the child hadn't seen before that was similar in shape and category to the target object.

For *recognition* and *production* a single photograph of the target object appeared in the middle of the page. For recognition the research assistant pointed to the picture and said, "Listen first then tell me the right name" then provided four names (one target, three foils), with the order of the target varying in relation to the foils. One foil was phonologically identical to the target word except that the initial consonant was changed to a consonant from a different category (e.g., a stop was substituted for a fricative), one foil was the name of another target object, and one foil was an unfamiliar two-syllable that was not used in the study. Children earned 1 point for each correct response on each assessment.

Results

Word Learning Comprehension and Production by Word/Object Type

Results for word learning comprehension and production were analyzed using separate mixed factorial ANOVAs with group (SLI, AM, VM) as the between-group factor and time (days 1, 2, 3, 4) and word/object type (high/familiar, low/familiar, high/unfamiliar, low/unfamiliar) as the within-group factors. The Greenhouse-Geisser Test was used for within-group comparisons. Estimated marginal means and standard errors for comprehension and production are reported in Tables 2 and 3. Planned post-hoc comparisons for significant main effects in each analysis employed a Bonferroni correction for multiple comparisons.

For comprehension a significant main effect was found for time $F(2.88, 837.70) = 67.16$, $p < .001$, $\eta_p^2 = .38$, but no significant between-group, word/object, or interaction effects. Results are illustrated in Figure 1. Post hoc analyses indicated that the mean number of correct responses for Day 2 (M =2.94) was significantly higher than the mean for Day 1 (M =2.38) ($p < .001$) and the mean for Day 3 (M =3.21) was significantly higher than the mean for Day 2 ($p < .001$). The means for Day 3 and Day 4 (M =3.30) did not differ significantly.

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For production a significant main effect was found for time $F(2.59, 867.71) = 188.45$, $p < .001$, $\eta_p^2 = .63$ and word/object type $F(2.85, 867.71) = 3.63$, $p = .015$, $\eta_p^2 = .032$, but no significant between-group differences and no interactions. Post hoc analyses indicated that the means for the number of correct responses each day were significantly higher than the day before (Day 1 *M* = .33; Day 2 *M* = 1.12; Day 3 *M* = 1.55; Day 4 *M* = 2.05; all *p*s < .001) (see Figure 2) and that the mean for low/unfamiliar words (*M* = 1.51) was significantly higher than all other word types (low/familiar *M* = 1.17, *p* = .02; high unfamiliar *M* = 1.23, *p* = .03; high/familiar *M* = 1.13, *p* = .006), which did not differ (see Figure 3). Generally, across word learning analyses, effect sizes indexed by η_p^2 were small.

Post-Task Assessment of Comprehension, Recognition and Production

Children completed comprehension, production, and recognition post-tasks at the end of word learning. Each child was assessed on one word from each of the four word/object types on each of the three tasks. We analyzed the effect of word/object type on post-task responses in comprehension, production, and recognition using separate two-way contingency table analyses. For these analyses groups were collapsed because there were no significant between-group differences. The two variables in the analyses were the word/object type with four levels (high/familiar, low/familiar, high/unfamiliar, low/unfamiliar) and response with two levels (incorrect, correct). For comprehension the relationship between the word/object type and the response was not statistically significant Pearson χ^2 (3, *N* = 445) = 4.87, *p* = .18. For production and recognition similar results were found. No significant relationship was found for production Pearson χ^2 (3, *N* = 456) = .70, *p* = .87 or recognition Pearson χ^2 (3, *N* = 456) = 6.54, *p* = .09. The Chi-square results suggest that the low/unfamiliar over high/familiar production advantage was not carried into post-task performance.

Discussion

The purposes of this study were to determine whether previous findings of a low phonotactic probability/unfamiliar object word learning advantage could be replicated in a study with preschoolers, whether this advantage would be apparent at different ‘stages’ of word learning, and whether findings would differ for children with SLI and TD who differed in age and vocabulary level. We hypothesized that results for the first day of word learning could reasonably reflect Samuel and Leach’s (2007) triggering process and that results for days 2–4 and the post test could reflect the configuration process.

