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Organization of the mental lexicon in children who stutter: A pilot study

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Organization of the mental lexicon in children who stutter: A pilot study

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Dedication

This thesis is dedicated to all of my friends at school. Knowing and spending time with you all has been the highlight of the last two years. Thank you for your friendship and encouragement!

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I would like to thank the number of individuals who participated in this project, including Erika Bodoin for her help recruiting participants, Angie Motal for her wonderful assistance conducting sessions, Sarah Hudson for her collaboration throughout this process, and to all of my participants and their families who gave of their time to help with this research. I would especially like to thank Li Sheng for her support and guidance, and Courtney Byrd for her counsel and sharing her knowledge of fluency disorders. Finally, I would like to express my gratitude to my family and fellow students who were a constant source of encouragement and support throughout this process.

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Abstract

Organization of the mental lexicon in children who stutter: A pilot study

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This thesis is the pilot study of an ongoing investigation of the organization of the mental lexicon in children with specific language impairment and children who stutter (CWS). The current study analyzes the performance of 8 CWS, ages 4; 11 – 10; 1 and their typically developing age matches (CWNS) on a list recall task adapted from Roediger and McDermott (1995). Talker groups were matched for maternal education level, male to female ratio, and standardized measures of nonverbal intelligence, expressive vocabulary, digit memory, and narrative comprehension and production. Similar to previous reports, the CWS performed significantly lower on a measure of receptive vocabulary and a measure of phonological memory than the CWNS. For both talker groups, there was a positive correlation between age and percentage of correctly recalled words on the list recall task. Older CWNS produced more semantic intrusions than younger CWNS; however the same trend was not demonstrated in CWS. False recall of semantically-related, phonologically-related, and unrelated words was not significantly different between talker groups. These findings provide preliminary evidence of differences between talker groups on a list recall task. The inclusion of a greater number of participants may provide stronger support for the hypothesis that lexical-semantic organization is less efficient in CWS.

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Introduction

Over the past several years, researchers have examined the relationship between stuttering and linguistic processes, gathering evidence to support the theory that stuttering is more than a simply a motor disturbance affecting fluency of speech. A growing body of research indicates that linguistic processes above the level of motor execution contributes to stuttered speech, with children who stutter (CWS) performing differently on many language measures when compared to children who do not stutter (CWNS) (Anderson, 2008; Anderson & Conture, 2000; Byrd, Conture, & Ohde, 2007; Hall, 2004; Kleinow & Smith, 2000; Wagovich & Bernstein Ratner, 2007). CWS are reported to score lower on tests of vocabulary and to have reduced lexical diversity as compared to their typically developing peers (Anderson & Conture, 2000; Hall, 2004; Wagovich & Ratner, 2007). Anderson and Conture (2000) hypothesized that CWS may have a disproportionate difficulty with lexical-semantic encoding, resulting in an imbalance among components of the speech production system, which leads to disfluencies. Additionally, at the age in development when there is thought to be critical growth in vocabulary which forces the typically developing child to begin to finely discriminate among the sounds in words. In contrast, CWS appear to have less specified phonological representations of words and persist in representing words holistically rather than transitioning to incremental processing (Anderson, 2008; Byrd et al., 2007). These deficits may also lead to immature organization of the lexical-semantic system in CWS.

Although performance differences on language measures in CWS are often subclinical, the current body of research suggests that deficits in linguistic processing are prevalent in this population. A greater understanding of the lexical-semantic system in CWS will increase clinicians' knowledge of the relevant behavioral manifestations of stuttering and facilitate the design of effective intervention practices.

The present study is part of an ongoing study on lexical-semantic organization in two clinical populations – children with specific language impairment (CSLI) and CWS. The long-term goal of this ongoing research is to identify the similarities and differences in the behavioral profiles of these two clinical populations. The pilot study completed for this thesis focuses on comparisons between CWS and CWNS. Children with SLI will be included in a later publication of this study, when data from more children with SLI become available.

One method to investigate lexical-semantic organization is through the use of a false memory paradigm, in which participants recall lists of words that are likely to induce semantic and/or phonological intrusions. These semantic or phonological intrusions are indicative of automatic activation of words that are similar in meaning or sound in a well-organized lexical-semantic network (Roediger & McDermott, 1995; Sommers & Lewis, 1999). The false memory paradigm has been used to investigate lexical-semantic organization in typically developing (TD) children (Dewhurst & Robinson, 2004). However, there is limited research on the organization of the mental lexicon in CWS. The objectives of the present thesis are 1) to pilot a list recall task adapted from Roediger and McDermott (1995) and Dewhurst and Robinson (2004) with children age 5 to 10; and 2) to analyze response patterns of CWS and CWNS. Understanding how the mental lexicon is organized in CWS will increase our understanding of the linguistic variables that may contribute to the development of and/or exacerbate stuttered speech. Furthermore, results from this study may offer support to the theory that CWS are slow to shift from holistic to incremental processing, indicating that lexical-semantic organization is inefficient in CWS (Byrd et al., 2007). These findings will allow clinicians to develop treatment strategies that may help CWS to more efficiently organize their mental lexicon, an increased organization that should in turn increase their ability to maintain fluent speech. In the following sections, literature on language processing differences in CWS will be reviewed, as well as theories of lexical-semantic organization in TD children and in CWS.

Linguistic Processing in Children Who Stutter

An emerging body of literature has demonstrated differences in performance on language measures between CWS and CWNS (Anderson & Conture, 2000; Anderson, Pellowski, & Conture, 2005; Byrd & Cooper, 1989; Murray & Reed, 1977). These studies have demonstrated significantly lower scores on receptive and receptive/expressive measures for CWS compared to CWNS.

