THE EFFECTS OF NEAR, MEDIUM, AND FAR PRIOR SPEECH CONTEXT ON FUNCTION WORD PERCEPTION

By

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A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

Communicative Sciences and Disorders - Master of Arts

2018

ABSTRACT

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When listening to rapid, casual speech, humans effortlessly perceive boundaries between words that may be only weakly encoded in the acoustic information. Research into the temporal characteristics of speech has demonstrated that when context speech rate is manipulated, the number of words heard by a listener can be altered. Building on this research, this study investigated how specific manipulations of different portions of recorded speech can produce a disappearing word effect in which a heavily co-articulated function word may be perceived as a part of the preceding syllable, e.g., "John didn't tell the junior or representative about it." The stimulus conditions entailed different numbers of syllables expanded/slowed, starting from the beginning of the sentence up through the target (underlined) portion. Participants (*n*=34) listened to these sentences and typed what they heard. Results were analyzed for proportion of function words reported. It was found that all slowed conditions resulted in a decreased frequency of hearing function words. A stronger effect was associated with additional expanded syllables. These results suggest that slowing non-adjacent prior context elicits the LRE, a finding that may inform communicative disorders research including dyslexia intervention.

Keywords: syllable segmentation, lexical rate effect, prior context

ACKNOWLEDGEMENTS

I would like to extend my heartfelt thanks to my thesis advisor, Dr. Laura Dilley, for her mentorship, wisdom, and encouragement during all stages of this experiment. I would also like to thank Dr. Brad Rakerd for his help throughout the process and Dr. Courtney Venker for her willingness to join the team late in the game. Thank you as well to Dr. Matt Lehet for his substantial assistance with stimulus selection and experiment design, especially with Praat and E-Prime, and to the members of the MSU Speech Perception-Production Laboratory, especially Lizzy Butterfield for running subjects when I could not be on campus. I would also like to thank my parents and fiancé, Joe, for their support and patience throughout this endeavor.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

KEY TO ABBREVIATIONS

LRE	Lexical Rate Effect
PRE	Phonetic Rate Effect
P	Far Prior Context
P2	Medium Prior Context
P1	Near Prior Context
T	Target Region

Introduction

Overview

The study of speech perception is an exciting frontier in communication sciences research. Traditionally, theories of speech perception and lexical recognition have posited that neural processes of auditory perception were geared toward extraction of a sequence of phonemes, which are the "building blocks" of words. On this view, all other acoustic information (e.g., rate and pitch variation) was treated as "noise" by the brain and was filtered out (see Diehl, Lotto, & Holt, 2004). However, with the introduction of technologically sophisticated tools in the middle of the 20th century, significant variability was uncovered and documented in the acoustic signals, specifically relating to speech timing (e.g., Lisker & Abramson, 1967; Miller & Liberman, 1979). Considerable progress has been made in recent decades in studying the role of various aspects of the acoustic signal in understanding spoken words, including the role of timing.

The advancement of speech perception research has enhanced theoretical and practical applications of various communication disorder areas (Bahr & Silliman, 2015). Basic research furthers scientific understanding of how people perceive spoken language, which is an integral aspect of communication from infancy through adulthood. This study focuses broadly on the role of prosody in recognition of spoken words, where prosody is defined as the timing, rhythm, pitch, and sometimes voice quality of the words spoken. Among these prosodic characteristics, this study focuses specifically on speaking rate, with the aim of enhancing knowledge of how diverse speech signals are decoded and encoded as words. Because this study focuses on the basic mechanisms of human oral-aural communication, the present research has the potential to

inform clinical understanding of communication disorders and enhance applied research across languages.

Background

The rate, or timing, of speech has been found to be a significant influence on the understanding of spoken words. Speech scientists have sought to manipulate speech rate in order to test its effects on listeners' perception of words. One well-known example of the dependency of lexical perception on timing is here termed the *Phonetic Rate Effect* (PRE). The PRE occurs when a phoneme with relatively "slow" timing characteristics, such as a long voice onset time for the voiceless plosive /p/ in English, is made to be perceived as a homorganic phoneme with relatively "fast" timing characteristics, in this case /b/, under a temporal manipulation of the speech signal. This can happen when the preceding context is slowed down, which makes the "slow" phoneme seem fast in comparison (Liberman, Delattre, Gerstman, & Cooper, 1956; Lisker & Abramson, 1967). Critically for motivating the present study, the PRE is defined more clearly here to involve a change to the perceived phonemic content of speech *without* a change in the number of phonemes perceived. The PRE is thus a kind of experimentally-induced perceptual effect which reveals basic mechanisms of speech perception, specifically by demonstrating that speakers take into account speech rate variations in making determinations about which communicative units of speech are present in the acoustic signal.

Other researchers built on this work to demonstrate that perceptual normalization of speech is affected by rate-based acoustic information in the speech signal, i.e., the context speech rate (Miller & Liberman, 1979). For instance, Newman and Sawusch (1996) investigated the size of the temporal window around a rate-sensitive phoneme which might affect that phoneme's perceived phonetic identity. This research showed that a temporal window of roughly 300 ms in

either direction is thought to be essential in eliciting the PRE (Newman & Sawusch, 1996; Sawusch & Newman, 2000).

More broadly, a significant body of research has investigated mechanisms of speech perception in both typical individuals and those with a communicative disorder by focusing on the kinds of acoustic information that may affect phonetic perception; the PRE is only one such effect. For example, related research has focused on how different kinds of acoustic information may affect perception of phonetic contrasts. In one illustrative study that revealed the importance of *context* in phonetic perception, Holt (2005) found that the phonetic identity perceived by listeners of a target stimulus differing in place of articulation, e.g., the minimal pair /dɑ/ vs. /gɑ/ was affected by the fundamental frequency of the acoustic context prior to the stimulus. Surprisingly, this effect persisted even when the frequency information was separated from the critical sound by up to 1300 ms.

In a further extension of the perceptual effects associated with the classical PRE (cf. Liberman et al., 1956; Lisker & Abramson, 1969), researchers have also investigated the effects of acoustic characteristics, such as rate, on the number of phonemes that are perceived in speech. One study (Reinisch, Jesse, & McQueen, 2011b) examined word pairs in Dutch in which a phoneme at the end of the first word could plausibly be the phoneme at the beginning of the second (e.g., "een**s** **s**peer" and "een**s** peer," meaning "once spear" and "once pear," respectively); this was labeled a juncture phoneme. The first word of the pair and both versions of the second, i.e., with or without the initial phoneme, were part of the Dutch lexicon. The researchers found that when the context speech rate preceding the pair was sped up, the juncture phoneme tended to be perceived as a part of both words, i.e., a longer phoneme relative to the shortened prior context. This was because the shorter preceding context cued the listener to expect the following

sounds to be similarly short, and the relatively long juncture phoneme was thus perceived as two shorter sequential sounds (Reinisch et al., 2011b).

Recent research has shown that in addition to the number of phonemes heard, rate manipulations may also affect the number of higher-level linguistic units that are perceived – syllables or words, as well as the perceived lexical content of speech. This phenomenon, first discovered by Dilley and Pitt (2010), is here termed the *Lexical Rate Effect* (LRE). The LRE provides evidence of perceptual normalization of a speech signal influenced through the incorporation of rate-based or temporal information. Co-articulation ensures that in rapid, casual speech, certain words will blend together, such that adjacent syllables across word boundaries will blend spectrally and take on acoustic characteristics of one another (Dilley & Pitt, 2010). In extreme instances of coarticulation, some distinct words evidence acoustically as localized prolongations of the preceding syllable; e.g., the word "or" in the phrase "minor **or** child"/"minor child" may be spoken as [ɚ], so that "—nor or" is realized as a localized prolongation of the rhotic, i.e., [ɚː].

Dilley and Pitt (2010) created phrases containing a function word that was prone to extreme coarticulation in which either its absence or presence in the sentence would be semantically plausible up to a specific point in the utterance. They tested the hypothesis that *distal* speech rate – defined generally as the rate of speech of material nonadjacent to the critical function word – would affect listeners' perception of this potentially disappearing function word. Stimuli included a *target portion* (T), defined as the function word, the syllable preceding it, and the first phoneme following it; this region corresponded to the portion of the speech that was proximal. Dilley and Pitt then manipulated (i.e., speeded or slowed) the rate of the remaining

portion of the phrase. They showed the novel result that the speech rate affected the lexical content, or number of words that were heard by the participants (Dilley & Pitt, 2010).