Across groups children’s comprehension performance increased significantly from days 1–3, but there was no significant word/object type effect. Production performance increased significantly for days 1–4 for all groups and there was a clear *low* phonotactic probability / unfamiliar object advantage during word learning, but not at post-test.

The finding of no word/object effect for *comprehension* differed from our previous study (Gray & Brinkley, 2011) where words with low probability sequences naming unfamiliar objects (low/unfamiliar) had more correct responses than those with high probability sequences naming familiar objects (high/familiar). In that study we hypothesized that low/unfamiliar words were learned best because they stood out in contrast to known words and because no previously stored name for the object competed for recall. There were two notable differences in the earlier and present study that could impact findings. The dependent variable in Gray and Brinkley was performance on the final day of word learning (vs. across 4 days of word learning) and performance was collapsed across conditions so that results reflected learning for 3 low/unfamiliar words compared to 1 low/unfamiliar word in this study. Fewer words could reduce the ability to detect this effect. We wondered whether our current findings would differ if we analyzed performance on the fourth day of word learning as in the previous Gray and Brinkley study; however, an analysis of that data showed that the main effect was not significant (p=.052).

The current comprehension results also differed from Storkel and Lee (2011), who taught 10 different words. They found that children learned words with low phonotactic probability (rare words) better than those with high phonotactic probability (common words) at the end of their training cycle, with the low phonotactic probability advantage retained at post-testing. It is important to note that our words contained a low phonotactic probability *sequence*, whereas Storkel and Lee's phonotactic probability calculation was based on all phonemes in the word. For that reason and because they sampled more words, it is likely that Storkel and Lee had a better chance of detecting phonotactic probability effects on comprehension than we did in this study; therefore, we do not interpret our lack of significant findings as evidence against a low phonotactic probability effect for comprehension learning and suggest that it is important to replicate Storkel and Lee's methodology more closely in future studies of children with SLI and their younger-matched peers.

Production findings suggested a *low* phonotactic probability/unfamiliar object advantage for word learning, but not at post testing. It is important to note that children had the opportunity to respond to only one token for each word/object type, which could limit the ability to detect an effect. The word learning results are consistent with Gray and Brinkley (2011), except that the low/unfamiliar effect was also present at post testing in that study when children had the opportunity to respond to three tokens of each word type. Results cannot be compared to Storkel and Lee (2011) because production performance in that study was too low to analyze. If low phonotactic probability is important for triggering, but high phonotactic probability is important for configuration, we would not expect this pattern of results unless the triggering advantage persists over time (H. Storkel, personal communication, December 15, 2011). Instead, it appears that low phonotactic probability promotes word learning as exposures accumulate. These results are consistent with Storkel and Lee's comprehension results for four-year-olds with TD and show that the low phonotactic probability advantage was also present in younger children with TD and 4–5 year olds with SLI. Together these results suggest that factor(s) other than phonotactic probability may differentially influence triggering (Storkel, 2011), configuration, and engagement processes (Leach & Samuel, 2007). Storkel and Lee argued that neighborhood density is one of those factors. They found a low (sparse) neighborhood density advantage at completion of training that decreased between the end of training and retention testing one week later, but a high (dense) neighborhood density word advantage apparent only at retention testing. In our study we held low neighborhood density (no neighbors) constant to permit examination of word/object effects. Based on Storkel and Lee's findings, low neighborhood density would be expected to promote word learning in this study. Because we did not manipulate neighborhood density we do not know whether the low phonotactic probability /unfamiliar object production advantage would remain if words were taken from higher density neighborhoods.

We propose that object familiarity (already having a name for an object) is another factor affecting triggering and configuration. In this and our previous study (Gray & Brinkley, 2011), children learned to produce low/*unfamiliar* words better than low/*familiar* words. This would be the expected result for the triggering process because children are more likely to realize they do not have a name for an unfamiliar object. We also expected an unfamiliar advantage for the lexical engagement process when, according to Leach and Samuel (2007), factual knowledge about a word accrues, including knowledge of the word's sounds and meaning. When the child hears the word associated with a familiar object in their view, presumably the stored phonological and semantic representations associated with the object

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are activated and compete for retrieval with the new phonological representation, likely inhibiting storage and retrieval of the new word. Thus, our current results are consistent with the idea that learning the name for an unfamiliar object is easier than a familiar object over time. We did not have a measure of lexical engagement in this study that would show whether adding these new words to the lexicon impacted other words. One potential way to accomplish this would be to show that the new words primed comprehension or production of related words. This would be an interesting manipulation in future studies.

