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Effect of Onset and Rhyme Primes in Preschoolers with Typical Development and Specific Language Impairment

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Abstract

Purpose—This study used cued shadowing to examine children’s phonological word form representations by studying the effects of onset and rhyme primes on lexical access.

Method—Twenty-five preschoolers with SLI, 24 age- and gender-matched (AM) and 20 vocabulary- and gender-matched (VM) children participated. Children listened to pairs of words and repeated the second word as quickly as they could. Primes included overlapping onsets, overlapping rimes, identical, or unrelated words.

Results—As expected, unrelated words inhibited production in the AM and VM groups. Overlapping rimes primed production in the AM group. No inhibitory or priming effects were found for the SLI group.

Conclusion—Phonological priming may be used to study the phonological representations of preschool-age children. Results suggest that none of the groups accessed words incrementally. Priming for overlapping rimes by the AM, but not the VM or SLI groups, may indicate that the AM group benefitted from lexical organization favoring nucleus + rime organization that has not yet developed for the VM or SLI groups. The lack of inhibition in the SLI group suggests that their phonological representations were not detailed enough to prime words in their lexicon, or that they did not process the prime or target words.

Lexical deficits are characteristic of many children with specific language impairment (SLI). As a group, they have difficulty learning new words during the initial fast-mapping stage (Dollaghan, 1987; Gray, 2003; Gray, 2004; Rice, Buhr, & Nemeth, 1990) and during the more protracted slow-mapping stage (Kiernan & Gray, 1998; Gray, 2003, 2004; Rice, Buhr, & Oetting, 1992; Rice, Oetting, Marquis, Bode, & Pae, 1994). Relative to their peers with typical development (TD), they also demonstrate slow initial vocabulary growth, (Paul, 1996; Rescorla, Roberts, & Dahlsgaard, 1997), produce a smaller variety of words (Watkins, Kelly, Harbers, & Hollis, 1995) and score lower on receptive and expressive vocabulary tests than their peers with TD (Gray, Plante, Vance & Henrichsen, 1999).

There is convincing evidence that poor word learning in children with language impairment is related to poor phonological working memory (e.g. Gathercole, Willis, Emslie, & Baddeley, 1992; Gathercole, Service, Hitch, Adams, & Martin, 1999; Jarrold, Thorn &

Stephens, 2009; Majerus et al., 2006). Poor short term memory may hinder children's efforts to store phonological representations of words. In fact, research suggests that many children with SLI have poorly specified phonological and semantic representations of words (Alt & Plante, 2006; Gray, 2005), that the links between these representations are weak, and that retrieval and output of words is difficult (Kail & Leonard, 1986). Bishop, North and Donlan (1996) and Edwards and Lahey (1998) have also argued that children with SLI may have phonological encoding deficits that interfere with lexical acquisition.

One productive way of evaluating children's phonological word form representations (lexemes) is through priming experiments because priming suggests successful lexical recognition and access that is affected by the quality of encoded and decoded information in working memory. When the target and prime words are presented, perception and recognition occur over a time course influenced by the acoustic cues for phonemes in the words. According to the interactive-activation model of speech perception (McClelland & Elman, 1986), processing occurs in a left to right pattern with all processed information impacting the processing of new information. As activation builds over the initial phonemes of each word, word level activations begin. Multiple words with equal levels of excitation compete for recognition until the level of excitation for a particular word reaches sufficient strength, relative to the activation of competing words, so that a decision is made in favor of the target word. If a child's phonological word form representations are poorly specified this could slow the recognition process. If the child does not have a lexical entry for the word this would preclude a lexical effect from speeding word recognition. Relative to other children, if a child had an impoverished lexicon, presumably fewer words would compete for recognition, which could speed the recognition process. Therefore, for the recognition process in a priming experiment, poor phonological word form representations could slow reaction time, as could the lack of a lexical entry; however, an impoverished lexicon could also speed recognition if the target word was in the lexicon.

To process the target word, according to the incrementalist approach to lexical access, as soon as the child hears the word the initial word segment is phonologically encoded, activating a set of acoustic-phonetic patterns in memory (e.g. Brooks & MacWhinney, 2000). Stored words that correspond to those patterns become activated and compete for retrieval. Although all primes that are not identical to the target word are expected to inhibit production, priming is shown when *inhibition is decreased* relative to a prime with no phonological overlap with the target. Primes sharing overlapping onsets with target words should speed production more than primes sharing overlapping rimes because they are processed earlier. However, if a child's phonological word form representations lack phonetic detail, this could preclude incremental processing and reduce or preclude a priming effect.