Research has indicated that CWS consistently perform lower on different standardized language measures than CWNS (Anderson et al., 2000; Anderson et al., 2005; Byrd et al., 1989, Murray et al., 1977). Murray et al. (1977) found that CWS performed significantly lower than CWNS on expressive and receptive language measures, as well as on the *Peabody Picture Vocabulary Test (PPVT*), a measure of receptive vocabulary. In Anderson et al. (2000), CWS ages 3; 0 to 5; 3 (years; months) scored within the average range, but performed significantly lower than a matched group of CWNS on both an omnibus measure of language (*Test of Early Language Development; TELD*) and the *PPVT-3*. The finding that CWS often perform more poorly on the *PPVT* suggests that vocabulary development may be either deficient or perhaps slower to develop in this population. In addition, Byrd and Cooper (1989) found that CWS performed significantly lower on an expressive language measure compared to typically developing children. Anderson et al. (2005) also found that even though CWS performed within the average to slightly above average range on all standardized measures, they still performed consistently lower than their normally-fluent peers, particularly with respect to overall expressive and receptive language.

Evidence of dissociations within the language systems of CWS has also emerged (Anderson et al., 2000; Anderson et al., 2005; Byrd & Cooper., 1989). Anderson, Pellowski and Conture (2005) found that in comparison to CWNS, CWS between the ages of 3;0 and 5; 11 were over three times more likely to exhibit dissociations, defined as the existence of an at least one standard deviation difference between two variables, across speech-language domains. CWS had the greatest number of dissociations between speech sound development and overall receptive language, with most CWS exhibiting patterns of greater speech sound development than receptive language (Anderson et al., 2005). Byrd and Cooper (1989) also found this type of dissociation as they reported that CWS performed significantly better on receptive than expressive language measures. Further, Anderson et al. (2000) found that, unlike CWNS, who demonstrated comparable scores on an omnibus measure of language and vocabulary, CWS performed significantly more poorly on the vocabulary than the language measure, suggesting that vocabulary may be an area of particular difficulty for these children. Taken together, these findings lend support to the notion that there may be an imbalance in the speech-language systems of CWS.

Lexical-Semantic Organization

Typically developing children first acquire and use words through fast mapping, or incidental word learning (Carey, 1978). Fast mapping involves encoding the phonological, semantic, and syntactic characteristics of words and retrieving lexical items for use. Slow mapping is a more prolonged period of lexical development in which children learn to differentiate newly acquired words from already-held semantic representations and refine hypotheses about the meanings of words (Carey, 1978; McGregor, Friedman, Reilly, & Newman, 2002). McGregor et al. (2002) found that children age 4; 0 – 6; 6 typically made taxonomic errors (e.g., *chair-saddle*) in naming; that is, the incorrect response was within the same semantic category as the target item (McGregor et al., 2002). Children also made phonological errors (e.g. *chair-bear*), wherein the incorrect name shared phonological, but did not share semantic characteristics with the target. These findings indicate that children access words according to both phonological and semantic properties.

Studies using word recall tasks with adults and children with normal language also indicate that words in the mental lexicon are organized according to both phonological and semantic attributes. Hearing a word (e.g., *cat*) activates words that share semantic relations (e.g., *dog, mouse, milk*) as well as words with phonological similarities (e.g., *mat, sat, cap*). Through development, the relative salience of these attributes changes. Sheng and McGregor's (2010) study of word association patterns showed that younger children often generate *clangs* that represent a pure phonological relationship to the target word. These responses alliterate (e.g., *candy-can*) or rhyme (e.g., *dig-fig*) with the targets, but do not relate to the targets semantically. Clangs predominate in preschoolers and kindergarteners, but quickly fade out after a year of schooling. The finding that older children frequently respond with semantic associates rather than clangs demonstrates that as children mature, they abandon a primitive sound-based organization in favor of a more meaning-based organization (Sheng & McGregor, 2010).

Phonological Processing and Encoding in CWS

In addition to organizing newly learned words by semantic properties, children must retain phonological information using the phonological loop, a limited-capacity component of working memory, specialized for storage and processing of incoming verbal information (Gathercole, Hitch, Service, & Martin, 1997). Repetition of novel stimuli, such as nonwords, is believed to be dependent on the capacity of short-term storage in the phonological loop (Gathercole, Willis, Baddeley, & Emslie, 1994). Hakim and Ratner (2004) found that CWS ages 4; 3 to 8; 4 repeated fewer words correctly and made more phoneme errors than CWNS on a nonword repetition task. This finding suggests that CWS have a diminished ability to remember and/or reproduce novel phonological sequences, possibly due to the deficits in short-term storage and processing within the phonological loop. In children with SLI and typically developing children, performance on nonword repetition tasks is highly correlated with vocabulary skills (Gathercole, Service, Hitch, Adams, & Martin, 1999; Gathercole et al., 1994). It is likely that nonword repetition and vocabulary skills are related in CWS as well, such that CWS who have difficulty remembering and reproducing novel words also have difficulty learning vocabulary.

An experimental study investigating the holistic versus incremental phonological encoding processes of young children found that the majority of 3 to 5-year-old CWS named pictures more quickly than CWNS when presented with a holistic prime (e.g.,. *-ed for bed*), and named pictures more slowly than CWNS when given an incremental prime (e.g.., *b- for bed*) (Byrd et al., 2007). Young CWS did not demonstrate a shift from being faster holistic processors to being faster incremental processors like their CWNS counterparts did. For CWNS, responses were significantly faster in 5-year-olds compared to 3-year-olds, when presented with incremental primes. Therefore, with development, young typically developing children learn to increasingly distinguish among phonologically similar sequences in the decoding and encoding of language. In contrast, young CWS continue to rely on holistic cues. Due to the lack of connectivity between words of similar sound sequences, CWS have difficulty learning and organizing new vocabulary. Thus, this evidence suggests that the lexical neighborhoods of CWS may not be as efficiently organized as are the lexicons of their fluent peers.