The discovery of the LRE was followed by significant gains in research relating to speech rate characteristics. One area of focus was how speech rate affects segmentation, or perceiving boundaries between words that are not actually represented in the acoustic signal (Dilley & Pitt, 2010; Newman, Sawusch, & Wunnenberg, 2011). Despite a lack of such boundaries, listeners can effortlessly segment words, i.e., perceive the spaces between them, in regular speech (Kleinschmidt & Jaeger, 2015). This ability is noteworthy in light of the fact that there is considerable variability in what constitutes a specific phoneme within an individual's speech and especially among speakers' productions (Kleinschmidt & Jaeger, 2015). For example, one speaker's casual production of /b/ may be indistinguishable from another speaker's /p/ in isolation. Listeners' ability to make rapid judgments when mapping acoustic cues to phonetic categories relates to the ability to identify situations that were heard in the past and generalize this learning, as well as adapt to new situations (Kleinschmidt & Jaeger, 2015). Further eye tracking evidence indicates that listeners are in fact constantly updating their predictions and categorizations in real time as they listen, as a function of distal context speech rate characteristics (Brown, Dilley, & Tanenhaus, 2018; Reinisch, Jesse, & McQueen, 2011a).

An extension of these novel findings by Dilley and Pitt (2010) has focused on which properties of context produce the LRE, i.e., the conditions under which rate information in distal context can be informative to listeners in a way that changes their lexical perceptions. Pitt, Szostak, and Dilley (2016) investigated whether the LRE could be produced by acoustic timing of non-speech or degraded speech information; this enabled testing whether the LRE is a domain-general or domain-specific effect. They designed multiple experimental conditions that

included a target with a (syntactically and semantically) nonobligatory function word, following stimulus creation steps in prior work by Dilley and Pitt (2010). In particular, they manipulated the rate of the preceding temporal information when that information consisted of the original speech signal, tone sequences, and/or intelligible and unintelligible modified speech (low-pass filtered or sine-wave replicas). In contrast to the PRE, which can be elicited by actual speech, degraded speech, and tones (Wade & Holt, 2005), Pitt et al. demonstrated that the LRE was observed only when an intelligible signal preceded the target portion of a stimulus. These findings support an element of top-down processing with the rate-based LRE because the listeners presumably made determinations based on knowledge of the words they heard rather than exclusively relying on the temporal characteristics of the acoustic signal, in contrast to the PRE (Pitt et al., 2016).

Building on research questions surrounding the PRE, a critical question concerns the temporal window around ambiguous phonetic material which may affect lexical perception as gauged by the LRE. Research by Baese-Berk et al. (2014) provided an initial test of the hypothesis that the temporal window of integration of distal speech rate information is considerably wider than that demonstrated for the PRE (cf. Newman & Sawusch, 1996; Sawusch & Newman, 2000). Baese-Berk et al. conducted experimental trials to measure the proportion of listener reports of non-critical function words in different stimuli by assigning listeners randomly to one of three "global" speech rate conditions in which they experienced different overall proportions of trials of a common set of distal speech rates. Over the course of about an hour-long experimental session, Baese-Berk et al. found a significant effect of the global speech rate, i.e., the statistical distribution of distal speech rates on the function word, over and above the

distal speech rate manipulation. Baese-Berk et al. attributed these changes to statistical learning over a relatively longer window of time in the LRE, in contrast to the PRE.

The present study was conducted to further elucidate whether mechanisms of speech perception revealed in the LRE and PRE are common or somewhat distinctive. In particular, the current research focused on further examination of the temporal extent of information in distal context that might produce an LRE. In the present study, a manipulation was conducted in which different numbers of syllables were slowed, starting from the beginning of the sentence, in order to better understand sensitivity of the speech perception mechanism active in the LRE to graded distal rate information. This was accomplished by creating four rate conditions: one baseline condition consisting of the original distal speech rate, and three comparison condition in which distal rate was altered in a graded fashion that involved manipulations to successive numbers of syllables from the beginning of the stimulus. The manipulated prior context was split into different regions: the far prior context included the material from the beginning of the sentence excluding the two syllables immediately before the target region, the medium prior context was the syllable following that, and the near prior context was the remaining syllable adjacent to T. The experiment sought further evidence that there could be a potential influence of the "far" distal context on the LRE – in contrast to prior studies' findings about the PRE – by controlling carefully for the proximity of the rate manipulation to the ambiguous phonetic material. In particular, the experiment carefully controlled for the size of the temporal window around the target region, given prior research on the PRE suggesting that the temporal window of influence is 300 ms (Newman & Sawusch, 1996). To further elucidate mechanisms of the LRE, the experiment limited rate manipulation to distal context which preceded, rather than followed, the T region.

This study investigated how different distal context portions which were differentially far away in time from the proximal target (T) portion might produce differential sizes of the LRE. The *a priori* hypothesis was that any slowing of the prior context would result in a graded decrease in proportion of function word reports based on prior research (e.g., Dilley et al., 2015; Heffner, Dilley, McAuley, & Pitt, 2013). Slowing successively larger windows of prior distal context was predicted to generate successively larger LRE effects. Especially of note, it was predicted that the temporal information beyond the near prior condition, e.g., the far prior, which is well outside the 300 ms window, would have an effect on the LRE, which would provide further evidence of distinct mechanisms being engaged than in the PRE.

Research Questions

The following research questions were addressed in the study:

1) How temporally distant can distal speech material be from the prior context and still affect function word perception in the LRE?
2) Do graded changes in the amount of rate-manipulated preceding distal speech material result in graded changes in perceptual response of a function word?

Methodology

Participants

Study participants (n=34) ranged in age from 18-22 (M=20.2, SD=1.3). They were students in the College of Communication Arts and Sciences at Michigan State University. There were 14 male and 20 female participants. Participants were awarded course credit in exchange for volunteering for the study. Exclusion criteria included hearing impairment, speech impairment, and non-native English speaking background (as indicated by self-reporting and confirmed by the experimenter's observations), as well as past participation in other "Understanding and Remembering Speech" studies or "Differences in Perceiving and Remembering Speech" in the MSU Speech Perception-Production Lab. Two participants' responses were excluded from consideration in the present data because they reported that their first language was not English. Further, participants who transcribed 33% or more of their trials inaccurately on the basis of criteria described below were removed, resulting in the exclusion of one person.

Design

This experiment involved manipulations designed to test the extent of prior distal temporal context that would produce an LRE. The independent variable was the amount of preceding distal context which was rate-manipulated, with four levels, given in (1)-(4) below. The rate-manipulation factor for the distal context expansion was 1.75, meaning that the duration of the slowed portion was 1.75 that of the original speech material comprising that portion; in each case, the remaining context of a sentence was manipulated by a factor of 1.0 (no change) in each stimulus. As a result of the manipulation, specific syllables were slowed down as described below to a speed that maintained their intelligibility but that was perceptually different from the

normal rate; the remaining portions of each item were presented at the speed in which they were originally spoken. The rate of 1.75 was chosen based on past research (Morrill, Baese-Berk, Heffner, & Dilley, 2015).

For all items, the target region (T) consisted of the function word, the syllable before it, and the phoneme after it. These were never slowed down, nor was the following context, i.e., the words that came after the target, consistent with past experiments (e.g., Heffner et al., 2013). The four manipulation conditions are listed below, with the text underlined to indicate the portions slowed by 1.75, in order from least to most slowed syllables:

1) "Normal Rate," i.e., no expanded material:
    a. Example: It's not easy to convey a likely position.
2) "Far Prior Slowed," i.e., stimulus onset up to second syllable before target expanded:
    a. Example: <u>It's not easy</u> to convey a likely position.
3) "Far and Medium Prior Slowed," i.e., stimulus onset and second syllable before target expanded:
    a. Example: <u>It's not easy to</u> convey a likely position.
4) "Entire Prior Slowed," i.e., everything that precedes target region expanded:
    a. Example**:** <u>It's not easy to con</u>vey a likely position.

By design, the independent variable was a within-subjects variable in order to allow all participants to respond to stimuli of each level. The dependent variable was a binary coding of the presence or absence of the critical function word within the target region indicated in the typed response (see description below).

A script in E-Prime was used to generate a random assignment of one of the four rate versions of each item (i.e., sentence fragment comprising a stimulus) to a participant on each

trial. Each item was thus experienced only once by each participant, with no confound in item-rate condition pairings across participants. Each participant completed a total of 56 trials, with 14 trials per condition. Items were further presented in a random order.

Stimuli

Stimuli were selected from a corpus generated in a past LRE study (Dilley & Pitt, 2010). In that study, 29 speakers recorded 100 unique sentences in a casual and continuous (rather than citation-style) manner. This manner was elicited by leading the subjects to believe they were being tested for memory rather than any aspects of speech (Dilley & Pitt, 2010). The possible function words in the sentences consisted of "a," "her," "our," "are," and "or." Each sentence contained a function word in the target region.

Using this corpus, Dilley, Arjmandi, Ireland, Heffner, and Pitt (2016) analyzed the amount of discontinuity around the function word. They assigned a rating to each stimulus on a five-point scale. A score of one represented no discontinuity between the syllable preceding the function word and the onset of the function word. A score of two represented very weak discontinuity, indicating ambiguous perceptual discontinuity, amplitude that either did not decrease or decreased by no more than 50 ms at the location in question, and for items with "her" as the function word, no F1 change in voicing. Items receiving a score of three had weak discontinuity including some perceptual discontinuity, and those receiving a four or five were characterized by clear perceived discontinuity and indicated strong and very strong discontinuity, respectively (Dilley et al., 2016).

