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LEXICAL DECAY RATE IN YOUNG ADULTS WITH SPECIFIC LANGUAGE IMPAIRMENT

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ABSTRACT

People with specific language impairment (SLI) experience poor sentence comprehension. It is unclear whether suboptimal maintenance of lexical information contributes to their comprehension problems. This study attempts to gauge the lexical decay rates of young adults with SLI, an understudied age group.

Twenty-three young adults with SLI and twenty-three age-matched controls participated in an auditory word detection reaction time (RT) task wherein they heard a target word followed by 500 milliseconds of silence and a sentence containing the target word. We manipulated the time between the initial presentation of the target and the occurrence of the target in the sentence by either playing the sentence at a typical rate or slowing it down by fifty percent. We took the difference in RT between the slowed and typical rate conditions to indicate the degree of lexical decay that took place. To remove the possibility that group differences in RT were due to group differences in the ability to predict the occurrence of the target, we used reaction time on a measure of sentence processing efficiency as a covariate. In the sentence processing efficiency task, participants were presented with an image accompanied by an audio recorded sentence and were asked to press one of two buttons to indicate whether the event in the image matched the event in the sentence.

The group with SLI showed a smaller difference in RT between the two conditions, suggesting that the young adults with SLI in our sample had a slower decay rate than their same-age peers.

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Chapter 1

Introduction

Specific language impairment (SLI) is the presence of significant difficulties with language acquisition in the absence of any other impairment that traditionally poses a challenge to language acquisition. A person with a diagnosis of SLI has undergone a battery of tests that have ruled out hearing loss, general cognitive impairment, frank neurological dysfunction and the presence of any syndromes or additional disorders as threats to language acquisition yet demonstrates low scores on tests of language ability (Leonard, 1998). Although most of the research on SLI has focused on children, there is evidence that SLI persists into adulthood, and certain tests for SLI have proven reliable in adults (Johnson et al., 2010; Fidler, Plante & Vance, 2011).

One of the ways SLI manifests itself is in sentence processing ability. A general slowing of sentence processing and a failure to detect certain kinds of agrammatical sentences in processing tasks have been observed in children and adolescents with SLI respectively (Montgomery, 2006; Leonard, Miller & Finneran, 2009). One explanation for this less efficient sentence processing is that individuals with SLI have weaker verbal working memories. Some studies attribute this weakness to generalized information processing limitations (Weismer, Evens & Hesketh, 1999; Miller, Kail, Leonard & Tomblin, 2001; Montgomery, 2000; Montgomery & Leonard, 1998), while other studies suggest problems in specific areas of information processing such as phonological processing or temporal processing of rapidly changing auditory stimuli (Corriveau, Pasquini & Goswami, 2007; Gathercole & Baddley, 1990; Gillam, Hoffman, Marler & Wynn-Dancy, 2002; Tallal, 1976). A study by Montgomery (2006) was designed to tease apart the implications of these two perspectives. He had children with SLI, age matched controls, and receptive language ability matched controls perform two word recognition reaction time tasks: one wherein the target word was part of a list of words and one wherein the target word was embedded in a sentence. When the target was part of a list, there was no significant difference in reaction time among the three groups, but when the target was embedded in a sentence, the SLI group demonstrated reaction times that were significantly longer than both control groups. These results seem to indicate that the difference between people with SLI and people with typical language development has to do with higher-order linguistic processing operations rather than acoustic-phonetic processing.