Priming has been successfully used to study lexical access in school age children with SLI. For example, Hennessey (2010) found that a school age group with SLI demonstrated significantly slower reaction times (RTs) for verbs primed by overlapping onsets (onset consonant or consonant cluster and vowel nucleus) than unrelated words with the inter-stimulus interval (ISI) set at 400 ms. Seiger-Gardner and Brooks (2008) reported the results of a phonological priming experiment with 7–11 year olds with TD and SLI using a cross-modal picture-word interference task. Children were asked to name pictures as they listened to auditory word distracters (primes) that were related to the target names by onset (bell-bed) or were unrelated (clown-bed), neutral (go-bed) or identical (bed-bed). Distractors were presented over headphones at three SOAs: –150 ms, 0 ms, or +150 ms. Overall, the SLI group demonstrated significantly slower response times (RTs) than the TD group. The TD group showed phonological priming effects in both the 0 ms and +150 ms SOAs, but the

SLI group only showed priming effects in the + 150 ms SOA. The authors attributed this to slower processing speed by children with SLI.

In a second experiment, Seiger-Gardner and Brooks (2008) examined priming for rhyme-related distracters in the same children using the same methods, except that the distracters rhymed with the target (chair-bear) or were unrelated (sock-bear), identical, or neutral, as in the previous experiment. They hypothesized that the SLI group would show rhyme-related priming because their lexical development would be more similar to younger children with TD, but that was not the case. Although RTs were significantly slower for the SLI than TD group, neither group showed a priming effect for rhyme-related words relative to unrelated distracters. The authors concluded that children with SLI, like their TD peers, use an incremental lexical activation strategy that emphasizes the onset, but not the rime, when encoding phonological information. However, this conclusion was qualified by finding that the SLI group demonstrated inhibitory (interference) effects for rhyming, as indexed by higher naming errors in that condition. The authors concluded that this ‘undermined’ their RT results, suggesting that the lexicons of children with SLI may not be structured to benefit from incremental articulation.

The Seiger-Gardner and Brooks (2008) results suggest that priming effects may differ for children with TD and SLI both in response latency and accuracy. Although they did not find strong evidence for their hypothesis that the SLI group could *not* use incremental word processing strategies, perhaps this was because their participants were at least 7 years of age. It is possible that younger children with SLI, because of more holistic phonological representations, may not show the same priming effects as their age- or vocabulary-matched peers with TD.

Few studies have investigated phonological priming in school age children with TD; however, the results of two experiments suggest that phonological priming effects are similar in school-age children with TD and adults. In a picture-naming experiment with auditory distractors, Jerger, Martin, and Damian (2002) found that phonological priming occurred for five- to seven-year olds with congruent onsets at 0 ms, -150 ms and +150 ms stimulus onset asynchronies (SOAs). Based on a second experiment using the same procedures with teenagers and their review of the adult literature, the authors concluded that speech production processes in children, teenagers and adults are very similar.

In another picture naming experiment, Brooks and MacWhinney (2000) examined phonological priming in 90 children ages four through 11 years. In their first experiment, children named common objects with monosyllabic names paired with interfering words in four conditions: identical, neutral, onset-related, and unrelated at -150, 0, and +150 SOAs. Their second experiment used the same methodology, except that the interfering words and target pictures rhymed. Results indicated that children of all ages showed strong onset-based phonological priming, but only the five- and seven-year-olds showed rhyme priming.

The results of these studies suggest that five-year-olds with TD have sufficiently differentiated phonological representations to make priming possible, because they demonstrated phonological priming effects for onset-related (single phoneme overlap) and rhyme-related primes when the prime preceded the target by at least 150 ms. An empirical question is whether younger children with TD or SLI would show phonological priming effects associated with segmental representations of words. The developmental transition from holistic to segmental representations is thought to begin when children have about 150 words in their lexicon (Sosa & Stoel-Gammon, 2006; Studdert-Kennedy, 1986) and some believe progresses into school age (Metsala & Walley, 1998; Nitttrouer, Studdert-Kennedy & McGowan, 1989). Indeed, Coady and Aslin (2004) showed that children with TD as young

as 30 months are sensitive to phonotactic probability in a nonword repetition task. Therefore, there is reason to believe that preschoolers with TD will demonstrate phonological priming effects. This may not be the case for preschoolers with SLI. Nonword repetition (Edwards, Beckman & Munson, 2004; Metsala, 1999) and phonological awareness studies (Foy & Mann, 2009) suggest that the degree to which words are represented segmentally is related to vocabulary size (Edwards et al., 2004); therefore, preschoolers with SLI, who not only have smaller vocabularies but perhaps less well specified phonological representations, may not demonstrate priming.

In addition to lexical deficits and poorer phonological representations of words, children with SLI are known to have poor metalinguistic skills (Kamhi & Catts, 1986; Kamhi & Koenig, 1985; Kamhi, Lee & Nelson, 1985; Lum & Bavin, 2007) and this could have an impact on priming results. Research suggests that priming experiments with a high proportion of trials involving the same relationship between a prime and target may result in participants developing implicit or explicit response strategies based on their expectation that the word pairs will share the same characteristics (Bowles & Poon, 1985; Goldinger, 1999). For example, if a child noticed that the target word is always phonologically related to the prime, they could use this metalinguistic knowledge to anticipate the target and this could result in faster RTs as the experiment progresses. If children with TD develop these strategies, but children with SLI do not, this could result in slower RTs for children with SLI relative to children with TD.