To date, studies of linguistic processing in CWS have focused on phonological processing and encoding in this population. However, there are reasons to believe that these children may also be delayed in organization of the lexicon at the semantic level. Storkel (2004) argues that the more time a child has had in linking the semantic representation to the phonological representations, the stronger each representation becomes, as well the link between them. She further argues that a delay in making these connections is one that will result in particular difficulty forming lexical representations and associations between lexical and semantic representations. This delay distinguishes children with speech sound disorders and, in the case of the present study, CWS from their typically developing peers. Given that CWS have smaller vocabularies than their peers and that vocabulary organization is driven by size of the lexicon, it follows that CWS may be delayed in the shift from sound-based to meaning-based organization.

List Recall Task

A widely used procedure for investigating lexical-semantic memory is the Deese-Roediger McDermott (DRM) paradigm. This procedure involves presenting lists of words that are semantic associates of a critical word that is not itself presented (Dewhurst & Robinson, 2004). For example, participants hear the words *hot, wet, ice, sick, warm, snow, freeze,* and *weather,* all of which are associates of the nonpresented word ‘cold’. Adults have demonstrated false recall of the nonpresented word as or more often than items presented in the middle of lists, but young children ages 5 and 7 have performed at near-floor levels for false recall of the nonpresented words (Brainerd, Reyna & Forrest, 2002; Roediger & McDermott, 1995). Fuzzy-trace theory explains that children are not as susceptible to the DRM effect because they fail to create gist memories of the semantic relatedness of the DRM lists. In other words, they do not falsely recall the word ‘cold’ because they are not automatically primed to do so by hearing eight words associated with ‘cold’. Dewhurst and Robinson (2004) suggest that children undergo a shift from phonological to semantic processing wherein different attributes of words are salient to children at different ages. They presented five lists of eight words each to 5-, 8-, and 11-year-old children with no history of speech or hearing difficulties. Each list was associated with a semantic theme and all words on the lists had at least one rhyme. Overall levels of correct recall increased with age such that 11-year-olds recalled more words than 8-year-olds, who recalled more words than 5-year-olds. All three age groups produced false memories, but the type of false memory varied as a function of age. Five-year-olds were more likely to recall words that were phonologically related to the words they heard than to produce semantic or unrelated intrusions, whereas 11-year-olds were more likely to falsely recall words that were semantically related than to produce phonological or unrelated intrusions. Eight-year-olds made the highest number of intrusions overall, though these were equally likely to be phonological, semantic, or unrelated to the study items. These findings indicated a shift from phonological to semantic organization of the mental lexicon in typical children between 5 and 11 years old.

In addition to studying the types of words recalled, researchers have demonstrated the importance of the serial position of words in free recall tasks. There is a pronounced serial position effect, such that words presented toward the beginning and end of lists are recalled at a higher rate than words in the middle of lists. This recall pattern is demonstrated by a U-shaped curve, with the beginning peak usually lower than the end peak (Glanzer & Cunitz, 1966). Words presented at the beginning of lists are stored and retrieved from long-term memory, and words at the end of lists are stored and then retrieved from short-term memory. Due to capacity limitations, individuals often fail to recall words presented in the middle of lists. These primacy and recency effects are expected to appear in participants' recall in the present study. However, the recency effect may be reduced in CWS, given reported deficits in working memory (Hakim & Ratner, 2004).

The Present Study

The present study will examine the performance of CWS on a list recall task as compared to CWNS controls. We will investigate the percentage of correct recall and error patterns of each group. In addition, we will explore the effects of serial order on words recalled. Relationships between standardized test scores and list recall performance will also be investigated.

We predict that CWS will correctly recall fewer words than CWNS, due to their smaller vocabularies and poorer phonological memories. Previous studies of typically developing children revealed that 5-year-olds generate mostly phonological intrusions, and 11-year-olds produce mostly semantic intrusions. Because participants in the current study have a mean age of 6; 7, these children might have become less sensitive to phonological properties of words, and show a tendency for more attention to semantic properties. Therefore, we also expect semantic intrusions to be more common than phonological intrusions. However, given the connection between the development of phonology and semantics, the delay in both of these linguistic areas may cause CWS to be less efficient in processing semantic information and produce fewer semantic intrusions than CWNS.

Regarding the effects of serial order on recall, we predict that more words would be correctly recalled from the beginning and end of lists, and fewer words would be recalled from the middle of the lists. In keeping with findings by Glanzer et al. (1966), we predict that participant's recall based on serial order will form a U-shaped curve that is higher on the right than the left, due to increased recall of later versus earlier presented words. We predict that recency effects will be reduced in CWS, compared to CWNS, due to deficits in working memory.

Finally, we predict that older children will correctly recall a higher percentage of list words than younger children, due to the increasing capacity of short-term memory with age. Furthermore, we predict that phonological memory performance will correlate with the percentage of correctly recalled words. Given the finding that CWS have difficulty with phonological encoding, we predict that CWS will recall fewer words than CWNS.

Methods

Participants

Sixteen children ages 4; 11 to 10; 1 (years; months) participated in this pilot study. All children were monolingual speakers of English with no history of neurological, hearing, or intellectual problems per parent report and examiner observation/testing. Children were identified for participation by their parents who heard about the study through advertisements in *Parent Wise* (an Austin parenting magazine), flyers posted in the Austin area, online forums for mothers, and referrals from speech-language pathologists.

Eight CWS and eight age (±8 months) and gender matched CWNS participated in this study. The mean ages of the CWS and CWNS groups were 79.5 months (range 59-121 mo.) and 79.1 months (range 62-113 mo.), respectively. Groups were also balanced for maternal education level and gender distribution.