Since linguistic processing relies on the activation of brain networks that support lexical knowledge, lexical decay may help facilitate the higher-order linguistic processing operations mentioned in Montgomery (2006). Lexical knowledge is stored in the nodes of the network, and the arcs of the network are pathways along which energy may travel to a node, raising the node's level of activation. Each node's level of activation is equivalent to the availability of the information contained in that node to the working memory. If a listener experiences a lack of activation of the nodes that correspond to the words in the sentence they are hearing, they will not have enough information in their working memory to make sense of what they are hearing. If a listener experiences an abundance of activation of nodes that are irrelevant to the sentence they are hearing, then the irrelevant information will interfere with comprehension of the sentence at hand. Lexical decay mitigates this interference by ensuring that the activation level of lexical nodes decreases over time. This means that nodes that have been activated most recently and are therefore more relevant to the current sentence are more active than nodes that were activated less recently. Lexical decay rate determines how quickly the activation decreases, maintaining the optimal balance between activation and interference in a given situation (Altmann & Gray, 2002). If an individual's lexical decay is not occurring at the most effective rate, they may experience inefficient sentence processing due to lack of activation of relevant nodes relative to the rest of the lexicon. We suspect that an inappropriate lexical decay rate could be one of the factors that account for the inefficient sentence processing of individuals with SLI.

Little research has focused on lexical decay in SLI. Two studies have found evidence for a difference in lexical decay rate for people with SLI although neither study was designed to look at lexical decay but to examine the timing of lexical access and word recognition processes respectively. Seiger-Gardner and Schwartz (2008) found a late semantic inhibition effect for children with SLI on a picture naming task that may be attributed to slower decay rates. Conversely, using a visual world paradigm, McMurray et al. (2010) found evidence that adolescents with SLI display lexical decay rates that are faster than normal. In a magnetoencephalography (MEG) study, Helenius, Parviainen, Paetau and Salmelin (2009) found an abnormally weak N400m response for a repeated stimulus in adults with SLI. The authors attributed it to impaired short-term maintenance of linguistic activation or unusually rapid release of irrelevant representations. Weismer and Hesketh (1996) observed that a fast speech rate put children with SLI at a disadvantage for lexical learning but that a slow speech rate did not necessarily aid their lexical learning. Furthermore, Montgomery (2005) found no evidence for lexical decay in children with SLI using a lexical processing RT task.

The purpose of the current study is to use a sentence-embedded word recognition reaction time task to determine whether there is a difference in lexical decay rate between adults with SLI and adults with typical language development. Much of the work on real-time lexical processing in children with SLI has used this task, which has proven sensitive to the timing of lexical processing in children with SLI as well as in typically developing children (Montgomery, 2006). Participants hear a target word before hearing a sentence that contains that word. When they detect the target word in the sentence, participants press a button. The time elapsed from when the target word appears in the sentence to when the button is pressed can be used to estimate the speed of lexical processing. The speed of processing is believed to correlate with the participant's level of activation for the target word. By manipulating the time elapsed between the initial activation of the target word and the instance of the target word in the sentence while controlling the amount of information involved in the task, we can estimate the decrease in activation of the target word over time, the decay rate for that item. Because our stimuli were sentences, we wanted to remove the effect of individual differences in sentence processing efficiency. Therefore, we used RT on a task designed to measure sentence processing efficiency as a covariate.

Chapter 2

Methods

Participants

Twenty-three adults (14 females) with SLI ages 18.75 to 27.75 years with a mean age of 22.3 years and 23 adults (20 females) with typical language development ages 18.83 to 25 years with a mean age of 21.48 years were recruited. All participants spoke English natively. The participants with SLI had 11to 14 years of education with a mean of 13.17 years. The typically developing participants had 14 to 16 years of education with a mean of 14.52 years. All participants passed a hearing screening at 25 dB HL. General cognitive impairment was ruled out by administration of the three subtests of the Wechsler Adult Intelligence Scale (Wechsler, 1997) to estimate performance intelligence quotient (PIQ).The participants were placed in either the SLI group or the typical group based on their composite performance on the Clinical Evaluation of Language Fundamentals-Fourth Edition Word Definition subtest (Semel, Wiig and Secord, 2003), a 15-word spelling test, and the Modified Token Test (Morice & McNicol, 1985) following the discriminant function suggested by Fidler et al. (2011) which has shown a sensitivity of 78% and a specificity of 83% for discriminating adults with language impairments from adults with typical language development. A positive group membership value indicated membership in the SLI group and a negative group membership value indicated membership in the typical language development group (Table 1). Participants also completed a history questionnaire. Those with a history of language and academic difficulties but negative group membership values on the discrimination function were excluded from the study. The TD group's mean estimated PIQ was significantly higher than that of the SLI group (*F* (44) =1.64, p<.001).