Their study revealed that the function words in the lowest two discontinuity categories were distinguished by heavy coarticulation with the prior syllable and that their segmentation was based on duration rather than other acoustic features. Overall, 77% of items had no to weak

discontinuity, and of those, 79% were in the no discontinuity category, demonstrating that for such sentences, function words tended to be articulated with the prior syllable (Dilley et al., 2016). Further research on the same corpus investigated the importance of residual timing cues in segmentation (Dilley, Arjmandi, Ireland, & Lehet, 2017). By studying the items without observable onset discontinuities that had been assigned a one or two, the researchers found that for function-word present sentences, the duration of the prior syllable and the function word was longer than in the function-word absent analogous items.

In order to ensure that items in the study possessed the appropriate spectro-temporal characteristics required to elicit the LRE such as an extended prior syllable, the present study's items were also drawn from those in the Dilley & Pitt corpus (2010) and contained no or only very weak discontinuity evidenced by ratings of one or two. Additionally, only those stimuli with at least four syllables of prior context before the target region (e.g., "Susan said those are our black socks from the attic") were considered. This was done to ensure at least two syllables of far distal context were available before the syllables of medium and near distal types.

The Praat algorithm Pitch-Synchronous Overlap and Add (PSOLA) was used for stimulus expansion (Boersma & Weenink, 2014). Stimuli were RMS normalized to a consistent value (.09). Praat was also used to truncate stimuli consistent with truncation points used in other studies within the lab. The truncation was performed in order to preserve the grammatical plausibility of items in both function word present and absent conditions. A portion of the speech following the target was truncated for stimuli that were otherwise rendered ungrammatical in one condition. For example, "Conor knew that bread and butter (are) both in the pantry" would not be grammatical as a complete sentence without the function word. However, when truncated to

"Conor knew that bread and butter (are) both ~~in the pantry~~," the fragment could plausibly end in a grammatical way.

Several truncation errors pertaining to grammaticality were carried over from past studies where items were truncated unnecessarily or not truncated (see Appendix A for the complete list of stimuli, including truncation points). However, past studies comparing obligatory and non-obligatory sentences found that obligatory status of the function word did not significantly predict the LRE (see Morrill et al., 2015). Unlike grammar, the semantics of the sentence were not used as exclusion criteria because of the finding that acoustic cues are significantly more influential in segmentation than lexical information (Newman et al., 2011).

In order to control for potential influence of the far distal context on the near distal context, the spectrogram of each stimulus was analyzed, and only items with a duration from the beginning of the near prior syllable to the point of discontinuity within the target of at least 300 ms were considered. (Stimulus selection was further refined to favor those items that contained the 300 ms mark as close as possible to that point rather than earlier.) This was done because this is the window shown in past research to extend the effect of auditory information. Thus, the intention was to enable the pinpointing of the precise effects of each syllable (Newman & Sawusch, 1996).

Potential stimuli were excluded if the speaker added, omitted, or changed any words. Items with shorter durations following the target were also given preference in order to lower the cognitive demands of recalling a long sentence that may interfere with function word perception. After the final list of 56 was assembled, an unfamiliar listener was tasked with transcribing each sentence in the normal rate condition to ensure that it was intelligible.

Stimuli were divided in several regions in Praat, with labels for the specific rate conditions corresponding to the names above (see Appendix B for the Praat script). The T region consisted of the function word, the syllable prior to it, and the phoneme following it, e.g., "That should be done before her gray hair sets in." The preceding context was divided into three sections: Region "P," or the far distal context from the beginning of the sentence, e.g., "That should be done before her gray hair sets in," region "P2," the second syllable before the target region, "That should be done before her gray hair sets in." and "P1," or the syllable prior to the target region, "That should be done before her gray hair sets in." Additionally, the context following the target region was labeled as F1, and for sentences that had a truncation point to preserve grammatical plausibility, the context following that point was labeled F2.

The syllable boundaries were marked based on spectral landmarks in Praat. In the case of multisyllabic words split across a boundary, the Cambridge American English Dictionary (Cambridge Dictionary, n.d.) was used to determine phonemic syllabification. For entries that did not indicate syllabification, the sonority sequencing principle – maximal onset principle was used (Kahn, 1976). Each item spectrogram was viewed and the .wav file listened to in Praat, and a three-stage process was utilized. First, the spectrogram was checked for discontinuities at the relevant point. If no discontinuities were present, then canonical, or steady-state, formant transitions were identified, and if a clear transition between the two phonemes was visible, the syllable was marked at that point. Barring this, consonant-vowel regions were split up so that two thirds of the region was assigned to the vowel and one third to the consonant. Final determinations of ambiguous boundaries were made by the advisor of the author.

In addition to the 56 stimuli, there were twenty fillers randomly interspersed (see Appendix C for the complete list of filler items). The sentence fillers consisted of short sentences

or fragments spoken in a casual manner but without a function word heavily co-articulated with the syllable before it. These items were included in order to prevent the participant from noticing the similarity of the stimuli.

Procedure

Participants completed the experiment in the Speech Perception-Production Laboratory in Oyer Speech & Hearing Building with one to three subjects participating in each session lasting under thirty minutes. The experiment was performed by the author, a post-doctoral speech science researcher, and undergraduate laboratory members trained by either of the former experimenters. IRB approval for research on human subjects was secured prior to beginning the experiment (see Appendix D). All subjects received an oral overview of informed consent prior to beginning and were given the opportunity to peruse a hard copy of the informed consent document (see Appendix E). They kept a copy of the document and signed another copy that was filed in the laboratory. A checklist with a script (see Appendix F) was utilized by each researcher to ensure consistency of administration across subjects.

Each participant was seated in front of a computer monitor. The monitor displayed the written context preceding the target. In cases where a multisyllabic word was split with one syllable as the near distal or P1 and the next syllable as part of the target, that word did not appear on the screen so the participant would not see any of the target. The written portion was followed by ellipses, e.g., “Anne wanted to…” for “Anne wanted to see a very funny movie.” They listened to the entire stimulus over headphones and were instructed to type the part of the sentence that had not appeared on the screen.

The experiment began with four practice items selected from the Dilley and Pitt corpus (2010) during which the experimenter closely monitored performance and answered questions or

re-explained the directions as needed without revealing any information regarding the study's purpose or the similarities among the sentences. The experimenter ensured that all questions were answered and that the room was silent before allowing the participants to proceed to the experimental items.

After finishing the task, the participants were asked to complete a background survey to gather information about age and gender, as well as to document that they met the inclusion criteria such as speaking English as their native language and not having a hearing impairment. The survey also included questions about what the participants thought the purpose of the study was in order to exclude trials from any subjects who intuited and described something close to the true nature of the study. The participants generally reported noticing the slowing of the sentences, but no participants mentioned the function words in the sentences.

Data Coding

All trials from the 34 participants who met inclusion/exclusion criteria were coded by the author to determine if a function word had been reported in the critical target region. A "1" was assigned to indicate the presence of *any* function word, and a "0" indicated the absence of a function word in the target region. To be included in the analysis, i.e., considered a valid trial, each response was required to have the syllable before and after the function word reported correctly or in a phonologically similar manner to the original sentence, e.g., for the target "monster (or) evil," responses such as "master evil" or "monster or evolve" were accepted. Items that did not contain the requisite preceding and following context were coded as N/A and not included in analysis (14%). One stimulus was removed due to greater than 90% of participants mis-typing it, leaving 55 total items in the analysis.

Regarding responses with misspellings and typos, those with a potentially substituted word (e.g., “back” when the expected response was “black”) in the syllables preceding and following the function word were coded as N/A. However, in the case of the very commonplace misspelling of “lose” for “loose,” these words were accepted as interchangeable. Other misspellings were accepted when clearly identifiable as the intended word. Also, if one additional reduced syllable was added adjacent to the function word but the trial also included the required preceding and following syllable, e.g., “a minor or **a** child” instead of “a minor (or) child,” such an item was coded as 1. Responses that assimilated the function word as a syllable of the following word, e.g., “fly along” instead of “fly (a) long” were coded as 1. Current research indicates that these items represent a reduced syllable phenomenon rather than a disappearing word phenomenon (Baese-Berk, Dilley, Henry, Vinke, & Banzina, under review).

Results

The mean rate of function word reporting and the standard error were calculated by subject for each condition in Excel. As shown in Figure 1, there was an overall decrease in function word reporting as the amount of slowed context was increased.