The purpose of this study was to examine children's phonological word form representations by studying the effects of onset and rhyme primes on lexical access. Three groups participated, preschoolers with SLI, preschoolers with TD matched by age and gender to preschoolers with SLI, and preschoolers with TD matched by raw expressive vocabulary scores and gender to preschoolers with SLI. Based on previous studies our hypothesis was that the older preschoolers with TD would show priming effects for both onsets and rhymes because of their more detailed phonological representations, that younger preschoolers with TD may show only rhyming effects because of their more holistic phonological representations associated with a smaller vocabulary, and that children with SLI may perform similarly to the vocabulary-matched group because of similar vocabulary levels, or that the SLI group could fail to show priming effects because of their lower vocabulary paired with impoverished phonological representations, even at the whole word (lexical) level.

Cued-Shadowing Paradigm

In cued-shadowing experiments, participants listen to pairs of words and repeat the second word as quickly as they can. The prime and target words are differentiated by using a woman's voice for the prime and a man's voice for the target, or visa versa. The advantages of this paradigm for young children are that the task is relatively simple to complete, no reading or naming is required, and error rates are low (Bates & Liu, 1996). Cued-shadowing has been used successfully in phonological priming experiments with older participants (Slowiaczek & Hamburger, 1992; Radeau, Morais & Sequi, 1995). Further, because visual information is not available (as in priming experiments using naming), children must rely entirely on phonological information.

Method

Participants

Sixty-nine children participated in the study: 25 with SLI, 24 age- (± 3 months) and gender-matched children with TD (AM group), and 20 vocabulary- and gender-matched (± 1 SD

using raw scores on the Expressive Vocabulary Test) children with TD (VM group). Participants were between the ages of 3;1 and 5;9 (years; months) and spoke English as their native language according to parent report. Table 1 provides descriptive information about the three groups. The number of males and females were 21 and 4 in the SLI group, 20 and 4 in the AM group, and 16 and 4 in the VM group. The higher number of male than female participants with SLI reflects the higher likelihood of SLI being identified in boys than girls (Leonard, 2000; Tomblin, Records, Buckwalter, Zhang, Smith & O'Brien, 1997). Parents of all participants consented to their child's participation and each child gave their assent per university Internal Review Board requirements for human subjects.

Children were recruited from local private and public preschool programs. After administrative approval, supervisors were asked to distribute recruitment information to all preschool special education teachers and teachers serving children with TD in the 3–5 year old range. Enrolled participants attended preschools from four different school districts and five different preschool or childcare programs. To be included in the study children with SLI were required to qualify for special education services for language impairment as determined by scores more than 1.5 *SDs* below the mean on two norm-referenced language tests. Each child with SLI also met the following inclusionary criteria:

1. Hearing within normal limits bilaterally (25 dB) at 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz (American National Standards Institute (ANSI), 1989).
2. Normal nonverbal intelligence, as indicated by a standard score of 75 or higher on the Nonverbal scale of the KABC-II (Kaufman & Kaufman, 2004).
3. No evidence or diagnosis 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 scoring the experimental procedures.

All children with TD met the following inclusionary criteria:

1. Hearing within normal limits bilaterally (25 dB) at 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz (American National Standards Institute (ANSI), 1989).
2. Normal nonverbal intelligence, as indicated by a standard score of 75 or higher on the Nonverbal scale of the KABC-II (Kaufman & Kaufman, 2004).
3. Normal speech, language, motor, and cognitive development as reported by parent and teacher.

In addition, researchers administered a battery of assessments to further describe the speech and language skills of all participants. These included the Peabody Picture Vocabulary Test—3rd Edition (PPVT-III; Dunn & Dunn, 1997); the Expressive Vocabulary Test (EVT; Williams, 1997); the Structured Photographic Expressive Language Test—3rd Edition (SPELT-III; Dawson, Stout & Eyer, 2003) or Structured Photographic Expressive Language Test—Preschool (SPELT-P; Werner & Kresheck, 1983); the Comprehensive Assessment of Spoken Language (CASL; Carrow-Woolfolk, 1999), Antonyms, Sentence Completion and Paragraph Comprehension subtests; the Bankson-Bernthal Test of Phonology (BBTOP; Bankson & Bernthal, 1990); and the Renfrew Bus Story (Cowley & Glasgow, 1994). Point-to-point scoring agreement between two scorers on 20% of randomly selected assessment protocols was 98.9% (range = 95.6% to 100%).

During the first experimental session the nonverbal subtests of the K-ABC-II and the hearing screening were administered. The order of administration for the remaining assessments was counterbalanced across participants within each group. One assessment

was administered during each experimental session after the priming experiment for that day was completed.