Table1: Group performance on IQ test and language measures

Group	Estimated PIQ[a]	Spelling test score[b]	CELF score[c]	Token test score[b]
Typical				
Mean	112.70	11.30	36.04	39.91
StDev	10.68	2.16	6.73	2.70
SLI				
Mean	98.91	4.17	25.13	31.00
StDev	9.13	2.53	8.70	7.21

Group membership=6.6626 + spelling score x -0.2288 + CELF score x -0.1475 + Token test score x -0.0893
[a]Mean standard score=100
[b]Total possible score=15
[c]Mean standard score=100
[d]Total possible score=44

Materials

The 80 sentences and target words used in the word detection task were taken from Leonard et al. (2009). Although Leonard et al. used both grammatical and ungrammatical sentences, the current study only used grammatical ones (Appendix A). The target appeared in one of three positions in the sentence (sixth, seventh or eighth word) to discourage participants from counting words yet provide some grammatical context. In the following examples, the target word is italicized.

(1) (a) She looked at the man's *watch* because she forgot her own.

(b) Brian likes it when he draws *cartoons* and funny faces.

(c) Cary knows that he will recognize his *brother* in his Halloween costume.

The 80 sentences were distributed across four conditions. Three of the sentences were used as practice. Thirty-four were played at a normal speech rate. Thirty-four were slowed down with PRAAT software (Boersma & Weenink, 2006) by 50%. The goal of the slowed condition was to increase the duration of the sentences by about one second. The nine remaining sentences were catch items wherein the sentence did not contain the target word. The purpose of the catch condition was to maintain the vigilance of the participant. An example of a catch item appears in (2). The target is in parentheses.

(2) Last week we biked ten miles with our friends. (*Swing*)

The number of items per condition was based on a power analysis that assumed a medium effect size. The target words were matched across normal and slow speech rate conditions on the log of the spoken frequency based on the Corpus of Contemporary American English (Davies, 2009).

The sentences and target words were recorded by a male native American English-speaker with vocal performance training in a sound booth using a head-mounted Shure WH20 microphone and a Marantz PMD650 minidisc recorder. After practicing each sentence to achieve natural intonation, the speaker made at least two recordings of each sentence and each target word in isolation. A research assistant then selected the version of each sentence and target word that sounded most natural. The selected recordings were then digitized at a sampling rate of 22 kHz, low-pass filtered, and amplitude normalized. Finally, the sentences were distributed randomly across the four conditions. There was no difference among conditions in the time elapsed from the beginning of the sound file to the sentence-embedded appearance of the target word before rate manipulation was applied.

The stimuli for the truth-value judgment task included 36 sentences, a third of which had a simple active structure (*The girl is chasing the boy.)*, a third of which had a simple passive structure (*The baby is being fed by the girl.)*, and a third of which had a compound subject (*The boy and the horse are washing the cow)*. The sentences were recorded with normal rate and prosody by a male speaker of standard American English. In half of the trials, the sentence agreed with the image, and in half it did not.

Procedure

Both tasks were presented by laptop computer using an E-Prime 2.0 script and a Psychological Software Tools serial response box positioned beside the computer and aligned with the participant's preferred hand. These were part of a larger set of tasks that were administered over the course of two sessions (Poll, Miller, & Hell, 2012).

The instructions for the word detection task were presented in written form on the screen but also given orally by the experimenter. Then, using headphones, participants performed a sentence-embedded word-recognition reaction time task wherein they heard a target word and were directed to press a button on the response box as soon as the target word appeared in the sentence that followed. The instructions emphasized responding as quickly and accurately as possible. The first three sentences were used as practice, and the remaining sentences were presented in two distinct counterbalanced pseudorandom orders. The constraints on randomization prevented more than five sentences from the same condition appearing in sequence, and ensured that at least one catch sentence appeared for each nine experimental sentences.