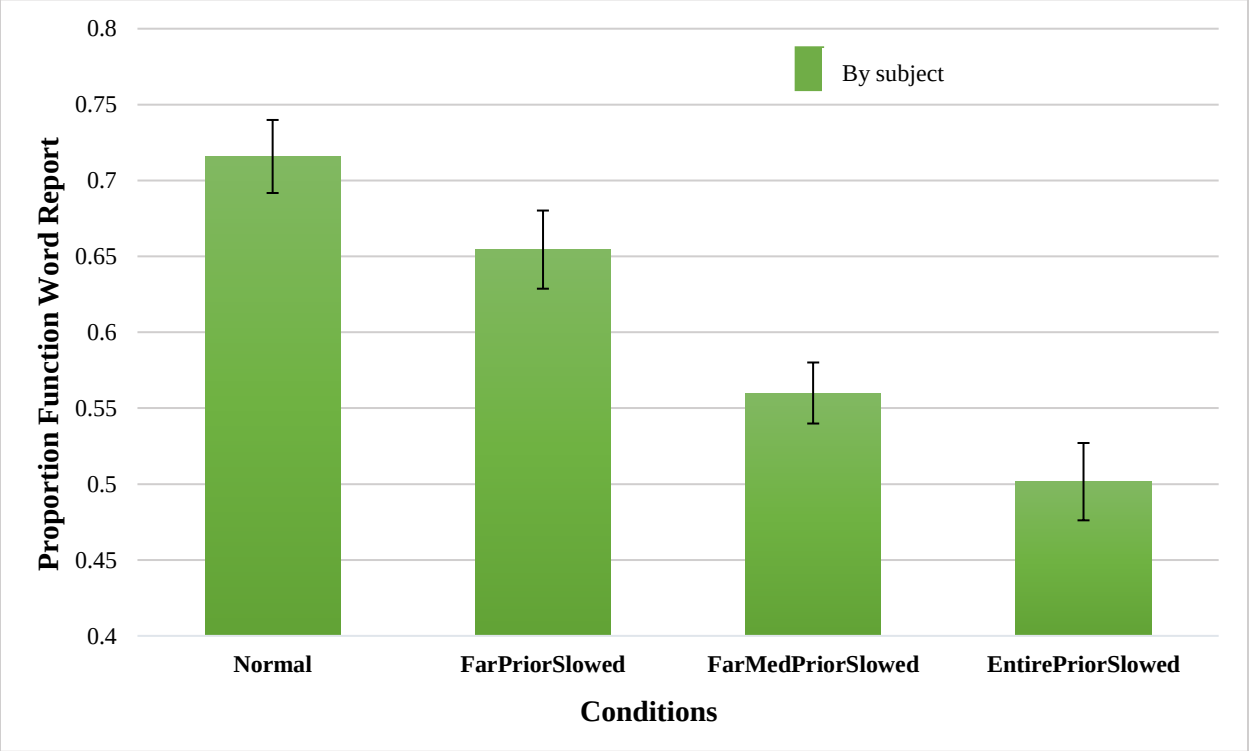

Figure 1: The Effect of Amount of Slowed Preceding Context on Function Word Reporting

A one-way repeated measures ANOVA was performed in Statistical Package for the Social Sciences (SPSS) to determine effect by subject and by item. For within-subject effects by subject, Mauchly's Test of Sphericity indicated that the assumption of sphericity had not been violated, $\chi 2(5) = 11.406$, $p = 0.983$. There was a significant effect of rate on function word reportage, $F_1(3, 99) = 15.14$, $p < 0.0005$, $\eta_p^2 = 0.315$. For within-subjects effects by item, Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated, $\chi 2(5) = 18.271$, $p = 0.003$, and therefore, a Huynh-Feldt correction to the degrees of freedom was used. There was a significant effect of rate on function word reportage, $F_2(2.528, 133.984) =$

14.048, $p < 0.0005$, $\eta_p^2 = 0.210$. Note that the discrepancy between degrees of freedom and original item count of 56 was due to one item failing to meet the minimum threshold of 90% valid trials, and a second item not available for analysis because one condition did not include any valid trials, i.e., all responses were coded as N/A.

To further assess the variability accounted for by subject differences, the within-subjects contrasts were calculated by subject. There was a significant effect of amount of slowed context on rate of function word reporting, $F_1(1,33) = 47.352$, $p < 0.001$, $\eta_p^2 = 0.589$. Additionally, to examine item difference variability, the within-subjects contrasts were calculated by item. There was a significant effect of amount of slowed context on rate of function word reporting, $F_2(1,53) = 23.789$, $p < 0.001$, $\eta_p^2 = 0.310$.

Given the significance of the within-subjects contrasts by item and condition, a min*F'* statistic was calculated to determine if experimental manipulations were significant over subjects and items simultaneously; min$F'(1,85) = 15.838$, $p < 0.001$. Therefore, the null hypothesis was rejected that there is no difference among the rates of function word reporting, and the alternative hypothesis that there is some difference among the rates of function word reporting was accepted.

Due to the overall statistical significance indicated by min*F'*, six paired samples t-tests for post-hoc comparisons between conditions were performed. The descriptive statistics derived from the by-item calculations were selected over the by-subject statistics due to the higher standard error of the by-item statistics compared to by-subject as evidenced in Figure 2. This ensured a more a conservative calculation.

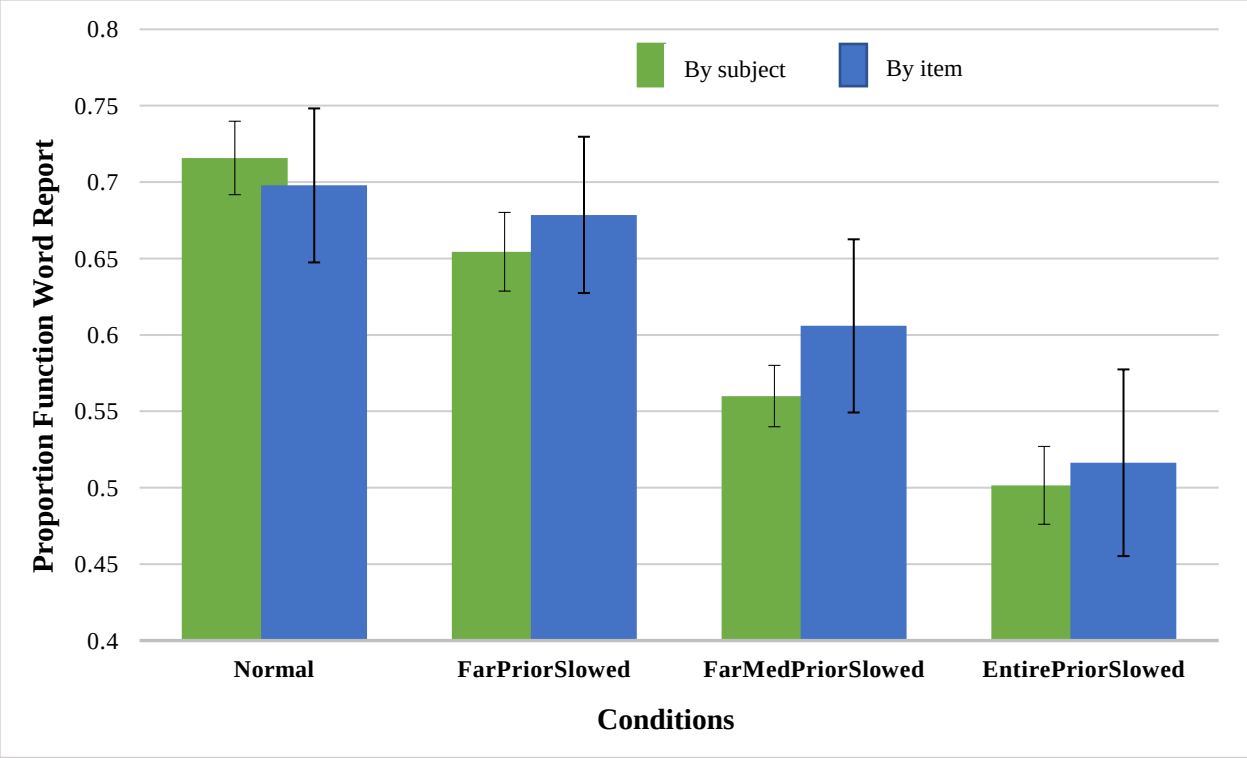

Figure 2: The Effect of Amount of Slowed Context By Subject and By Item

Because of the a priori hypothesis that greater slowing would result in reduced function word reporting, a one-tailed t-test was used. A Bonferroni correction was applied to divide the standard alpha level of 0.05 by the number of tests (six), resulting in a threshold of significance of $p = 0.0083$.

Normal Rate/Far Prior Slowed: A first paired samples t-test measured the difference between the normal rate ($M_{NR} = 0.70$, $SD = 0.37$) and far prior slowed ($M_{FPS} = 0.68$, $SD = 0.38$) conditions. The difference was not significant, $t(33) = 1.848$, $p = 0.037$.

Normal Rate/Far & Medium Prior Slowed: A second paired samples t-test measured the difference between the normal rate ($M_{NR} = 0.70$, $SD = 0.37$) and far & medium prior slowed ($M_{FMPS} = 0.61$, $SD = 0.42$) conditions. The difference was significant, $t(33) = 4.741$, $p < 0.0005$.