We taught words in a ‘supported learning context’ that was designed to insure that all children in the study learned to comprehend and produce at least some words. Children received multiple models of words over several days and feedback about their responses while they played with the objects they were learning to name. They were asked to repeat the words many times. In this and a previous study (Gray & Brinkley, 2011) we found no between-group differences in word learning performance. Although this seems unusual, the language test scores reported in Table 1 indicated that the SLI group was language impaired. Thus, we conclude that the characteristics of the words and objects and the teaching methodology combined to make it possible for the SLI group to learn as many words as their age- and gender-matched peers with TD and for the younger children with TD to learn as many words as their older peers with TD. Importantly, just as in the Gray and Brinkley study with preschoolers, low phonotactic probability in conjunction with object familiarity appeared to promote word learning for all children.

Conclusions

Results of this study, in conjunction with Gray and Brinkley (2011), help to establish that preschoolers with TD and SLI show a low phonotactic probability/unfamiliar object production advantage during word learning that is not restricted to the first few exposures to words, but continues over time. These studies show how the interaction of phonological characteristics in nascent and extant words can affect word learning.

When considered in the context of previous word learning research, it is also clear that multiple factors affect word learning and that each should be controlled and manipulated in word learning research. These include the form characteristics of phonotactic probability and neighborhood density (Hoover, Storkel & Hogan, 2010; Storkel & Lee, 2011), the semantic characteristics of referents or actions that children learn to name (Alt, Plante & Creusere, 2004; Alt and Plante, 2006; Gray & Brinkley, 2011; Horst, Scott, & Pollard, 2010; Storkel & Adlof, 2009), and other factors impacting processing such as the number of words to be learned, the number of distractors present during learning assessments, the word learning context, and the distribution of teaching and testing within studies.

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Appendix A

Target Words and Objects

Description of Target Words and Objects

Object Type	Sublexical Frequency	Set A	PP	Set B	PP	Set C	PP
Unfamiliar	Low	/vugim/(copper tube)	−13.11	/moiped/(plastic plug)	−13.11	/jugoin/(bag clamp)	−12.42
	High	/maebep/(plastic wheel)	−8.09	/vIdaeg/(silver connector)	−8.73	/bogib/(wooden peg)	−9.71
Familiar	Low	/tedaum/(kind of orange)	−13.31	/donug/(kind of apple)	−13.31	/motauk/(kind of tree)	−13.31
	High	/bedaeg/(kind of flower)	−9.79	/petik/(kind of cactus)	−9.48	/podaud/(kind of nut)	−10.67

Note. PP= log transitional probabilities of target sequences in words calculated from the MHR database (Moe, Hopkins, & Rush,1982) as reported by Edwards, Beckham, and Munson (2004).