The materials and procedure for the truth-value judgment task were taken from a study completed by Miller, Kail, Leonard and Tomblin in 2001. Participants saw a black and white line drawing of an event for two seconds before they heard a sentence that either did or did not describe the event in the drawing. They were instructed to press a green or red button as soon as they could to indicate whether the sentence did or did not match the image. When the button was pressed, the image was replaced, and a new trial began.

Chapter 3

Results

Prior to the analysis, negative reaction times (RT) and outliers were excluded. Outliers were computed on an individual basis and were defined as any RT that was more than twice the mean RT for that participant. Of the non-catch trials, 4.8% of the typical group's responses and 7.2% of the SLI group's responses were excluded as a result. Catch trials were not analyzed. Due to the right-skewed nature of the RT data, we ran the parametric statistical tests on the inverses of the RTs. A summary of the results before the transformation are shown in Table 2. A mixed between-within subjects ANCOVA was run with the between subjects variable being group (typical or SLI), the within subjects variable being speech rate, and the covariate being mean RT on the truth-value judgment task. There was no significant difference in RT on the truth-value judgment task between groups (F (1, 42) = 3.45, $p > .05$; $\eta_p^2 = .076$). In the word recognition task, RTs tended to be longer for the slowed sentences than for the sentences played at the recorded rate, but this effect was not significant (F (1, 42) = 3.94, $p > .05$; $\eta_p^2 = .086$). The reaction times of the SLI group were significantly longer than those of the typical group (F (1, 42) = 4.77, $p < .05$; $\eta_p^2 = .102$). Most importantly, the RT's of the SLI group differed less between conditions than those of the typical group as seen in Figure 1 (F (1, 42) = 6.86, $p < .05$; $\eta_p^2 = .140$).

Table 2: Mean RT (standard deviation) for each condition by group without covariate

Group	**Condition**	
	Normal speech rate	**Slowed speech rate**
Typical	341 (60)	408 (91)
SLI	429 (121)	473 (145)