All participants met the following inclusion criteria: (a) Nonverbal IQ above 80 as measured by the Matrices subtest of the *Kaufman Brief Intelligence Test – Second Edition* (*K-BIT-2*; Kaufman & Kaufman, 2003); (b) normal hearing based on the American Speech-Language and Hearing Associations guidelines for hearing screening; (c) absence of social, emotional, or psychiatric problems according to parent report.

Participants in the CWNS group met the following additional criteria to verify their status as typically developing: (a) scores no lower than 1 standard deviation below the mean on the following measures: Non-word Repetition subtest of the *Comprehensive*

Test of Phonological Processing (*CTOPP*; Wagner, Torgesen & Rashotte, 1999), the *Structured Photographic Expressive Language Test – Third Edition* (*SPELT-III*; Dawson, Stout & Eyer, 2003), and the *Test of Narrative Language* (*TNL*; Gillam & Pearson, 2004); (b) no current or prior parent concern regarding speech and language development; and (c) judgment by graduate clinicians and licensed speech-language pathologists of speech and language within normal limits.

Participants in the CWS group met the following additional criterion for inclusion: Current or prior enrollment in special service for treatment of stuttering, or diagnosis of stuttering based on observation and testing by a licensed speech-language pathologist. All children were also administered (and scored within normal limits) on the *Peabody Picture Vocabulary Test – Fourth Edition* (*PPVT-IV*; Dunn & Dunn, 2007) and the *Expressive Picture Vocabulary Test – Second Edition* (*EVT-II*; Williams, 2007). Table 1 provides participant characteristics and mean scores on standardized measures.

The mean scores on standardized measures of CWS and CWNS were compared to determine differences between groups. Talker groups differed in performance on the Non-Word Repetition (NWR) subtest of the *CTOPP*. A two-sample t-test was conducted to compare the mean score of CWS and CWNS on the NWR subtest. There was a significant difference in the scores for CWS (M=8.88, *SD*=1.46) and CWNS (M=12.25, *SD*=1.04) for the NWR subtest; $t(14)=-5.34$, $p<.001$. In other words, CWS performed more poorly than CWNS on a test of phonological memory that requires brief verbatim storage of auditory information (Wagner, Torgesen, Rashotte, 1999).

There was also a significant between groups difference in performance on the *PPVT-IV* (CWS *M*=117, *SD*=4.57; CWNS *M*=129.13, *SD*=8.56); t(14)=-3.53, *p*<.005. This demonstrates that CWS performed more poorly than CWNS on a measure of receptive vocabulary.

Table 1: Participant characteristics and mean standardized test scores

	Age Range (months)	Male: Female Ratio	Maternal Education (years)	*K-BIT-II*[a]	*PPVT-IV*[b]	*EVT-II*[c]	*NWR*[d]	*MD*[e]	*TNL*[f]
CWS	59 - 121	5:3	16.63	114	117*	115	9*	10	107
SD			2.33	12	5	8	1	3	14
CWNS	62 - 113	5:3	15.88	112	129*	124	12*	11	112
SD			1.36	15	9	9	1	1	15

*Significant (p < .01) difference in means; a. *Kaufman Brief Intelligence Test – 2nd Edition*; b. *Peabody Picture Vocabulary Test – 4th Edition;* c. *Expressive Vocabulary Test – 2nd Edition*; d. *Non-word Repetition subtest of CTOPP*; e. *Memory for Digits subtest of CTOPP*; f. *Test of Narrative Language*

Stimuli

The stimuli consisted of 12 lists of eight words each. The stimuli were constructed using a published study of false memory (Roediger & McDermott, 1995) and existing word association norms (Nelson, McEvoy, & Schreiber, 1998). To ensure that the stimuli were familiar to young children, we examined the frequency of occurrence of these words using an online corpus of children’s lexicon, which contains a total of 4,832 words (Storkel, Hoover, & Kieweg, 2008). All but one word (i.e., fur) were found in this corpus. All stimuli were early-acquired nouns, verbs and adjectives that would be familiar to young children. To allow for both semantic and phonological intrusions, each word list was developed around a semantic theme word that was not presented (e.g. *cold, sweet, high*), and all presented words had at least one rhyme. Log word frequency ranged from

1.00 to 4.79 (*M*= 3.02, *SD*=0.77). The number of neighbors for presented words ranged from 1 to 27, with the exception of the word *up*, which had 154 neighbors (*M*=12, *SD*=16). Table 2 shows the 12 stimuli lists used in this study.

Table 2: List recall stimuli

Critical Unpresented Word	Presented Words
Cold	hot, wet, ice, sick, warm, snow, freeze, weather
Sweet	sour, candy, sugar, tooth, good, taste, pie, cake
High	low, up, tall, sky, kite, over, jump, tower
Black	white, dark, color, sheep, coal, blue, cat, gray
River	lake, stream, flow, boat, fish, run, water, creek
Window	glass, door, shade, curtain, look, frame, house, ledge
Sleep	dream, bed, night, pillow, rest, wake, peace, nap
Soft	hard, feather, skin, light, touch, silk, fur, loud
Bread	dough, food, eat, slice, bake, wheat, milk, toast
Chair	table, sit, couch, stool, legs, seat, bench, wood
Foot	shoe, toe, sock, hand, ball, smell, kick, soccer
Mountain	hill, climb, top, valley, bike, ski, goat, steep