Stimuli

Sixty-four one-syllable target nouns were selected from the MacArthur Communicative Development Inventory MCDI (Fenson et al., 1993), the PPVT-III and the EVT. Words selected from the MCDI were known by 80% of three-year-olds. Words from the PPVT-III and EVT were those administered to children beginning in the three-year-old range. An example of prime-target word pairs for each condition may be found in the appendix. The target words were paired with four types of primes: identical (bed-bed), overlapping onset (two phonemes) (bed-best), overlapping rime (bed-red) and unrelated (bed-duck). Phonological primes were selected to have no semantic relation with the target word and unrelated primes had no overlapping onset or rime with the target word; however, after completion of the experiment it was determined that two phonological primes were semantically related to target words, at least for adults. These were cat/calf and head/hen. Unrelated words did not appear as primes in any other condition.

The target and prime words were individually recorded as 16-bit audio files at 60 dB by both a male and a female native English speaker. Each prime word and target were then copied into a single .wav file with an ISI of 750 ms. Thus, each condition was blocked in an experiment containing 64 sound files consisting of a prime, the ISI, and a target word. Each of these blocks was divided into 32 word pairs, resulting in eight blocks total (two for identical, two for overlapping onsets, two for overlapping rimes, and two for unrelated), so that in half of the blocks for each participant (counterbalanced across participants) the prime was spoken by a male and the target by a female and in the other half the prime was spoken by a female and the target by a male. This manipulation specified for the child which word they were to repeat, 'the word the lady said' or 'the word the man said.' Block order and male/female or female/male presentations within each block were counterbalanced across participants in each group, except that the identical block always occurred first. The word pairs within each block were randomly ordered for each participant.

Procedures

The blocks were presented on a Dell laptop computer using DMDX software developed at Monash University and the University of Arizona by Forster and Forster (2003). Participants listened to stimuli through a high quality headset with an attached microphone. Their verbal responses were digitally recorded on the computer. Before the first block, each participant was given a short 10-item practice trial of 50 ms beeps to condition verbal responses (the word 'yes') to an auditory stimulus. Then, beginning with the identical condition, children listened to a set of instructions presented in a .wav file that asked them to listen to both words and repeat the last word (spoken by the lady or the man) as quickly as possible. Enough practice trials (i.e. 3–5) were provided for each block to ensure that the child was able to perform the experimental task.

After the first 32 word pairs in each block were presented, there was a short break during which the child engaged in a game or activity. The second set of 32 word pairs was then administered. One complete block of 64 words was administered each day. In addition to the digital recording of responses, a research assistant (RA) wrote the words that the child said on a paper protocol. Small prizes were awarded upon completion of each experimental session.

Scoring

Each child's sound files were individually scored for repetition accuracy using Adobe Audition 2 software. Accurate responses were those where the child correctly repeated the target word. Incorrect responses were those meeting one of 12 criteria listed in Table 2. Trials with incorrect responses were not included in the RT analyses. If a child responded correctly to less than 50% of trials within a block, that block was excluded from the RT analyses.

RTs for accurate responses were computed by DMDX. When viewing the sound files, if another sound (e.g. cough, ambient noise) prevented DMDX from calculating an accurate RT, it was hand calculated by measuring the wave form on Adobe Audition 2. Twenty percent of sound files were randomly selected for reliability scoring by comparing hand calculations of RTs to DMDX RTs. Point-to-point agreement was 94% (range = 62.6 to 99.9).

Results

Preliminary Analysis

Because the design of the experiment included fixed effects for subject groups and experimental conditions and a random effect for subjects, a mixed model was used to perform an analysis of variance. The RT measurements were first examined with respect to children's error rates. For each condition each child was administered two blocks of 32 word pairs for a total of eight blocks. Any block on which a child had fewer than 16 valid trials was deleted from the analysis. Two children, one from the AM group and one from the VM group, were deleted entirely, thus the *n*'s for the groups included in the analyses include 25 SLI, 24 AM, and 20 VM. The deleted blocks were distributed relatively evenly across conditions and groups. The percentage of retained blocks was 99.5% for the SLI group, 96% for the AM group, and 80% for the VM group. As reported in Table 2, an examination of error types also showed that they were remarkably similar across groups.

Next, the RT measurements were examined using histograms and probability plots. The distribution of these measurements was extremely skewed to the right, which is very common for RT measurements (Ratcliff, 1993). Log and inverse transformation, as well as trimming outliers, was considered using RTs at the level of word trials. Various distributions, including exponential, Weibull, and gamma, were also considered. None of these approaches using RTs at the level of word trials were satisfactory for the purpose of correcting skew and non-normality. Data points were then created by calculating the mean and median of the RTs for participants for each block. These data point values were still skewed to the right, so a log transformation was employed. The resulting distributions were close to normal within cells of the experiment, with log of medians showing a slightly better appearance in normality plots. An analysis of variance was conducted using both the log of the means and the log of the medians. Similar analysis of variance results were obtained for the log of the means and log of the medians. Results for the log of the medians are reported. By using the log of medians as the summary RT measure for each block the data values used for analysis of variance reported below satisfied normality assumptions, so the issues of non-normality were adequately dealt with prior to the analysis.