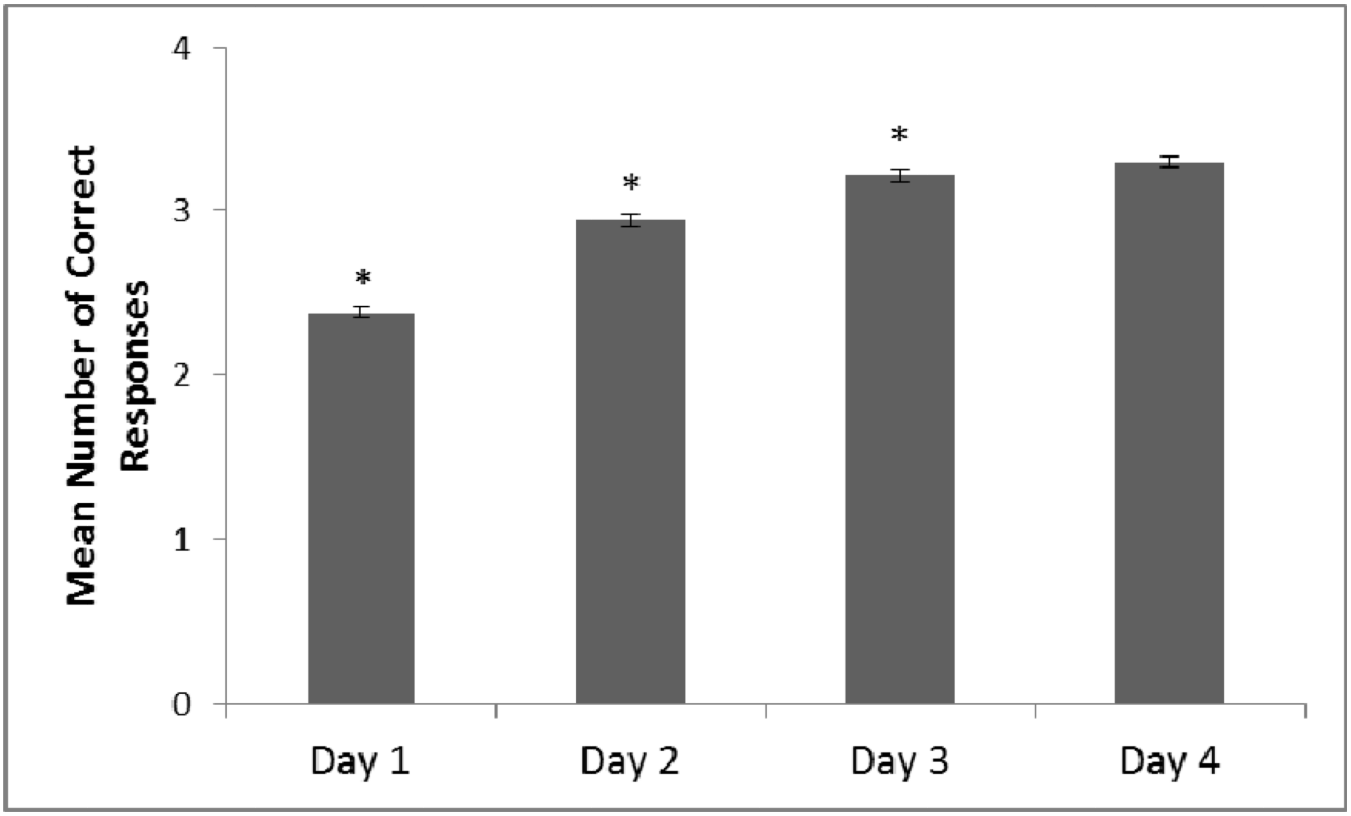

Figure 1.
Estimated marginal means for the number of correct responses to comprehension probes each day (maximum possible = 4). Error bars represent standard errors. * indicates means are significantly different at $p < .001$.