Procedures

Lists were presented through a KRK Rokit 5 speaker at the 70dB level. There was with two-second interval between words. Children were invited to play a memory game and given the following instructions: *"Now you will be listening to groups of words. There are eight words in each group. I want you to listen carefully because you have to tell the words back to me. Try to remember as many words as you can. Are you ready? Let's practice first."* After listening to a trial word list, the examiner prompted the child to *"Tell me as many words as you can remember"*. Once the examiner confirmed understanding, the experimental trial lists were presented. ” The examiner recorded all responses in the order they were given. Some children verbally stated their completion of each list (e.g. *“That’s it.”* or *“I can’t remember any more.”*). When the child did not volunteer this information, the examiner confirmed with the child that they were finished naming words before continuing to the next list. Non-contingent positive reinforcement was used throughout the false memory task and children were periodically encouraged to continue to try to recall as many words as they could. There were a total four practice word lists (*girl, slow, music* & *spider*) and 12 experimental word lists (*cold, sweet, high, black, river, window, sleep, soft, bread, chair, foot* and *mountain*). The false memory task was administered in blocks of 4 to 6 lists over at least two sessions, so that no child completed all 12 lists in one day. The first administration of the false memory task began with one to two practice lists selected randomly by the examiner. Once the child demonstrated understanding of the rules, lists to be analyzed were administered. Before subsequent administrations of the false memory task, the examiner reminded each child how to play this game, and additional practice was used, as needed. The 12 lists used in data analysis were administered in a random order for each participant to control for order effects.

The false memory task was administered in a sound booth designed to minimize ambient noise. During administration of the false memory task, the child was seated in a chair facing the speaker which was approximately 2 feet away. The examiner sat by the child and faced the computer screen.

A female native English speaker with a standard American accent recorded the stimuli using a digital Zoom H4 recorder in a soundproof booth. The recording was segmented into individual sound files, each containing one word list. Intelligibility of the spoken words was verified by asking three research assistants blind to the purpose of the study to listen to and write down all words from the 12 lists. All three research assistants correctly identified all list words.

Coding

Responses were coded into eleven categories: 1) correct; 2) false memory; 3) phonological intrusion; 4) semantic intrusion; 5) phonological/semantic intrusion; 6) inflection error; 7) previous list error; 8) previous list error/phonological intrusion; 9) previous list/semantic intrusion; 10) repetition; 11) unrelated error. These categories were determined and agreed upon by the author and both supervisors, who considered children's early response patterns in the list recall task. A false memory was defined as recall of the unpresented semantic theme word. A phonological intrusion was coded when a response had the same onset (vowel, consonant, or consonant cluster) and the same number of syllables, or rhymed with a word from the presented list (e.g., *gray-great*, *tower-sour*). A semantic intrusion was coded when a response related in meaning to a presented word through a categorical (e.g., *up-down*), functional (e.g., *bike-ride*), descriptive (e.g., *wood-stick*), thematic (e.g., *jump-run*, *toast-eggs*), causal (e.g., *sick-sneeze*), or part-whole relationship (e.g., *finger-hand*). A phonological/semantic intrusion was coded when a response fit the criteria for both of these categories. An inflection error was coded for recalling a different form of the presented word (e.g., *color-colors*, *taste-tasting*). A previous list error was coded when a participant recalled a presented word from a list he or she heard earlier during the same session. A previous list/phonological intrusion was coded when a response fit the criteria for each of these categories. Repetition of a word within a response period (e.g., ***color***, *sheep, blue, cat, gray*, ***color***) was also coded for analysis. An unrelated error was coded when a child's response did not fit into any of the aforementioned categories. Table 3 defines and gives examples of each error type.

Table 3: Error Types and Example Responses

Error Types	**Example Responses**
False Memory - Subjects said critical unpresented word.	COLD: weather, snow, freeze, **cold,** sick (*'Cold'* is the critical unpresented word.)
Phonological Intrusion - Response had same onset (vowel, consonant, or consonant cluster) and same number of syllables, or rhymed with a word from the presented list.	MOUNTAIN: goat, steep, valley, **deep** (*'Deep'* rhymes with *'steep'*.)
Semantic Intrusion - Response was semantically related to any word from list.	HIGH: tower, jump, sky, up, **down** (*'Down'* is categorically related to *'up'*.)
Phono./ Semantic Intrusion - Response fit criteria for phonological *and* semantic intrusion.	BREAD: toast, **meat,** bake, slice *('Meat'* rhymes with *'eat'* and is categorically related to *'food'*.)
Inflection - Response was a different form of a presented word.	COLD: weather, snow, freeze, hot, **froze,** ice (*'Froze'* is the past tense inflection of *'freeze'*.)
Previous List - Response was a word from a list presented previously within the same session.	SWEET: pie, cake, taste, tooth, **fast** (*'Fast'* was presented in the list prior to 'SWEET' and is not phonologically or semantically related to any words in this list.)
Previous List/Phono. - Response was a word from a list presented previously within the same session *and* fit criteria for phonological intrusion.	HIGH: tower, **sour** (*'Sour'* rhymes with *'tower'* and was presented in the list 'SWEET' prior to 'HIGH'.)
Previous List/Semantic – Response was a word from a list presented previously within same session *and* fit criteria for semantic intrusion.	CHAIR: wood, logs, sit, **bed** ('*Bed'* is semantically related to '*couch'* and was presented in the list 'SLEEP' prior to 'CHAIR'.)
Repetition - A correct response was repeated within the recall period for a particular list.	SLEEP: peace, nap, bed, dream, **bed** (Although **t**he first response of *'bed'* was coded as correct, the next production was coded as a repetition.)
Unrelated - Response did not fit any of the above criteria, as judged by researchers.	SOFT: touch, sin, **'moke'**, loud (*'Moke'* cannot be related semantically because it is a nonword, and is also not phonologically related to any of the list words.)

Reliability

Reliability of transcription was verified by an undergraduate research assistant who listened to audio-recordings of 30% of the analyzed lists and wrote down the participants' responses verbatim. The research assistant was blind to the identity and group placement of the children. The research assistant and the author had 97% point-to-point agreement.