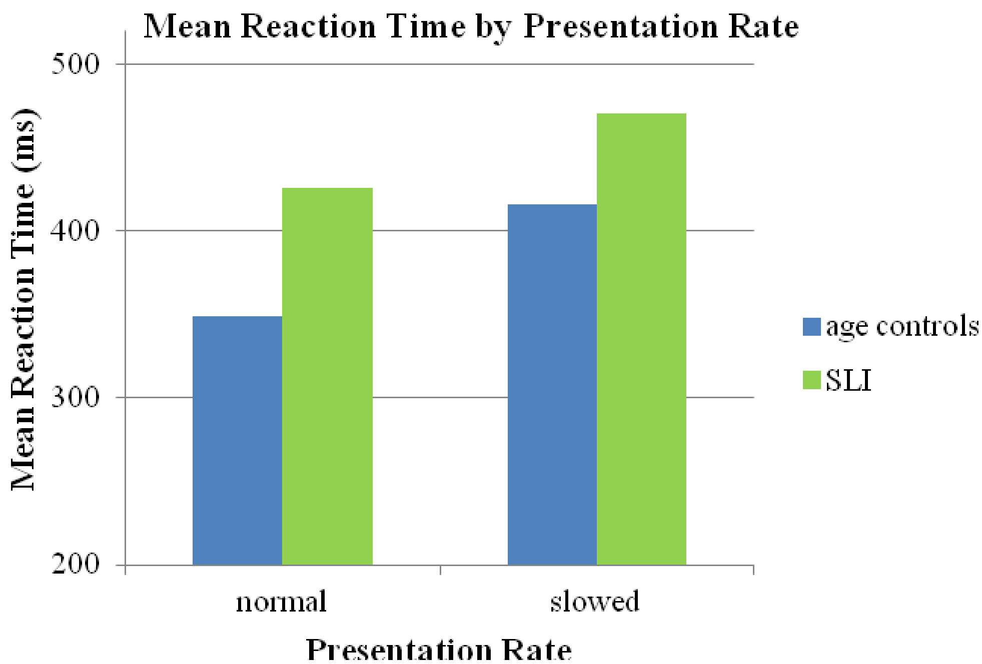

Figure 1

Chapter 4

Discussion

The goal of this study was to determine whether there is a difference in lexical decay rate between adults with SLI and adults with typical language development using a sentence-embedded word recognition reaction time task. We found that although both groups had longer RTs in the slowed speech rate condition than in the normal speech rate condition, the RTs of the SLI group did not differ as much between the conditions as the RTs of the typical group did. This pattern remained after we adjusted the RT's for individual performance on a measure of sentence processing efficiency and suggests that the SLI group had a slower lexical decay rate than the typical group. This slower decay rate presumably led to less disruption in the slowed speech rate condition, but could lead to greater interference and less efficient sentence processing in naturalistic listening situations for individuals with SLI. A limitation of our results is that we did not measure the participants' reaction times to a non-linguistic auditory stimulus. This information would have allowed us to isolate the time spent on linguistic processing from the total response time.

Our results are inconsistent with McMurray et al. (2010) and Helenius et al. (2009) which suggest a faster than typical lexical decay rate for adolescents and adults with SLI respectively. However, they confirm Seiger-Gardner and Schwartz (2008), which found a slower than typical decay rate in children with SLI. The observation made by Weismer and Hesketh (1996) that a fast speech rate is detrimental to lexical learning in children with SLI is consistent with our results.

These seemingly contradictory results can be resolved in terms of functional decay theory (Altmann & Gray, 2002). Functional decay theory proposes that decay and interference are functionally related and that decay rate adapts to the rate of memory updates. Altmann and Gray (2002) propose that decay rate is not stable; rather it is regulated by a mechanism for controlled decay. A mechanism for controlled decay that is less flexible in people with SLI can account for all the literature on lexical decay rate in SLI mentioned above. The rate of memory updates can correspond to the word presentation rate used in experimental tasks. Studies that suggest a faster lexical decay rate in SLI such as McMurray et al. (2010) and Helenius et al. (2009) use word presentation rates of less than one word per second. Studies that suggest a slower lexical decay rate in SLI such as Seiger-Gardner and Schwartz (2008), Weismer and Hesketh (1996), and the present study use word presentation rates of two words per second or more. This combination of results suggests that people with SLI do not adjust their lexical decay rate to a given word presentation rate as well as typically developing controls, which may contribute to sentence processing issues for people with SLI overall. Ironically, the SLI group in the present study adjusted better than the typical group in that their RTs did not increase as much in the slowed condition. This may be attributable to the mixed presentation of the stimuli, which may not have allowed the typical group to adjust to either speech rate as well as they would have with a block design.

A presentation design variable of blocked versus mixed stimulus presentation can determine whether prolonged exposure to a particular speech rate helps listeners adjust their lexical decay to the optimal rate for the stimulus. If the controlled decay mechanism of typically developing individuals is better at adjusting to speech rates, then the block design would decrease the RT of the typical group more than the SLI group for each speech rate condition.

The typically developing children in Montgomery (2005) mimicked our pattern of increased RT's for word detection in increasingly slow sentences, but the SLI group in the same study demonstrated the opposite pattern. It is interesting that the SLI group in Montgomery (2005) showed no sign of lexical decay because the task they participated in was very similar to the task used in the current study. One difference is that the target word appeared in the second of two sentences involved in each trial, which may have increased the duration that participants were asked to maintain the target word and opportunity for interference, decreasing the influence of the initial presentation of the target word. Future research might ask participants to maintain the target word for a wider spectrum of durations to get a better idea of the shape of the decay function.

Appendix A

Stimuli

Practice sentences
The babysitter on weekends often bakes cookies for a treat.
When not studying, Sue listens to music in her room.
The thief in movies always admits guilt when questioned.