Model Selection

Traditional approaches to the analysis of repeated measures have several drawbacks in terms of restrictive assumptions when applied to RT experiments. These restrictive assumptions include no missing data, a compound symmetry structure for the covariance matrix of repeated measures, and homogeneity of within-group variances. Since none of assumptions

were appropriate for our measurements, SAS PROC MIXED was used to obtain results for a mixed model analysis of variance (Jennrich & Schluchter, 1986; Wolfinger & Chang, 1995). Group (SLI, AM, VM), experimental condition (identical, overlapping onset, overlapping rime, unrelated), repetition within condition (each block of 32 pairs with male or female speaker) and group by condition interaction were included as fixed effects. Participants had as many as eight repeated measurements from two blocks on each of four conditions. A Levene test for homogeneity of variance was conducted, and the null hypothesis of homogeneity was rejected. Based on this result, the mixed model was specified to allow heterogeneity of variance among subjects across groups.

RT Results

The mixed model results showed significant effects for group $F(2, 66) = 5.35, p = 0.0070$, condition $F(3, 413) = 11.23, p < 0.000$, and group by condition $F(6, 413) = 3.72, p = 0.0013$. Repetition of blocks within condition (e.g. two sets of 32 trials that formed a block) was not significant $F(4, 413) = 0.44, p = 0.78$. Results are summarized in Table 3. An examination of residual plots revealed no outliers or violations of model assumptions. RTs for the SLI group were significantly faster overall than both the AM and VM groups, but RTs for the AM and VM groups did not differ significantly. The least squares means resulting from the ANOVA for log RTs and the least squares means inverse transformed to RTs in ms are shown in Table 4 for all groups and conditions. The transformed means are reported to permit easier comparison of RTs to other studies.

Of primary interest are the within-group results for condition to assess whether overlapping onsets or rimes primed production. In the results reported below, we used a Bonferroni correction for the alpha level of $0.05/3 = 0.0166$ to reflect the comparisons for the unrelated to the other three conditions when testing within-group comparisons, and we report Cohen's d effect sizes.

A comparison of the identical and unrelated conditions provides an estimate of the inhibition effect associated with no phoneme overlap – in other words, an estimate of the maximum inhibition effect. Results indicated that for both the AM $t(413) = -4.30, p < .0001, d = .82$ and VM groups $t(413) = -2.56, p = .0108, d = .76$, RTs for the identical condition were significantly faster than the unrelated condition, demonstrating that unrelated words inhibited responses. Effect sizes were large for both groups. In contrast, the difference between the identical and unrelated conditions for the SLI group was not significant $t(413) = .37, p = .7132$, indicating the lack of an inhibitory response.

A comparison of the overlapping onsets and overlapping rimes to the unrelated condition provides an estimate of their priming effect. Although all primes that do not overlap 100% with the target word are expected to inhibit production, priming is shown when *inhibition is decreased* significantly relative to the unrelated condition. RTs for the unrelated and overlapping onset conditions did not differ significantly for any group, suggesting that overlapping onsets did not prime word production for any group; however, RTs for the overlapping rime condition were significantly faster than the unrelated condition for the AM group $t(413) = -4.01, p < .0001, d = .61$, demonstrating a priming effect. Unrelated and overlapping rime RTs did not differ significantly for either the SLI $t(413) = .12, p = .9025$, or VM groups $t(413) = -1.84, p = .0668$, demonstrating a lack of rhyme priming.

Expectation Effect

The analysis of subject expectation was based on RTs for overlapping rimes because a significant priming effect was found for the AM group in that condition. The mixed model described above was used for a repeated measures analysis to test a linear trend over trials.

The linear trend was not significant overall ($p < 0.12$) and it was not significant in any of the three groups considered separately. Thus, there was no evidence of an expectation effect.

Summary

In summary, overlapping onsets did not prime word production for any group, but overlapping rimes primed production for the AM group. No inhibitory or priming effects were found for the SLI group under any condition. Although the SLI group had faster RTs overall, this appeared to be due to the lack of inhibition effects. Their RTs in the identical condition did not differ significantly from the AM or VM groups, who also did not differ. No expectation effect was observed in conjunction with the priming effect in the overlapping rime condition.

Discussion

As children develop, the quality of their phonological word form representations evolves to include more detailed phonological information (Walley, 1988; Walley, Smith & Jusczyk, 1986). Accurate, fine-grained representations are important for phonological awareness development and for learning the alphabetic principle (Claessen, Heath, Fletcher, Hogben & Leita, 2009; Elbro, 1998). The refinement process may be related to vocabulary expansion that necessitates more detailed phonological information to discriminate among words in the lexicon (Walley, 1988).

Many children with SLI have difficulty learning new words that has been attributed to short-term phonological memory deficits that preclude storage of fine-grained phonological word form representations (Gathercole, Willis, Emslie, & Baddeley, 1992; Gathercole, Service, Hitch, Adams, & Martin, 1999; Jarrold, Thorn & Stephens, 2009; Majerus et al., 2006), or to poor phonological encoding (Bishop, North & Donlan, 1996; Edwards & Lahey, 1998). The purpose of this study was to examine the effects of onset and rhyme primes on preschooler's lexical access to determine whether the phonological word form representations of the SLI group differed from age- or vocabulary-matched children with TD. By using these two comparison groups it was possible to assess whether differences might be attributed to vocabulary size, language impairment, or both.