Results

Prior to statistical analysis, the numbers of correctly recalled words and intrusion errors were calculated for each participant. Intrusion errors were coded according to criteria described in Table 2. To allow for comparisons between semantic, phonological, and unrelated errors, certain coding categories were combined. Semantic intrusions included false memory of the critical unpresented word, other words that were semantically related to list items, and inflections of list items (e.g., *colors* instead of *color*). Phonological and unrelated intrusions included only the errors consistent with the definitions in Table 3. Words recalled from previous lists, ambiguous errors, and repetition errors were not included in the comparison of semantic, phonological, and unrelated errors. Table 4 shows all participants' performance on the list recall task.

Table 4: Correct responses and intrusions by talker and group

Subjects						Intrusion Types									
Participant ID	Talker Group 1=CWS, 0=CWNS	Gender	Age (Months)	% Recalled correctly	Mean correct per list	False Memory (FM)	Phonological (PH)	Semantic (SE)	PH/ SE	Word Inflection (WI)	Previous List (PL)	PL/ PH	PL/ SE	Repetition (REP)	Unrelated (UR)
18	1	F	59	27%	2.2	0	2	2	0	0	0	1	0	0	1
14	1	F	66	41%	3.3	1	0	0	0	0	0	0	0	0	0
7	1	F	69	40%	3.2	2	0	0	0	1	0	0	0	0	0
16	1	M	70	32%	2.6	1	1	0	0	0	0	0	0	1	1
20	1	M	74	37%	2.9	2	5	3	0	0	0	0	0	1	1
6	1	M	75	45%	3.6	0	1	0	0	0	0	0	0	0	0
19	1	M	102	41%	3.3	3	1	2	0	0	0	1	0	1	1
13	1	M	121	74%	5.9	1	1	0	0	0	1	0	0	3	1
M[a]			79.5	42%	3.4	1.3	1.4	0.9	0	0.1	0.1	0.3	0	0.8	0.6

26	0	F	62	33%	2.7	1	1	1	0	0	0	0	1	2	2
10	0	M	67	35%	2.8	3	3	0	0	0	0	1	0	2	3
17	0	M	70	52%	4.2	1	0	1	1	1	2	0	0	0	0
15	0	F	72	41%	3.3	1	3	0	0	0	0	0	0	0	0
21	0	M	75	46%	3.7	2	2	1	0	0	0	0	0	0	1
22	0	M	77	54%	4.3	0	0	0	0	0	1	1	2	2	0
9	0	M	97	65%	5.2	2	2	0	1	0	1	0	0	0	0
4	0	F	113	66%	5.3	5	0	4	0	1	0	0	0	1	0
M[b]			79.1	49%	3.9	1.9	1.4	0.9	0.3	0.3	0.5	0.3	0.4	0.9	0.8

Table 4 continued

a. Group means for children who stutter (CWS); b. Group means for children do not stutter (CWNS)

List Recall Performance

The mean number of correctly recalled words per list was calculated for each participant by dividing the total number of correct responses by the number of lists presented. Twelve lists were included in this calculation for all but one participant. Due to a computer malfunction, the responses of one CWNS (#15) were not included for the list '*River*'. Consequently, this participant's total number of correct responses was divided by 11 instead of 12. As Figure 1 shows, the mean number of correct responses per list for CWS and CWNS was not significantly different. CWS correctly recalled a mean of 3.36 words per list (*SD*=1.12), and CWNS correctly recalled a mean of 3.92 (*SD*=0.98) words per list.

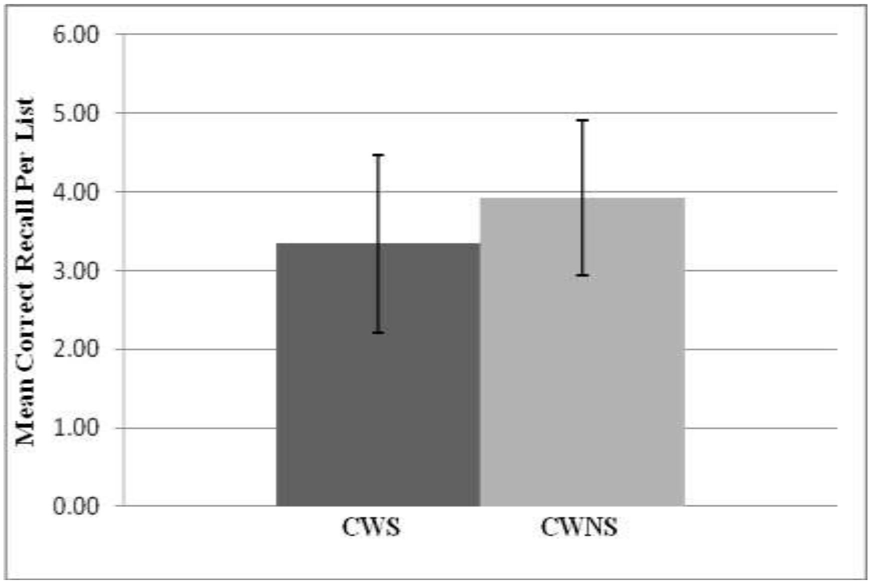

Figure 1 - Mean correct recall for children who stutter (CWS) versus children who do not stutter (CWNS)

The mean number of intrusions per list was calculated based on all intrusion types listed in Table 3. There was not a significant difference in the mean number of intrusions between CWS and CWNS (CWS *M*=.45, *SD*=.32; CWNS *M*=.62, *SD*=.23).