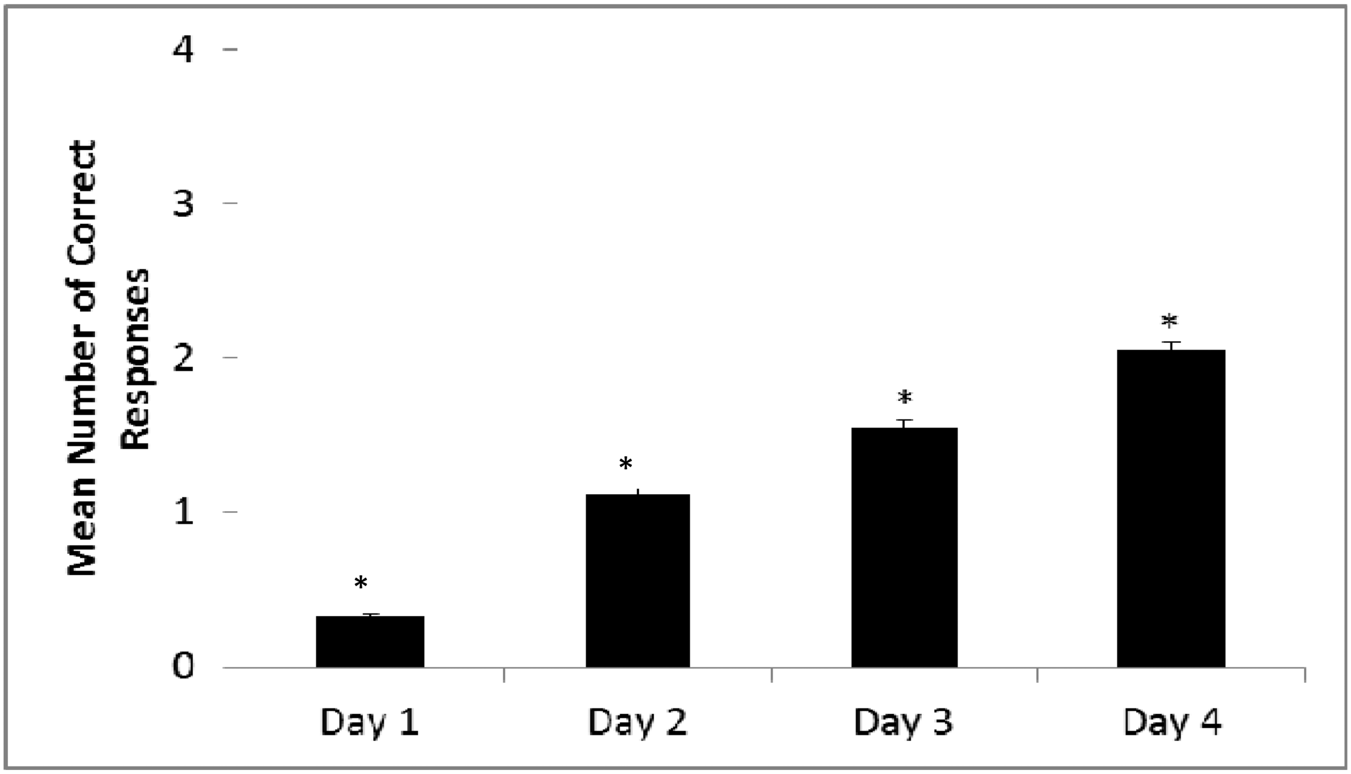

Figure 2.
Estimated marginal means for the number of correct responses to production probes each day of the study (maximum possible = 4). Error bars represent standard errors. * indicates means are significantly different at $p < .001$. Scores for each day were significantly higher than the preceding day.