For phonological priming to occur the prime must activate words in the lexicon with overlapping acoustic-phonetic sequences. When the target word shares phonological properties with the prime, residual activation from the prime facilitates recognition of the target word, speeding response time. Primes sharing overlapping onsets with target words should speed production more than primes sharing overlapping rimes, because they are processed earlier.

Our results indicate that each participant group responded differently to the phonological primes. The SLI group showed no observable response. Their overall RTs were significantly faster than the overall RTs for the AM and VM groups, who did not differ. This was not a speed-accuracy trade-off, as only correct productions were included in the RT analyses and the response accuracy of the groups did not differ. Rather, the SLI group's faster overall RTs were a function of their lack of inhibition. A comparison of RTs in the identical condition, where inhibition was not expected, revealed that RTs did not differ significantly among groups. Previous research has shown that 7–11 year olds with SLI demonstrated significantly *slower* RTs than an age-matched group with TD (Seiger-Gardner & Brooks, 2008), but this was not the case with our preschoolers, even in the identical condition.

One possible reason for the SLI group's lack of inhibition could be that their phonological word form representations were not sufficiently differentiated to support segmental

processing. This may occur because children with SLI develop poorer phonological word form representations than their peers, regardless of their vocabulary size. A second possibility is that children in the SLI group actually had smaller vocabularies than the VM group (despite vocabulary score matching), in which case their phonological neighborhoods may not yet require fine-grained phonological representations. There is evidence, however, that the restructuring process begins when children have only 50 words in their vocabulary (Leonard, Rowan, Morris & Fey, 1980; Nitttrouer et al., 1989). Further, Dollaghan (1994) has argued that even very young children must have some level of detail in their phonological representations, or they would not be able to differentiate between lexical neighbors in their extant vocabulary. Nevertheless, lexical restructuring is likely to be more protracted in children with SLI, and there is evidence that it may not end until 8 years of age in children with TD (Leonard, Rowan, Morris & Fey, 1980; Nitttrouer et al., 1989).

Other than poor phonological representations or low vocabulary, what could account for the SLI group's lack of inhibition? Is it possible that rather than processing the words, they just repeated them? Bates and Liu (1996) considered whether cued shadowing could 'perhaps be done without doing a full lexical analysis' (p. 581), but concluded that this was not likely given the semantic priming effects obtained in experiments using this task. Slowiaczek (1994) specifically tested the hypothesis that single-word shadowing involves lexical memory and found that it did in adults. Yet it is possible that the SLI group held the words in phonological working memory then articulated them, bypassing lexical processing. The error analysis results are not consistent with this hypothesis, however. The number of trials without errors did not differ significantly among groups and the types of errors for deleted trials were similar in number and distribution across conditions and groups. In particular, the SLI group did not say unrelated words more often than their AM peers, as might be expected if children were not processing the meaning of words. In addition, the SLI group produced a rhyming word in error as often as the AM and VM groups, suggesting they were processing phonology.

The length of the inter-stimulus interval could have played a role. We deliberately selected a relatively long ISI of 750 ms in case the SLI group required more processing time than their peers with TD (Edwards & Lahey, 1996; Miller, Kail, Leonard & Tomblin, 2001; Seiger-Gardner & Brooks, 2008). We wanted to ensure sufficient processing time for the prime before presenting the target word. It is possible that automatic spreading activation for the prime could have decayed during the 750 ms ISI in the SLI group so that the prime 'expired' before the target word was presented. For form-based priming with overlapping onsets, inhibitory priming effects have been observed in adults over long ISIs (Monsell & Hirsh, 1998); however, children with SLI are known to have phonological working memory deficits that could result in shorter retention periods. This hypothesis should be tested empirically by systematically varying ISIs in a future experiment.

The method used to present primes and targets could have differentially impacted the SLI and TD groups. Common single-word priming methodologies use auditory stimuli, printed stimuli, or both. In auditory versions of lexical decision tasks participants typically hear two words and are asked to indicate whether the second word is a real word (e.g. Radeau, Morais & Segue, 1995). In a print version, one letter string might be presented, then a second, with participants asked to indicate whether both were real words (e.g. Chapman, Chapman, Curran & Miller, 1994). Naming tasks require participants to name a picture, typically after hearing an auditory prime (e.g. Pellowski & Conture, 2005). Unlike the cued-shadowing task used in this study, priming tasks with print or pictures do not require participants to hold both the prime and target presentation in short term phonological memory because the target is present visually while the prime is being processed. This could reduce working memory load and benefit children with SLI, who often demonstrate phonological working

memory deficits (Conti-Ramsden, 2003, Dollaghan & Campbell, 1998, Edwards & Lahey, 1998, Gathercole & Baddeley, 1990; Gray, 2006). It would be interesting to manipulate these factors in experiments with young children to determine whether outcomes with visually represented primes or targets would differ from those in this study.