For each talker group, the average number of phonological, semantic, and unrelated intrusions was calculated for responses throughout the list recall task. On average, CWS produced 1.38 (*SD*=1.60) phonological errors, 2.25 (*SD*=1.91) semantic errors, and 0.63 (*SD*=0.52) unrelated errors. CWNS produced an average of 1.38 (*SD*=1.30) phonological errors, 3.00 (*SD*=3.02) semantic errors, and 0.75 (*SD*=1.16) unrelated errors. Based on these measures, there was not a significant difference in types of errors produced by CWS and CWNS, as shown in Figure 2.

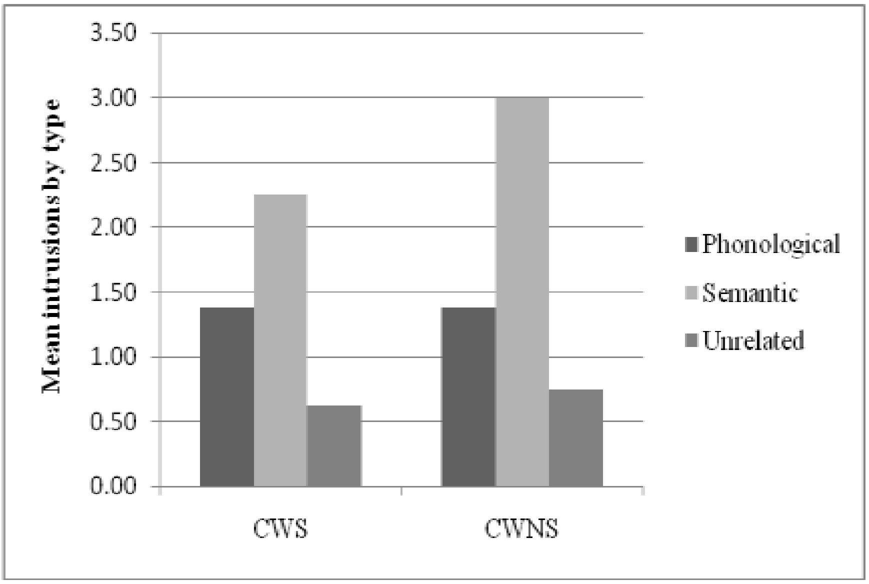

Figure 2 - Mean phonological, semantic, and unrelated intrusions by group

The proportion of correct recall by order of word presentation was calculated for CWS and CWNS. These percentages are shown in Figure 3. Percent correct recall of words presented in the beginning of lists (first and second) for CWS and CWNS was 43% and 42%, respectively. For words presented in the middle of lists (third through sixth), CWS only recalled 24%, compared to CWNS, who recalled 38%. Participants in the CWS and CWNS groups both recalled 77% of the last two words from each list.

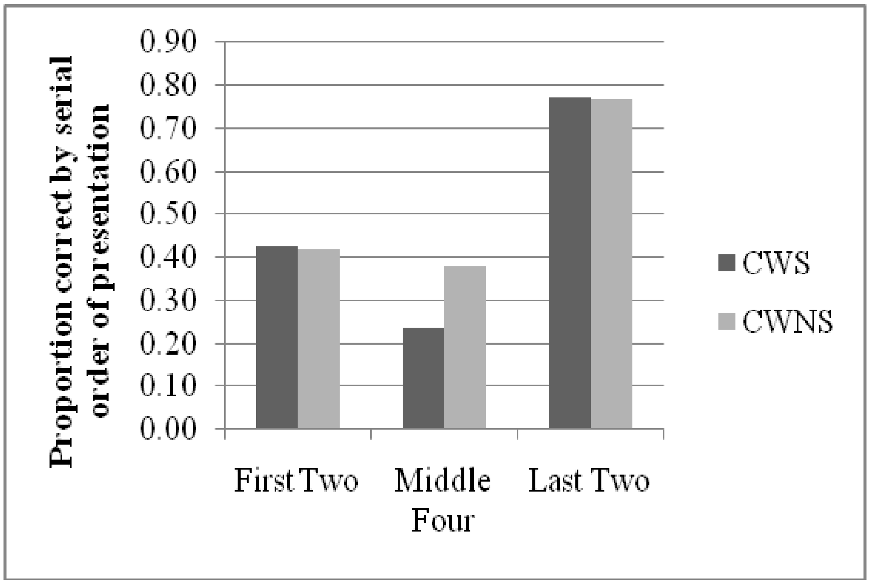

Figure 3 - Proportion correct recall by serial order of presentation for children who stutter (CWS) versus children who do not stutter (CWNS)

A two way Repeated Measures ANOVA with the within subjects factor of order group (i.e., whether it was the first two word presented, middle four words, and/or the last two words) and the between subjects factor of talker group revealed a significant main effect for order group $F(2,28) = 31.145$, $p \leq .0001$, $eta^2 = .690$. Tukey post hoc tests indicated that the last two words in the lists were recalled with higher accuracy than the first two words as well as the four words in the middle of the lists ($p < .001$). The first two words in the lists and the four middle words were recalled with similar accuracy. There was no significant between subjects effect and also no significant interaction between talker group and order group. However, observation of the descriptive statistics indicated a non-significant trend for the CWS to recall a smaller percentage of words presented sixth, compared to CWNS. As a group, CWS recalled 25% (*SD*=18) of words presented sixth, whereas CWNS recalled 55% (*SD*=15) of words presented sixth.

Correlational analyses revealed a strong correlation between talker age in months and percentage of correctly recalled words for CWS (r=0.84, p=.01) and CWNS (r=0.88, p=.01). In both talker groups, there was a positive relationship between participant age and percentage of correctly recalled words. However, for semantic intrusions there was a positive correlation between age and the number of semantic intrusions for CWNS (r=0.71, p=.05), but not for CWS (r=.11, p>.10).