Normal Rate/Entire Prior Slowed: A third paired samples t-test measured the difference between the normal (M_{NR} = 0.70, *SD* = 0.37) and entire prior slowed (M_{EPS} = 0.52, *SD* = 0.45) conditions. The difference was significant, $t(33) = 6.257$, $p < 0.0005$.

Far Prior Slowed/Far & Medium Prior Slowed: A fourth paired samples t-test measured the difference between the far prior slowed (M_{FPS} = 0.68, *SD* = 0.38) and far & medium prior slowed (M_{FMPS} = 0.61, *SD* = 0.42) conditions. The difference was not significant, $t(33) = 2.507$, $p = 0.009$.

Far Prior Slowed/Entire Prior Slowed: A fifth paired samples t-test measured the difference between the far prior slowed (M_{FPS} = 0.68, *SD* = 0.38) and entire prior slowed (M_{EPS} = 0.52, *SD* = 0.45) conditions. The difference was significant, $t(33) = 4.413$, $p < 0.0005$.

Far & Medium Prior Slowed/Entire Prior Slowed: A sixth paired samples t-test measured the difference between the far & medium prior slowed (M_{FMPS} = 0.61, *SD* = 0.42) and entire prior slowed (M_{EPS} = 0.52, *SD* = 0.45) conditions. The difference was not significant, $t(33) = 1.663$, $p = 0.053$.

These results indicate that the normal rate condition differed from the far and medium prior slowed condition, the normal rate condition differed from the entire prior slowed condition, and the far prior slowed condition differed from the entire prior slowed condition, and

Discussion

The purpose of the study was to investigate the effect of slowing different amounts of preceding context on listener reports of a function word within a target region. The study was modeled on other LRE studies (e.g., Dilley & Pitt, 2010; Baese-Berk et al., 2014) which explored various forms of rate manipulation on function word perception. By slowing syllables in different portions of the distal context, while ensuring that a window of at least 300 ms existed between the point of discontinuity at the function word and the beginning of the near prior syllable, the study measured how amount of slowed context affects the rate of function words reported by listeners.

Findings

It was hypothesized that slowing the prior context would result in a decrease in function word reporting. This was observed in the item mean differences and further validated by the inferential statistical findings in ANOVA. Analyzing data by item and by subject ensured that the overall effect was not driven by a small number of items and allows confidence in the statistical significance.

An additional hypothesis was that a gradient change in function word perception would be observed as a greater amount of preceding context was slowed. It was expected that this change would occur irrespective of the 300 ms window, which was at or earlier than the boundary between P1 and P2. For the majority of the stimuli, the boundary was in fact almost exactly at this point between the near and medium prior syllables rather than before it. The post-hoc findings of the t-tests provided insight into this prediction as they compared conditions on the cusp of this boundary. The three significant and three non-significant differences are depicted in Figure 3.

	Normal	Far Prior Slow	Far & Med. Prior Slow	Entire Prior Slow
Normal		**No**	**Yes**	**Yes**
Far Prior Slow	**No**		**No**	**Yes**
Far & Med Prior Slow	**Yes**	**No**		**No**
Entire Prior Slow	**Yes**	**Yes**	**No**	

Figure 3: Significant Paired t-test Differences

The three non-significant results were from the tests of adjacent conditions, e.g., far prior slowed/far & medium prior slowed. These results make sense given that the differences between these pairs involved the smallest difference in amount of context slowed. Conversely, the three statistically significant pair tests reflect the three possible pairs that have a larger difference in amount of slowed context, e.g., while far prior slowed and far & medium prior slowed differ by only one slowed syllable and did not yield a statistically significant difference, the far prior slowed/entire prior slowed, differing by the slowing of the far *and* near prior syllables, *were* significantly different. Further, the three significant pairs were well within the realm of statistical significance with *p*-values less than 0.0005.

It is worth noting, however, that the far & medium prior slowed/far prior slowed nearly met the *p*-value set for statistical significance based on the Bonferroni correction of 0.0083 – this item was $p = 0.009$. Again, these figures were more conservatively run from the by-items descriptive statistics to guard against a Type II error. Thus, there is confidence in the robust differences between items in these pairs that met the significance threshold.

The adjacent conditions of far & medium prior slowed and entire prior slowed shed light on the possible influence of the 300 ms as a temporal window for distal rate influence. Items in the entire prior slowed condition include one slowed syllable within this window, and items in the far & medium prior slowed condition contain little to no slowed material within the window. There was not a statistically significant difference between these two conditions, but their means were indeed different. Further, if the 300 ms window were indeed critical in determining the cut-off point for relevant temporal information in perceiving a function word, it would not follow that a significant difference between the normal rate condition and the far & medium slowed condition would be found because nearly all of the rate information conveyed in the latter is outside of the 300 ms window. This gives weight to the proposition that the 300 ms window is not critical in lexical perception, and that more distal information has an effect. Future studies with higher numbers of participants or more consistency in number of valid trials across items might indeed produce a statistically significant effect.

Strengths and Limitations

One strength of the study design was that all subjects saw a version of each item and had an equal balance of items in every condition, increasing the power of the study and preventing fatigue effects. For this reason, it can be concluded with reasonable confidence that the calculations of subject variance were indeed accurate. Additionally, use of a min*F'* statistic was a strength of the study because use of separate by-item and by-subject statistics that are each significant does not ensure that their combined variability is also significant (Clark, 1973), but min*F'* can supplement this information.

The effect size based on η_p^2 was found to be large (Richardson, 2011) for both by-subject and by-item results. However, the by-subject effect was considerably larger. Part of the issue

stems from the relatively small number of items for each condition which does not provide a large sample. Additionally, the rate of N/A trials of 14%, even after excluding an item mis-transcribed by the bulk of participants, is higher than the roughly 10% average in past studies (e.g., Morrill et al., 2015; Dilley et al., 2010). A possible issue was the truncation of items which posed a greater threat to validity because of errors pertaining to grammatical status perpetuated from a past study. The target portions of truncated sentences were also more likely to be mis-transcribed (16%) compared to non-truncated sentences (11%). Additionally, as shown in Table 2 (see Appendix G), the specific function words used in sentences were associated with different percentages of valid trials. For example, sentences containing "or" had 91% of their trials coded as a 1 or 0 rather than N/A, while sentences containing "her" had only 81% valid trials.

The selection criteria for the stimuli presented some challenges in being confident of the results' replicability across items. After the corpus was winnowed down based on the acoustic criteria outlined in the "Methods" section, the remaining items were not randomly selected but hand-picked by the author. Picking them randomly in future studies would allow greater confidence in the idea that by-item findings would be replicated in future studies. A different approach could also be formal pilot testing, which could potentially increase the robustness of differences between conditions by-item, as well as ensure that all target areas were easy to transcribe irrespective of function word presence or absence.

A closer analysis revealed mean differences across item conditions based on the specific function word in the sentence. As seen in Table 1, the word "a" was typically heard, i.e., reported as present, by listeners. Conversely, the word "or" was reported in less than half of trials even in the normal rate condition. In general, the rate of reporting decreased as more syllables were slowed for each sentence despite the variability across the function words. It should be noted that

only one item was used with the function word "our," and that the number of sentences for each function word was not balanced, posing a possible limitation to the present study.

Function Word	Normal	Far Slow	Far/Med Slow	Entire Slow
a	0.98	0.96	0.91	0.92
are	0.85	0.87	0.82	0.74
her	0.65	0.69	0.58	0.53
or	0.46	0.37	0.31	0.11
our	0.25	0.20	0.20	0

Table 1: Proportion of Function Word Report with Rate Condition

Implications

One noteworthy instance of the LRE relates to one of the nation's best-known quotations. When Neil Armstrong stated, "That's one small step for man…" he later explained that he had truly said, "That's one small step for **a** man" (Baese-Berk, Dilley, Schmidt, Morrill, & Pitt, 2016). The grammatically ambiguous sentence was found to have a duration of the syllable in question that didn't clearly signal whether it was its own word or an extension of the previous syllable. It provides an excellent case study into the importance of studying reduced syllables and how auditory information is recovered as an important facet of psycholinguistic research (Baese-Berk et al., 2016).

LRE findings additionally add to a body of knowledge within the field of communicative sciences and disorders. The implications for clinical research are likely to be numerous. In addition to adding to the understanding of speech perception that is relevant from infancy to adulthood in normal language development, this body of research enhances scientific understanding of communication disorders. These related disorders include dyslexia, language impairment, and stuttering.

The connection between dyslexia and prosody is particularly intriguing since children with developmental dyslexia have been shown to have poorer speech discrimination on average,

especially in noise, and to be more influenced by prosodic variability (Hazen, Rosen, & Messaoud-Galusi, 2010). Prosody and dyslexia were explored by Goswami in the "Temporal Sampling of Speech" framework (2011) based on research experiments on individuals with developmental dyslexia (e.g., Goswami, Gerson, & Astruc, 2010). Goswami posited that the root of the phonological processing deficit implicated in the disorder is the direct result of frequency-based temporal sampling of speech and offered the general suggestion of educational intervention related to prosody and syllables to remediate deficits, including syllable parsing and syllable stress.