Normal rate sentences
A good dog should learn *tricks* when it is a puppy.
The librarian at the desk always reads *books* and magazines.
On Sundays, Marcy volunteers her *time* at the homeless shelter.
Jerry likes to carve the *turkey* with a sharp knife.
The young woman next door always wears *gloves* when raking.
The grocer at the market always buys *pears* and bananas.
The reporter at work always carries *pens* and a notebook.
We are hoping that Michael's *wish* comes true soon.
Today we are releasing the *bird* into the wild.
Henry would like it if Chris marries *Peter* in a traditional ceremony.
The carpenter on TV always bangs *nails* with a very big hammer.
Brian and Amy will pack a *suitcase* tonight.
She is always annoying the *driver* of our bus by shouting loudly.
The hostess's job is to take *guests* to their tables.
Many people will whisper in *church* because it is quiet.
The doctor will be caring for *grandma* when she goes home.
The band at the club usually begins *concerts* on time.
The hiker at Yosemite always cooks *dinner* over a campfire.
He will be repeating the *class* next year because he failed it.
The boy at parties always wins *prizes* in silly contests.
I will be buying my *father* a book for his birthday.
She is likely to arrive at *work* late because traffic is heavy
The young woman is choosing *flowers* to put in her scrapbook.
The daughter at college usually borrows *money* to buy school books.
Many parents like to name *babies* after someone in the family.
The salesman rang the woman's *doorbell* but no one was home.
I wish I had Sally's *tan* instead of my sunburn.
During the holidays, she always decorates *rooms* with holly and mistletoe.
My parrot at home always bites *bars* of his large cage.
Thomas and Sam are always kicking *rocks* and hurting their toes.
In the morning I dropped Sue's *daughter* at school.
The store in the mall always accepts *cash* or credit cards.

Slowed sentences
For her party, Chris is making *cards* on pink paper.
My sister in Texas usually calls *father* instead of emailing him.
The ghost jumps up and scares my *mother* at the haunted house.
The musician in town always beats *drums* to recorded music.
The police like to arrest *robbers* on TV.
Every year she travels and tours *museums* in big cities.
The coastguard is rescuing the *ship* that had radioed for help.
In archery you aim the *arrow* at the target.
You should watch closely as he paints *fruit* and flowers.
My mother always ignores our *jokes* that she considers in bad taste.
Some kids like to dare a *friend* to do something dangerous
Their mother likes to show *pictures* to the children at bedtime.
The man likes sailing and owns a *boat* at the yacht club.
I put a nail in my neighbor's *wall* to hang his painting.
She must be accepting the *job* offer at the big company.
If the man dies, the son inherits *land* and money.
The nurse in the hospital always gives *pills* to patients with water.
Mother says that my whistling bothers my *sister* when she is studying.
The lawyer read the parent's *will* to her family.
I am always running with *dogs* in the park.
The groom lifted the bride's *veil* during the wedding ceremony.
The child at the preschool always grabs *toys* from other children.
The famous star acts in and directs *movies* that make big money.
This rainy weather is ruining the *picnic* for the school.
The little girl found Martin's *ball* under the chair.
Brian likes it when he draws *cartoons* and funny faces.
You should never try to copy *answers* from a friend.
It is rude to swear at *dinner* but my brother does it.
The Boy Scout troop is selling a *bike* to raise money.
The girl at the mall always admires *women* wearing expensive clothes.
When company visits, Betty pours *tea* and Clara passes out cookies.
The gardener at the park never waters *flowers* after sunset.
My sister keeps borrowing my *phone* but never says thank you.
We plan to cheer our *team* loudly if they win the game.

Catch sentences
Father turned his boat around in the water. (*Moon*)
The people watched as the bull charged at the man. (*Whisker*)
Last night, she talked on the phone. (*Walnut*)
Last week I called my friend from home. (*Button*)
Last week we biked ten miles with our friends. (*Swing*)
Yesterday I buttered my toast at breakfast. (*Plane*)
When he cooked dinner he burned his finger on the pot. (*Lamp*)
Last week he passed his test with an A. (*Target*)
Yesterday, the storm damaged our roof. (*Net*)

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