Our results indicate that both the AM and VM groups demonstrated inhibition, but priming was observed only for overlapping rimes in the older AM group. Previously Jerger, Martin and Damian (2002) found priming effects in 5–7 year olds in words with congruent onsets in a picture naming task and Brooks and MacWhinney (2000) found priming effects for overlapping initial phonemes and overlapping rimes in a group of children ages 4;11–5;11, also in a picture naming task. The mean age of our AM group was 54 months, younger than either of these studies. We expect children in this age range to be progressing from more holistic phonological word form representations of words that rely on intonation, syllable, and lexical level characteristics, to incremental processing of individual sounds from the beginning to the end of words (Charles-Luce & Luce, 1990; Walley, 1988). We also expect that the organization of their mental lexicon is shifting toward that of adults, where words are stored in similarity neighborhoods by overlapping position including onset + nucleus, onset + coda, and nucleus + coda (Luce & Pisoni, 1998). In her review of studies investigating the lexical organization of young children, Storkel (2002) concluded that young children may initially organize their lexical neighborhoods using just one overlapping position, but there is disagreement whether it is the onset + nucleus or the nucleus + rime.

Our results suggest that the VM group, whose mean age was 3 years 8 months, had more holistic phonological representations than the AM group because they demonstrated inhibition, but not priming. The older AM group was primed by overlapping rimes, but not overlapping onsets. These results are difficult to interpret from an incrementalist view that predicts faster RTs for overlapping onsets than rhymes if phonological representations are sufficiently detailed for phoneme by phoneme processing. Results suggest that the AM group was not processing incrementally, but if not, why would they demonstrate priming for overlapping rimes? We suggest that this may be attributed to the organization of their lexical neighborhoods, which favor nucleus + rime organization. Because rhyming words were stored in close proximity, they were activated faster and this facilitated production. Following this logic, the overlapping rime effect may have not been observed in the VM or SLI groups because their smaller vocabularies have not been organized by overlapping position yet. The lack of inhibition in the SLI group suggests that the quality of their phonological word form representations is not sufficient to prime words in their lexicon in an auditory-only priming experiment. Thus, results are consistent with prior research suggesting that children with SLI have poorer phonological representations of words than their peers (Alt & Plante, 2006; Gray, 2005).

It is important to acknowledge that the cued shadowing task used in this study provided an end-state measure of processing rather than a time course measure of processing like event-related potentials. Questions raised by this study could potentially be addressed by using real time processing measures.

Conclusion

Using cued-shadowing this study showed that phonological priming may be used to study the phonological word form representations of preschool-age children. Results suggest that none of the groups accessed words incrementally; however, real time measures of processing are needed to confirm this hypothesis. Priming for overlapping rimes by the AM, but not the VM or SLI groups, could indicate that the AM group benefitted from lexical organization favoring nucleus + rime organization that has not yet developed for the VM or SLI groups. The lack of inhibition in the SLI group suggests that their phonological word

form representations were not detailed enough to prime words in their lexicon, or that they did not process the prime or target words.

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Participant Description Information Including Summary of Test Results (mean standard scores and standard deviations) for the SLI, AM, and VM groups

Table 1

Measure	SLI Group (n = 25)		Age-Matched Group (n = 24)		Vocabulary-Matched Group (n = 20)		F	p	η_p^2
	M	SD	M	SD	M	SD			
Age	54.32	5.78	53.88	6.18	45.95	6.49	12.60	<.001	0.28
Mother's ed	14.88	1.62	15.88	1.54	15.47	1.93	2.13	0.127	0.06
K-ABC II	100.96	13.50	120.79	15.28	111.65	12.62	12.48	<.001	0.27
PPVT-III	100.36	9.24	117.29	11.36	109.50	11.94	15.30	<.001	0.32
EVT SS	100.72	9.95	113.46	11.88	112.75	9.01	11.35	<.001	0.27
EVT RS	45.65	6.23	55.58	10.48	47.00	5.39	11.39	<.001	0.27
BBTOP-WI	78.28	14.02	103.88	10.15	101.90	11.14	34.11	<.001	0.51
CASL-SC	95.04	8.37	110.96	14.38	114.10	13.95	15.98	<.001	0.33
CASL-PC	88.56	15.21	110.61	21.12	101.55	21.43	7.97	0.001	0.20
SPELT-III ^a	79.08	12.14	105.00	13.64			-6.82	<.001	
SPELT-P ^b					18.00	4.80			
CASL-A ^c	9.32	4.20	14.26	4.39	9.85	3.59	10.19	<.001	0.24
Bus Story-I ^d	12.76	5.62	20.30	9.43	14.68	5.27	7.18	0.002	0.18
Bus Story-L	5.71	1.78	8.48	2.53	7.26	1.48	11.59	<.001	0.27

Note: SLI = specific language impairment; Age is reported in months. The following tests' normative mean = 100, SD = 15. K-ABC II = Nonverbal scale of the Kaufman Assessment Battery for Children, Second Edition (Kaufman & Kaufman, 2004); PPVT-III = Peabody Picture Vocabulary Test—3rd Edition (Dunn & Dunn, 1997); EVT SS = Standard Score on the Expressive Vocabulary Test (Williams, 1997); EVT RS = Raw Score on the Expressive Vocabulary Test (Williams, 1997); BBTOP = Bernthal-Bankson Test of Phonology (Bankson & Bernthal, 1990); WI = Word Inventory subtest; CASL = Comprehensive Assessment of Spoken Language (Carrow-Woolfolk, 1999); SC = Sentence Completion subtest; PC = Paragraph Comprehension subtest; SPELT-III = Structured Photographic Expressive Language Test—3rd Edition (Dawson, Stout & Eyer, 2003).