One experiment specifically implicated difficulty with perceiving rise-time as an onset marker of stressed syllables in people with dyslexia (Goswami et al., 2010). LRE experiments with tasks similar to the one conducted in the present study that compare people with dyslexia to controls could investigate potential temporal differences in syllable segmentation based on durational, rather than frequency-based, characteristics, a particularly salient direction given this population's reduced ability to discriminate between minimal pairs that differ in voicing (Hazen et al., 2010), which could indicate differences in processing durational factors. A more complete understanding of temporal phonological processing as it relates to dyslexia would inform the selection of specific prosody-based clinical interventions.

Additional research has investigated the importance of speech context rate in language acquisition and understanding. For example, Dilley, Morrill, and Banzina (2013) designed an experiment to compare LRE elicitation among native Russian speakers, native English speakers with high intermediate Russian proficiency, and native English speakers with low intermediate Russian proficiency, confirming that the LRE can occur in other languages as well as uncovering differences in how native and non-native speakers process rate-based information. Further,

research by Bosker and Reinisch (2015) applied the concept of speaking rate to analyze listeners' perception of speed between native and non-native speakers of Dutch, finding that even when syllables were temporally matched, listeners reported that non-native speech sounded faster. Such studies shed light on auditory processing and second language acquisition. Also, a study by Janse, Nooteboom, and Quene (2003) investigated the changes that speakers made to the duration of stressed and unstressed vowels when intentionally speaking quickly, as well as listeners' ability to understand speech when the rate was manipulated based on these findings. The researchers' methodology drew from past prosodic and speech-rate research, and the results were directly relevant to understanding how artificial speech rate manipulation could improve comprehension.

Concluding Remarks

This study demonstrated that distal rate information outside of the 300 ms temporal window associated with the PRE (Newman & Sawusch, 1996) affected function word perception, supporting the hypothesis that the LRE and PRE involve different mechanisms. This experiment was among the first in the LRE literature to investigate graded change in rate manipulation. Future studies might investigate slowing the prior context backward from the target rather than forward from the beginning of the sentences, with the conditions of normal rate, P1 (near prior syllable) slowed, P1 & P2 (near and medium prior syllables) slowed, and entire prior context slowed. Examining the current study in conjunction with future studies could build on the effect of context rate and specifically shed more light on the influence of the 300 ms window. It would also allow for more comparisons of the effect of slowing specific syllables between the two studies. These comparisons would further the understanding of the importance

of localization in understanding speech by comparing the effects of syllables of the same duration but at different points in a stimulus.

Overall, the findings indicate a significant effect of amount of prior context slowed on the rate of reporting function words. Additionally, the study provides evidence that non-adjacent material can be outside of a 300 ms window and still influence function word perception. There was evidence that graded changes in amount of manipulated preceding context result in similar graded changes in perceptual response. However, these changes were not found in the adjacent conditions. The study results contribute information about specific temporal changes to the body of LRE research.

APPENDICES

APPENDIX A:

Stimuli and Practice Items

Stimuli and Practice Items

Stimuli:

The message was clear after her blank ~~stare said it all.~~

Conor knew that bread and butter are both ~~in the pantry.~~

Jane wanted the number or eight times back.

It takes a lot of work to review a personal ~~file.~~

Mark said he would pursue a liberal ~~vote.~~

It costs a lot to tattoo a pink flamingo.

It's not easy to convey a likely ~~position.~~

Ron didn't tell his elder or son about it.

John said he would obey a rebel ~~leader.~~

Taylor knew the principal and teacher are from Ohio.

The value went up after her rich neighbors moved in.

People were offended after her rude comments.

George thought my father and brother are like good ~~friends.~~

We won't have any winter or wet weather this year.

Evan said the writer and actor are like two ~~friends he knows.~~

Steve pitched the ball to center or left last week.

Jill had never tried to dry a yellow lab.

The boy wanted to glue a broken ~~toy.~~

Anne wanted to see a very funny ~~movie.~~

Fred would rather have a summer or lake house.

Deena doesn't have any leisure or time this week.

Dave asked how long it takes to repay a large debt.

Ruth saw the maid and butler are at the top ~~of the stairs.~~

The Perrys thought carefully after her wise advice ~~was given.~~

Jim warned them before her gloves ~~were needed.~~

It's not long before her rare wit comes out.

Don must see the harbor or boats ~~this year.~~

Donna will call the master or carpenter ~~this week.~~

Glenn thought his friend and neighbor are like plenty ~~of others.~~

Susan said those are our black ~~socks from the attic.~~
Bill didn't want to fly a longer ~~distance.~~
Dan couldn't watch the monster or evil ~~in the movie.~~
Wilson wanted to renew a passionate ~~vow.~~
Jon called her sugar or honey ~~most of the time.~~
Dan took off after her young ~~friend was hired.~~
Dawn said that it's easy to go to a regular ~~store.~~
Chris said his mother and father are both old.
Marty gave him a dollar or twenty ~~last week.~~
Chris was very quick after her sharp ~~mind got in gear.~~
Frank thinks that sadness and anger are both ~~bad.~~
Claire said that sour and bitter are both ~~flavors~~.
They promised him the future or aid ~~last week.~~
George turned left at the river or bank last week.
Dean saw the buyer and seller are in ~~the next room.~~
Joan didn't want to face the stranger or ailment ~~this time.~~
The company moved to a different ~~location~~.
The leaves fell after her green ~~lawn dried up.~~
They were sad after her poor dog was put down.
It's not long before her bad back goes out.
That should be done before her gray hair sets in.
Lance said goodbye before her large car got towed.
Lisa was done before her loose curls got tangled.
John didn't tell the junior or representative ~~about it.~~
Jake didn't vote for the member or constituent last week.
Anyone must be a minor or child to enter.
Sally sold all her silver or jewelry last month.

Practice items:
The Smiths wouldn't buy a butterball turkey.
The sign was replaced after her black car got stolen.
Tina decorated with paper or lace in most rooms.
Sally might try a liquid detergent.

APPENDIX B:

Praat Script for Stimuli

Praat Script for Stimuli

```
 #open files in the folder
#where the raw files are stored
directory$ = "C:\Users\Corinne PC Win10\Documents\Thesis\Working Directory\"
#where you want the modified files to be stored
directory2$ = "C:\Users\Corinne PC Win10\Documents\Thesis\Reject\"
#where you want the modified files that meet the criteria to be stored:
directory3$ = "C:\Users\Corinne PC Win10\Documents\Thesis\Accept\"

Create Strings as file list... file-list 'directory$'*.TextGrid
number_of_files = Get number of strings

# loop through wav files in the folder
for x from 1 to number_of_files

    select Strings file-list

    current_file$ = Get string... x

# open wave files and textgrids
# Read in that file:

        Read from file... 'directory$"current_file$'
        object_name$ = selected$ ("TextGrid")

# Add a new Tier and labels
        Duplicate tier... 1 1 syll
        starttime = Get time of point... 3 1

        #starttime = Get start point... 1 2
        starttime2= starttime - 0.3
        Insert boundary... 1 'starttime2'

        interval_label$ = Get label of interval... 1 2
        if interval_label$ == ""
        Set interval text... 1 2 A2
        tierid = 2
        elsif interval_label$ == "A" or interval_label$ == "A "
        Set interval text... 1 3 A2
        tierid = 3
        endif
# open the editor and allow changes to the markings
```

```
        Read from file... 'directory$"object_name$'.wav
        plus TextGrid 'object_name$'
        Edit
beginPause ("move the A2 boundary to the start of the 2 back syllable")
        boolean ("clearFW",0)
        boolean ("wordboundary", 0)
        yes = endPause ("Continue",0)

        select TextGrid 'object_name$'
        starttimeA2 = Get start point... 1 'tierid'

# save the textgrid file and go on to the next.

if (starttime - starttimeA2 ) < 0.3 and 'clearFW' = 1 and 'wordboundary' = 1
        select TextGrid 'object_name$'
        Write to text file... 'directory3$"object_name$'.TextGrid

        else
        select TextGrid 'object_name$'
        Write to text file... 'directory2$"object_name$'.TextGrid

        endif

# Remove the objects that we are through with.



    select all

    minus Strings file-list

    Remove

endfor


# Clean up, and the end message


select Strings file-list

Remove
```

APPENDIX C:

Filler Items

Filler Items

Being early is b-

Chest containing manuscripts.

Children under 10.

Ellen glared at her.

He took her to dinner.

Jane has allowed Sue to go.

John was sent to acquire new skills.

Put on your mitten.

Rose knew that.

She needed apart-

She toured the cit-

The center of attention.

The font was too sm-

The man was sent to accompany.

The writer prayed day and night.

The young girl had a.

There are many gray sh-

The wedding planner of the actress.

Will pushed through the cr-

With winter tires.