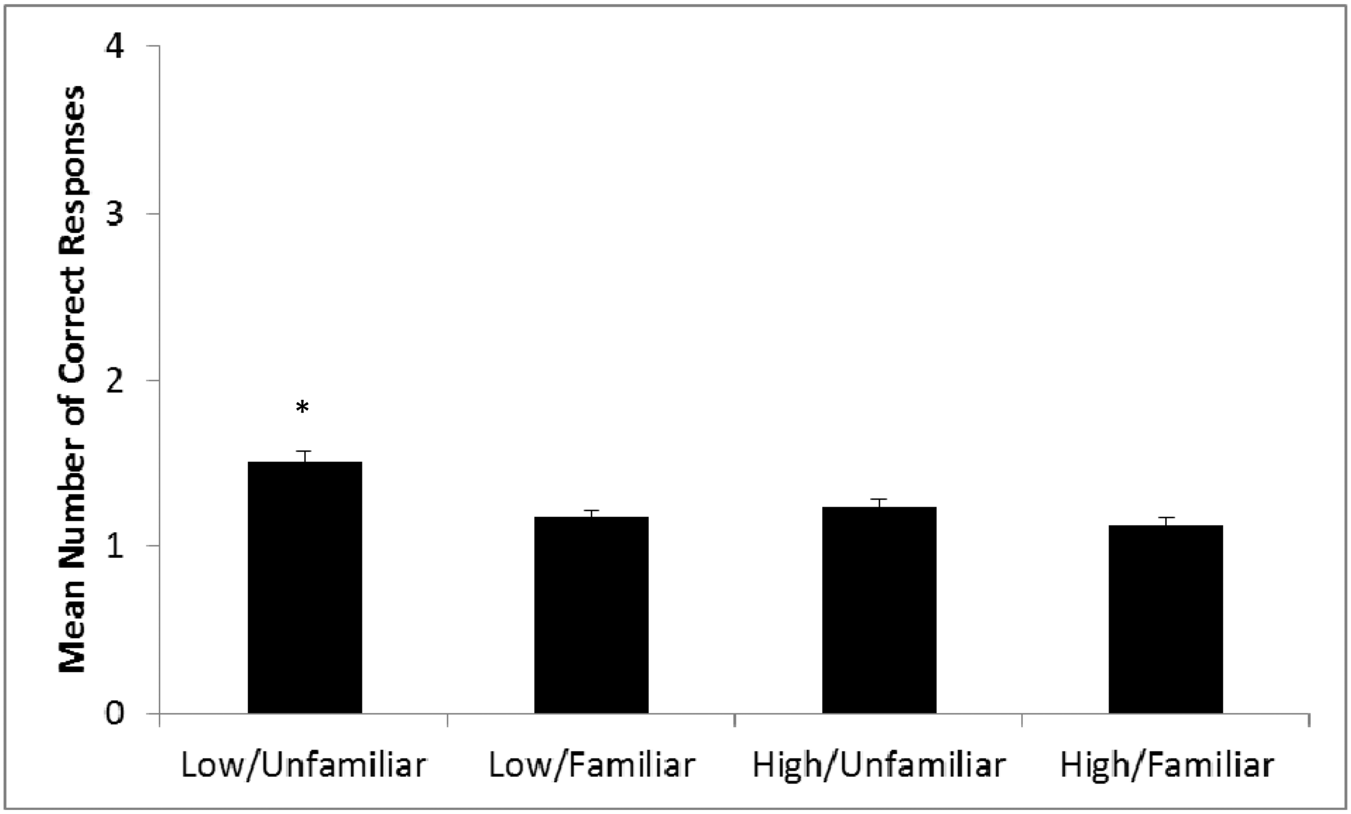

Figure 3.

Estimated marginal means for the number of correct responses to production probes for each word/object type (maximum possible = 4). Error bars represent standard errors. * indicates mean for low/unfamiliar was significantly higher at $p < .001$ than means for all other word/ object types, which did not differ.

Table 1

Participant Description Information Including Means and Standard Deviations for Age, Mother's Years Of Education, and Assessment Scores

	SLI Group *n* = 40		AM Group *n* = 39		VM Group *n* = 35	
Measure	**M**	**SD**	**M**	**SD**	**M**	**SD**
Age in Months	56.58**	5.02	55.95††	4.43	48.26**††	7.45
Mother's Yrs of Ed	14.38	2.28	14.85	2.13	15.18	2.04
K-ABC II SS	97.33**††	11.25	109.18**	11.58	107.54††	14.4
PPVT-III SS	93.55††*	10.85	105.79††	10.68	100.77*	11.44
EVT RS	45.57**	6.30	50.43**††	5.83	45.51††	6.21
EVT SS	95.0**††	8.01	101.51**	8.55	104.67††	9.35
BBTOP-WI RS	42.05**††	20.84	67.74**	11.88	64.33††	12.09
BBTOP-WI SS	78.58**††	12.36	98.54**	17.85	97.97††	12.27
CASL-SC SS	90.18**††	8.97	103.21**	9.88	103.51††	16.31
CASL-PC SS	94.23	15.55	99.38	21.08	97.38	25.77
CASL-A RS	9.68*	3.46	12.15*†	3.28	9.67†	3.47
SPELT-P2 SS	72.83**††	12.47	108.0**	9.25	103.9††	10.45
NWR-PPC	55.59**††	16.67	77.41**	9.53	71.42††	12.07