^a Administered only to 4- and 5-year olds. Result displayed is a *t* statistic.

^b SPELT-P = Structured Photographic Expressive Language Test-Preschool (Werner & Kresheck, 1983). Administered only to 3-year olds (n = 15), raw scores reported.

^c CASL-A = Comprehensive Assessment of Spoken Language (Carrow-Woolfolk, 1999), Antonyms Subtest raw scores.

^d Bus Story = The Renfrew Bus Story (Cowley & Glasgow, 1994), I = Information units raw scores; L = Length of sentence raw scores.

Table 2

Percentage of Types of Response Errors by Group and Condition

Condition	Type of Error	Identical	Overlapping Onset	Overlapping Rime	Unrelated
No response					
SLI		5.55	5.22	5.31	4.05
AM		5.38	6.89	5.97	9.42
VM		9.26	7.02	7.07	8.22
Repeated first word					
SLI		0.51	1.30	3.46	3.54
AM		0.55	2.44	2.80	3.86
VM		0.47	1.14	3.74	1.61
Response overlapped target					
SLI		4.66	1.16	2.42	1.07
AM		5.28	0.46	0.60	0.32
VM		8.01	0.47	0.21	0.47
Unintelligible					
SLI		1.26	1.12	0.98	0.70
AM		0.18	0.69	0.60	0.69
VM		0.21	0.42	0.31	0.83
Child talking					
SLI		0.37	0.84	0.89	0.42
AM		0.64	0.78	0.78	0.69
VM		0.94	0.57	0.68	1.04
Technical problem					
SLI		0.33	0.28	2.14	1.21
AM		1.33	0.41	0.41	1.70
VM		0.10	1.14	0.26	0.42
Said unrelated word					
SLI		0.61	0.75	0.79	0.51
AM		0.55	1.10	1.15	0.87
VM		0.42	0.73	0.68	1.20
Said part of the target					
SLI		1.12	1.16	0.65	0.98
AM		0.87	0.83	1.10	0.92
VM		0.78	0.62	0.62	0.52
Said initial sound of the target					
SLI		0.47	0.47	0.28	0.33
AM		0.41	0.87	0.32	0.60
VM		0.26	0.42	0.42	0.26
Said final sound of the target					
SLI		0.65	0.75	0.47	0.47
AM		0.09	0.32	0.09	0.05

Condition	Type of Error	Identical	Overlapping Onset	Overlapping Rime	Unrelated
VM		0.78	0.26	0.16	0.36
Said a rhyming word					
SLI		2.05	1.77	1.63	1.68
AM		1.47	1.93	1.52	1.38
VM		2.13	1.20	1.92	1.72
Produced additional phonemes					
SLI		0.00	0.09	0.05	0.09
AM		0.05	0.18	0.05	0.00
VM		0.36	0.10	0.00	0.00
Total percentage of errors					
SLI		17.58	8.39	16.82	7.46
AM		16.8	7.57	15.95	7.22
VM		23.72	5.93	13.42	6.82

Table 3

Summary of Mixed-Model ANOVA with Factors of Block (1, 2) Group (SLI, AM, VM), and Condition (Identical, Unrelated, Overlapping Onsets, Overlapping Rime)

Source	Degrees of freedom	<i>F</i> ratio	Significance level
Blocks	4	0.44	.78
Group	2	5.35	.0070
Group x Condition	6	3.72	.0013
Condition	3	11.23	<.000

RT Least Squares Means and Log Least Squares Means in ms (Number of Blocks in Analysis) by Group and Condition

Table 4

Condition	SLI Group (n=25)		Age-Matched Group (n=24)		Vocabulary-Matched Group (n=20)	
	RT	Log RT	RT	Log RT	RT	Log RT
Identical	413.56	6.04 (50)	365.66	6.21 (47)	440.59	5.92 (39)
Unrelated	417.35	6.01 (50)	547.53	6.33 (48)	590.58	6.34 (36)
Overlapping onset	432.76	6.06 (50)	532.86	6.37 (46)	577.00	6.29 (40)
Overlapping rime	406.92	6.01 (49)	434.82	6.23 (44)	527.54	6.08 (40)

Appendix

Examples of Prime-Target Word Pairs by Condition

<u>Identical</u>	<u>Overlapping Onsets</u>	<u>Overlapping Rimes</u>	<u>Unrelated</u>
bed	best	red	duck
clown	cloud	town	grass
hand	half	sand	toy