APPENDIX D:

IRB APPROVAL LETTER

IRB APPROVAL LETTER

MICHIGAN STATE UNIVERSITY

Renewal Application Approval

August 25, 2017

To: Laura Dilley
116 Oyer Speech and Hearing

Re: **IRB# 16-884** Category: EXPEDITED 7
Renewal Approval Date: August 25, 2017
Project Expiration Date: August 24, 2018

Title: Making words disappear or appear: A neurocognitive and behavioral investigation of effects of speech rate on spoken word perception [CGA# 135650]

The Institutional Review Board has completed their review of your project. I am pleased to advise you that the renewal has been approved.

The review by the committee has found that your renewal is consistent with the continued protection of the rights and welfare of human subjects, and meets the requirements of MSU's Federal Wide Assurance and the Federal Guidelines (45 CFR 46 and 21 CFR Part 50). The protection of human subjects in research is a partnership between the IRB and the investigators. We look forward to working with you as we both fulfill our responsibilities.

Renewals: IRB approval is valid until the expiration date listed above. If you are continuing your project, you must submit an Application for Renewal application at least one month before expiration. If the project is completed, please submit an Application for Permanent Closure.

Revisions: The IRB must review any changes in the project, prior to initiation of the change. Please submit an Application for Revision to have your changes reviewed. If changes are made at the time of renewal, please include an Application for Revision with the renewal application.

Problems: If issues should arise during the conduct of the research, such as unanticipated problems, adverse events, or any problem that may increase the risk to the human subjects, notify the IRB office promptly. Forms are available to report these issues.

Please use the IRB number listed above on any forms submitted which relate to this project, or on any correspondence with the IRB office.

If we can be of further assistance, please contact us at 517-355-2180 or via email at IRB@msu.edu. Thank you for your cooperation.

Office of Regulatory Affairs
Human Research Protection Programs

Biomedical & Health Institutional Review Board (BIRB)

Community Research Institutional Review Board (CRIRB)

Social Science Behavioral/Education Institutional Review Board (SIRB)

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www.hrpp.msu.edu

MSU is an affirmative-action, equal-opportunity employer.

APPENDIX E:

IRB Informed Consent

IRB Informed Consent

Participant Information for Research Study:
"Understanding and Remembering Speech and Language"

You are being asked to participate in a research project. Researchers are required to provide a consent form to inform you about the study, to convey that participation is voluntary, to explain risks and benefits of participation, and to empower you to make an informed decision. You should feel free to ask the researchers any questions you may have.

Researcher and Title: Dr. Laura C. Dilley, Associate Professor
Department and Institution: Communicative Sciences and Disorders, Michigan State University
Address and Contact Information: 102 Oyer Speech and Hearing, Michigan State University, East Lansing, 48824, ldilley@msu.edu

1. PURPOSE OF RESEARCH:

- You are being asked to participate in a research study aimed at learning more about understanding communication.
- You have been selected as a possible participant in this study because you have expressed an interest in participating and you meet our inclusion criteria of being a member of the MSU community with relevant background.
- From this study, we hope to learn more about how people communicate.
- In the entire study, approximately 30 people are being asked to participate.
- Your participation in this study will take between 15 minutes and 2.5 hours.
- If you are under 18, you cannot participate in this study.

2. WHAT YOU WILL DO:

- If you agree to participate, then any of the following may happen.
- You may be asked to listen to sounds or phrases or look at words or pictures on a computer screen, and make simple responses.
    - For example, you may be asked to say whether you heard a particular word, to respond whether you could tell two words or speech-like sounds apart, to transcribe the words that you heard, to speak or repeat a sentence, to name or click on a picture, or to do a similar task.
    - Responses will be made either by providing a written response, by pushing buttons and/or typing on a special response device or computer mouse/keyboard, or by making a verbal response.
- You may be asked to speak words or phrases. The words or phrases that you are asked to speak may either be scripted (i.e., written on a page or computer screen) or unscripted.
    - If speaking is required in this study, then you may be recorded for the purpose of acoustic analysis and/or for generating materials for subsequent perception experiments. (See #5 for more information on recording.)
- After the study is over, you will be asked to fill out a form about your background and about the responses you gave during the study.
- The research findings are likely to be published in peer-reviewed research journals, and these are available to the public. The results of research study will not be provided to individual participants.

3. POTENTIAL BENEFITS:

- You will not directly benefit from your participation in this study. However, your participation in this study may contribute to understanding of how humans perceive and produce speech.
- The findings from this study will contribute to basic and applied science research on speech perception and production and may in turn help to direct future research on various speech-related disorders and speech-related technologies (e.g., automatic speech recognition by computer).

4. POTENTIAL RISKS:

- There are no foreseeable risks associated with participation in this study.

5. YOUR RIGHTS TO PARTICIPATE, SAY NO, OR WITHDRAW

This consent form was approved by a Michigan State University Institutional Review Board.
Approved 08/25/17 – valid through 08/24/18. This version supersedes all previous versions. IRB # 16-884.

- Participation in this research project is completely voluntary. You have the right to say no.
- Choosing not to participate or withdrawing from this study will not make any difference in benefits to which you are otherwise entitled.
- You may change your mind at any time and withdraw. If you withdraw before the experiment is completely over, you will be compensated with course credit or monetarily (as indicated below) commensurate with the amount of time you spent participating in the study.
- You may choose not to answer specific questions or to stop participating at any time.
- Whether you choose to participate or not will have no affect on your grade or evaluation.
- You will be told of any significant findings that develop during the course of the study that may influence your willingness to continue to participate in the research.

6. COSTS AND COMPENSATION FOR BEING IN THE STUDY:

- For participating in this study, you will receive one of the following two forms of compensation:
  - Course credit commensurate with time spent during study participation in terms of credits per hour for offerings through the Communicative Sciences and Disorders Department, or as outlined in course syllabus for offerings through the Department of Communicative Sciences and Disorders, OR
  - Monetary compensation at a rate of $12/hr. The length of this study is _____.
- If monetary compensation is selected, payment for participation will take place within 3 weeks.

7. ALTERNATIVE OPTIONS

- If you are in a course taught by Dr. Laura Dilley, a research report may be performed in place of (rather than in addition to) research participation in order to earn research credits or extra credit. You are under no obligation to participate in this research study, and alternative options exist for being awarded course credit which do not involve study participation. These alternatives can be substituted without penalty. You are also free to choose whether you wish to receive course extra credit, research credits, or monetary compensation for participation.

8. CONTACT INFORMATION FOR QUESTIONS AND CONCERNS

If you have concerns or questions about this study, such as scientific issues, how to do any part of it, or to report an injury, please contact the researcher (Dr. Laura Dilley, 102 Oyer Speech and Hearing, Department of Communicative Sciences and Disorders, Michigan State University, ldilley@msu.edu, 517-884-2255).

If you have questions or concerns about your role and rights as a research participant, would like to obtain information or offer input, or would like to register a complaint about this study, you may contact, anonymously if you wish, the Michigan State University's Human Research Protection Program at 517-355-2180, Fax 517-432-4503, or e-mail irb@msu.edu or regular mail at 4000 Collins Rd, Lansing MI, 48911.

9. PRIVACY AND CONFIDENTIALITY:

- Your confidentiality will be protected to the maximum extent allowable by law.
- Data will be tracked and analyzed using a method that involves very low risk of revealing your identity.
- Each participant will be assigned an alphanumeric ID directly which is identifiable only to investigators with access to password-protected computer systems. This ID will be used for data coding and analysis.
- Your name appears on any reimbursement records or course rosters; your name will not appear elsewhere in our records. Reimbursement records and course rosters will not be directly linked to the alphanumeric ID.
- Throughout the project, access to any obtained consent forms, reimbursement records, and course rosters will be limited to laboratory members, and access to data will be limited to authorized personnel. Authorized personnel include laboratory members (i.e., researchers and research staff), collaborators of Dr. Dilley, the MSU Human Research Protection Program (HRPP), sponsors and agencies supporting the work (i.e, the National Science Foundation and National Institutes of Health), and authorized investigators at collaborative institutions (i.e., University of Massachusetts – Amherst and University of Kansas). Obtained records will be stored in the

This consent form was approved by a Michigan State University Institutional Review Board.
Approved 08/25/17 – valid through 08/24/18. This version supersedes all previous versions. IRB # 16-884.

Communicative Sciences and Disorders Department at MSU in secure filing cabinets accessible only to lab members for at least three (3) years after the close of the study.

- The results of this study may be published or presented at professional meetings, but the identities of all research participants will remain anonymous.
- Participants in this study may or may not be audiotaped. However, if you are one of the participants where audiotaping is required, you give your consent for audiotaping.

10. DOCUMENTATION OF INFORMED CONSENT.

Your signature below means that you voluntarily agree to participate in this research study.

_____ _____

Signature Date

You will be given a copy of this form to keep.

This consent form was approved by a Michigan State University Institutional Review Board.
Approved 08/25/17 – valid through 08/24/18. This version supersedes all previous versions. IRB # 16-884.