For CWNS, scores on Non-word Repetition (NWR) and Memory for Digits (MD) subtests of the *CTOPP* correlated with the number of phonologically related intrusions produced during the list recall (NWR, r=-0.72, p=.05; MD, r=0.66, p=.10). In contrast, for CWS, these correlations were not significant (NWR, r=-.41, p>.10: MD, r=.16, p>.10).

Discussion

Based on the data from eight CWS and eight age-match CWNS, there was not a significant difference in the mean percentage of correctly recalled words, nor was there a significant difference in the mean number of intrusions per list. When considered separately, the mean numbers of phonological, semantic, or unrelated intrusions did not differ significantly between talker groups. Although these measures did not differ significantly, they varied in the expected direction, such that CWNS recalled a greater percentage of list words and produced a greater number of semantically related errors, compared to CWS. Additional participants may strengthen the findings to a level of significance.

Although not significant, the percentage of correct recall for CWS was lower than for CWNS, suggesting a less efficient system for successfully recalling words previously heard. Furthermore, there was a trend for the CWS to produce fewer semantically related intrusions overall, compared to CWNS. As suggested by Sheng and McGregor (2010), typically developing children demonstrate a shift from sound-based to more meaning-based organization of words. However, CWS have demonstrated less efficient organization of the mental lexicon from a young age, as indicated by a slower shift from holistic to incremental processing (Byrd et al., 2007). The strong correlation between age and number of semantic intrusions for CWNS, and the lack of correlation between the same factors for CWS demonstrates variation from typical language development, and depressed meaning-based organization compared to typically developing peers.

The significant main effect of order group on the recall of CWS and CWNS supports the earlier finding that serial order of presentation influences word recall (Glanzer & Cunitz, 1966). Talkers from both groups recalled words at the end of lists to a greater extent than words in the beginning and middle. Interestingly, the greatest variation between CWS and CWNS on order effects was in the recall of words presented sixth, or third from last, in a list. While CWNS recalled 55% of words presented sixth, CWNS only recalled these words 25% of the time. The recency effect, which explains the tendency to recall words just heard (*i.e.*, at the end of lists) more readily than words heard earlier, allowed CWNS to recall a greater percentage of recently-presented items compared to CWS (Glanzer et al., 1966). It appears that the recency effect was strongest for the last two words in CWS, and dropped for the third-to-last word, whereas CWNS more frequently recalled the last three words. This suggests a diminished ability in CWS to store information in short-term memory for accurate retrieval. This deficiency may also have contributed to lower scores on the Non-Word Repetition subtest of the *CTOPP* in CWS, compared to CWNS.

Apart from any relationship to list recall performance, it is important to note the difference in standard score means between CWS and CWNS on both the Non-Word Repetition subtest of the *CTOPP* and the *PPVT-IV.* The findings in the present study lend support to past findings that CWS perform more poorly than CWNS on nonword repetition tasks and measures of receptive vocabulary (Anderson et al., 2000; Hakim & Bernstein Ratner., 2004; Murray et al., 1977). Both characteristics may contribute to less efficient organization of the mental lexicon in CWS.

In contrast to CWS, for CWNS, the performance on the Memory for Digits (MD) subtest of the *CTOPP,* correlated positively with the number of phonological intrusions on the list recall task. In other words, the better CWNS performed on Memory for Digits, the more phonological intrusions they generated during the list recall task; a relationship that was not found for the children who stutter. One explanation of this finding is that these individuals were strong in the skill required to hold multiple pieces of information in short-term memory for recall. However, the MD subtest does not require specific attention to phonological properties of the stimuli because they are all numbers. Therefore, children who were able to recall a string of numbers accurately do not necessarily have the skill to recall words without making phonological errors, especially given that stimuli lists for the present study were purposely composed to allow for such phonological intrusions. Although it is not immediately clear why MD scores and phonological intrusions correlated positively for CWNS, it is possible that children with the capacity to recall a greater number of items attempted to guess more words on the list recall task.

Perhaps more logical was the finding of a negative correlation between performance on Non-Word Repetition (NWR) subtest of the *CTOPP* and the number of phonological errors, for CWNS, but again, not for CWS. In other words, in the CWNS group, children who performed better on the NWR subtest generated fewer phonological intrusions on the list recall task. Thus, a measure of phonological memory on one test carried over to a different task, list recall, which measured a similar characteristic. The lack of a correlation for CWS between the number of phonological intrusions and performance on either MD or NWR subtests provides further evidence of the inefficient organization of their mental lexicons.

Recommendations

The purpose of this study was to pilot a list recall task on CWS and compare their performance on the task to CWNS. The procedures used to administer the list recall task in this study can be used in future studies. Piloting the list recall task proved to be a worthwhile venture to test the selected stimulus lists and determine the best procedure for administering this task to children. The stimulus lists for this study can be used in future studies, with a few suggested revisions. In order to investigate the difference in recall of CWS for high and low neighborhood density and word frequency, lists should be balanced for these characteristics. By including stimuli with both high and low neighborhood density and word frequency, future studies could determine how these characteristics relate to recall in CWS. As described by Byrd et al. (2007), CWS have more difficulty retrieving words with many phonological neighbors, compared to those with fewer phonological neighbors. A list recall task focused on these features may support the idea that CWS are able to recall words with few phonological neighbors more accurately than those with many phonological neighbors.

This pilot study only included eight CWS and eight age matched CWNS. Although there were observable differences between groups, the small number of participants did not yield significant differences between groups on most measures. The inclusion of more participants in future studies would help researchers determine where the meaningful differences lie between CWS and CWNS regarding list recall. Given the observation that CWS are less likely to recall the last three words of a list, compared to CWNS, and that CWS performed significantly more poorly on the Non-Word Repetition subtest of the *CTOPP*, further research into the short-term and phonological working memory of CWS is warranted.

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Vita

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