Note. SLI = specific language impairment; AM = age-matched group; VM = vocabulary-matched group. K-ABC II SS = Nonverbal scale of the Kaufman Assessment Battery for Children - Second Edition Standard Score (Kaufman & Kaufman, 2004); PPVT-III SS = Peabody Picture Vocabulary Test—3rd Edition Standard Score (Dunn & Dunn, 1997); EVT-RS = Expressive Vocabulary Test Raw Score (Williams, 1997); EVT SS = Expressive Vocabulary Test Standard Score; BBTOP WI RS= Bankson-Bernthal Test of Phonology Word Inventory Raw Score (Bankson & Bernthal, 1990); BBTOP WI SS= Bankson-Bernthal Test of Phonology Word Inventory Standard Score ; CASL-SC SS = Comprehensive Assessment of Spoken Language Sentence Completion Subtest Standard Score (Carrow-Woolfolk, 1999); CASL-PC = Comprehensive Assessment of Spoken Language Paragraph Comprehension Subtest Standard Score; CASL-A RS = Comprehensive Assessment of Spoken Language Antonyms Subtest Raw Score. SPELT-P2 SS = Structured Photographic Expressive Language Test—Preschool Second Edition Standard Score (Dawson, Stout, Eyer, Tattersall, Fonkalsrud, & Croley, 2005);. NWR-PPC = Nonword Repetition Percent Phonemes Correct (Dollaghan & Campbell, 1998).

* $p < .05$.

† $p < .05$.

** $p < .01$.

†† $p < .01$.

Table 2

Estimated Marginal Means and Standard Errors for the Number of Correct Responses to Comprehension Probes for Each Word/Object Type (Maximum Possible = 4)

	SLI Group *n* **= 40**		**AM Group** *n* **= 39**		**VM Group** *n* **= 35**	
	M	**SE**	**M**	**SE**	**M**	**SE**
Comprehension						
Low/Unfamiliar						
Day 1	2.52	.17	2.56	.18	2.21	.19
Day 2	3.00	.18	3.33	.18	2.83	.19
Day 3	3.25	.15	3.44	.15	3.31	.16
Day 4	3.35	.16	3.38	.18	3.26	.18
Low/Familiar						
Day 1	2.35	.19	2.38	.19	2.06	.20
Day 2	3.02	.18	2.82	.19	2.69	.19
Day 3	3.40	.15	3.03	.15	3.29	.16
Day 4	3.25	.17	3.28	.17	2.86	.18
High/Unfamiliar						
Day 1	2.55	.18	2.38	.18	2.40	.19
Day 2	2.95	.17	3.18	.17	2.89	.18
Day 3	2.90	.16	3.31	.16	3.17	.17
Day 4	3.22	.16	3.54	.16	3.11	.17
High/Familiar						
Day 1	2.32	.17	2.56	.17	2.23	.18
Day 2	3.00	.18	2.82	.19	2.80	.20
Day 3	3.35	.18	3.31	.18	2.83	.19
Day 4	3.56	.14	3.51	.14	3.23	.15

Note. SLI = specific language impairment group; AM = age-matched group; VM = vocabulary-matched group.

Table 3

Estimated Marginal Means and Standard Errors for the Number of Correct Responses to Production Probes for Each Word/Object Type (Maximum Possible = 4)

	SLI Group ***n* = 40**		**AM Group** ***n* = 39**		**VM Group** ***n* = 35**	
	M	**SE**	**M**	**SE**	**M**	**SE**
Comprehension						
Low/Unfamiliar						
Day 1	.45	.15	.61	.15	.31	.16
Day 2	1.17	.24	1.69	.25	1.26	.26
Day 3	1.72	.27	2.13	.28	1.74	.29
Day 4	2.10	.26	2.38	.27	2.57	.28
Low/Familiar						
Day 1	.35	.11	.28	.11	.20	.12
Day 2	1.15	.20	.79	.20	.97	.21
Day 3	1.30	.25	1.44	.26	1.43	.27
Day 4	2.05	.26	2.08	.26	2.06	.28
High/Unfamiliar						
Day 1	.40	.13	.20	.13	.37	.13
Day 2	.97	.23	1.23	.23	1.23	.24
Day 3	1.35	.26	1.90	.27	1.43	.28
Day 4	1.82	.27	2.15	.27	1.74	.29
High/Familiar						
Day 1	.35	.11	.20	.11	.20	.11
Day 2	.87	.21	1.31	.21	.74	.22
Day 3	1.60	.23	1.46	.23	1.09	.25
Day 4	1.95	.25	2.15	.26	1.57	.27

Note. SLI = specific language impairment group; AM = age-matched group; VM = vocabularymatched group.