APPENDIX F:

Procedural Checklist

Procedural Checklist

Experimenter Name: _____ Date: _____ Time: _____

Code(s) for participant(s) run today: _____

PROCEDURAL CHECKLIST - BEFORE START OF EXPERIMENT

SET UP:

_____ Remove 2 consent forms per participant from the file cabinet in **Oyer B1**.
_____ Log-on to the computer [**Username: Dilly Research User, Password: MSUlab**].
_____ **DO NOT:**
-**DO NOT** change the start-up settings (these are pre-set).
-**DO NOT** unplug the Ethernet cables (computers are unable to connect to the Internet).
-**DO NOT** change any screen settings (e.g. screen saver, power, etc.).
_____ Make sure the **VOLUME** is set to 30 (double click sound icon on taskbar).
_____ Make sure all programs are **SHUT DOWN.**
_____ Make sure the **HEADPHONES** are plugged in to the back of the computer tower.
_____ Fill out the Experiment Log Sheet as the day goes on.
_____ Fill out your name above and participant codes as the day goes on.
_____ Place the **Experiment in Progress** sign on the room door.

PARTICIPANT:

_____ Greet the participants in the lobby and ask them their name(s). Escort them to B1. Wait 5 minutes if anyone is late.
_____ Ensure that you have the correct participant ID for SONA credit. Do not write the participant's **name** in the runbook.
_____ Politely ask the participant to **TURN OFF** their cell phone and it at a computer. Ask them to leave all personal items on the floor by their desk.
_____ Read this statement to the participant:
"We ask that you pay full attention and try your hardest during the experiment today. If you feel you can't do this for some reason, like if you have a time constraint and will feel rushed, we are happy to reschedule for a time that is more convenient for you. You will be participating in 1 experiment today, which will take a total of about 30-45 minutes. It is also important for you to know that your participation is completely voluntary, and you can opt out at any time without penalty."
_____ Read the following short instructions to the participants:
"In this experiment you will be asked to listen to recordings over the headphones and use the keyboard to type words in response. By reading and signing this consent form, you agree to participate in the experiment."
_____ Have the participants sign **one copy** of the consent form. This is the lab's copy and should be put in the filing cabinet. Give them a second blank copy of the consent form to keep.
_____ Fill out the run sheet for that participant.

EXPERIMENT:

_____ Double click on the purple E-Prime Experiment run icon in the folder titled "Corinne's Thesis" corresponding to Experiment 1 or 2.
_____ Enter the first 2 letters of the participants' first and last name (same as on Experiment Log sheet) and the **Run Number**, and click **OK.**
_____ Confirm that you have typed the information correctly and click **Run.**

PLEASE REMAIN VIGILANT AND IN THE ROOM FOR THE DURATION OF THE EXPERIMENT!
EXPERIMENT INSTRUCTIONS:

_____ Ask the participant to put on the **HEADPHONES**. Pay attention to **R** and **L** sides.
_____ **During the practice trials,** make sure the participant is making an effort to type the words that end each phrase (see below). **Do not inform participants of the ambiguities in sentences.** Once complete, make sure the participants do not have questions.
_____ **After the experiment is completed,** press **Enter** to exit the experiment.
_____ **If there are at least 5 minutes remaining, we are having participants complete the background and strategies form.** It is in the "Corinne Thesis" folder and titled "Remembering Speech B&S 12-2-17." Select the purple run icon.
    _____ If the participant ran out of time, verbally collect and write the following on the experiment log: Gender, Race, Hispanic/Non-Hispanic, Native Language, Age.
_____ Enter the **Subject Number** (just the run number, no initials)
_____ Enter the **Session Number** as 1 for Experiment 1 or 2 for Experiment 2 and click **OK**.

_____ Enter **your initials** as the experimenter and don't change the experiment name.
_____ Tell participant they will not need headphones.
_____ Press the **F12** to exit E-Prime when they finish.
_____ Thank the participants for the time. **Make sure you have their name for SONA credit.** Ensure they know how to exit the building.
_____ Comments should be made in the runbook if anything seems unusual about the participant's behavior, responses, or if anything goes wrong during the experiment (wrong condition, crashing script, leaving early, etc.).

AFTER PARTICIPANTS LEAVE

_____ Put the signed **Consent Forms** in the correct folder in the filing cabinet in Oyer B-1.
_____ Put all papers EXCEPT consent forms in the navy blue folder on the shelf to the left of the filing cabinets.
_____ There will be **SIX** new files in the **Corinne Thesis** folder (two .edat files and two .txt files, and an XML file). They will be labeled with the **Name of the Experiment, Participant Number** and **Session Number.** Move these new files into the **DATA** sub-folder**. (One set of data files is from the experiment and one set is from the B&S)**
_____ **Wipe down** each computer with an antibacterial wipe and make sure the room is as neat as when you came in.
_____ **DO NOT** shut down the computer (this will automatically happen at midnight).
_____ Shut down the computer monitor.
_____ **Make sure to give the participant CREDIT on the HPR system** (or email Corinne so she can do it).

Comments:

APPENDIX G:

Table 2: Proportion of Function Word Present by Function Word Type

Table 2: Proportion of Function Word Present by Function Word Type

Proportion of FW Present/Absent by FW Type	Code			
Function Words (x= truncation)	**Present**	**Absent**	**N/A**	**Total**
a	**81%**	**4%**	**15%**	**100%**
Anne wanted to see a very funny movie.X	100%	0%	0%	100%
Bill didn't want to fly a longer distance.X	32%	18%	50%	100%
Dave asked how long it takes to repay a large debt.	94%	0%	6%	100%
Dawn said that it's easy to go to a regular store.X	59%	12%	29%	100%
It costs a lot to tattoo a pink flamingo.	79%	0%	21%	100%
It takes a lot of work to review a personal file.X	88%	3%	9%	100%
It's not easy to convey a likely position.X	79%	9%	12%	100%
Jill had never tried to dry a yellow lab.	62%	3%	35%	100%
John said he would obey a rebel leader.X	85%	0%	15%	100%
Mark said he would pursue a liberal vote.X	91%	6%	3%	100%
The boy wanted to glue a broken toy.X	100%	0%	0%	100%
The company moved to a different location.X	91%	3%	6%	100%
Wilson wanted to renew a passionate vow.X	91%	0%	9%	100%
are	**65%**	**19%**	**16%**	**100%**
Chris said his mother and father are both old.	94%	6%	0%	100%
Claire said that sour and bitter are both flavors.X	88%	0%	12%	100%
Conor knew that bread and butter are both in the pantry.X	94%	6%	0%	100%
Dean saw the buyer and seller are in the next room.X	0%	29%	71%	100%
Evan said the writer and actor are like two friends he knows.X	97%	0%	3%	100%
Frank thinks that sadness and anger are both bad.X	88%	0%	12%	100%
George thought my father and brother are like good friends.X	91%	0%	9%	100%
Glenn thought his friend and neighbor are like plenty of others.X	50%	0%	50%	100%
Ruth saw the maid and butler are at the top of the stairs.X	12%	88%	0%	100%
Taylor knew the principal and teacher are from Ohio.	35%	65%	0%	100%
her	**50%**	**31%**	**19%**	**100%**
Chris was very quick after her sharp mind got in gear.X	68%	0%	32%	100%
Dan took off after her young friend was hired.X	79%	0%	21%	100%
It's not long before her bad back goes out.	74%	21%	6%	100%
It's not long before her rare wit comes out.	6%	9%	85%	100%
Jim warned them before her gloves were needed.X	0%	91%	9%	100%
Lance said goodbye before her large car got towed.	91%	0%	9%	100%
Lisa was done before her loose curls got tangled.	3%	88%	9%	100%
People were offended after her rude comments.	21%	79%	0%	100%

Table 2 (cont'd)

That should be done before her gray hair sets in.	35%	62%	3%	100%
The leaves fell after her green lawn dried up.X	85%	12%	3%	100%
The message was clear after her blank stare said it all.X	71%	18%	12%	100%
The Perrys thought carefully after her wise advice was given.X	35%	9%	56%	100%
The value went up after her rich neighbors moved in.	47%	44%	9%	100%
They were sad after her poor dog was put down.	88%	3%	9%	100%
or	**27%**	**64%**	**8%**	**100%**
Anyone must be a minor or child to enter.	79%	3%	18%	100%
Dan couldn't watch the monster or evil in the movie.X	24%	71%	6%	100%
Deena doesn't have any leisure or time this week.	47%	50%	3%	100%
Don must see the harbor or boats this year.X	18%	74%	9%	100%
Donna will call the master or carpenter this week.X	0%	100%	0%	100%
Fred would rather have a summer or lake house.	12%	88%	0%	100%
George turned left at the river or bank last week.	3%	94%	3%	100%
Jake didn't vote for the member or constituent last week.	35%	50%	15%	100%
Jane wanted the number or eight times back.	0%	100%	0%	100%
Joan didn't want to face the stranger or ailment this time.X	18%	26%	56%	100%
John didn't tell the junior or representative about it.X	6%	94%	0%	100%
Jon called her sugar or honey most of the time.X	41%	56%	3%	100%
Marty gave him a dollar or twenty last week.X	26%	68%	6%	100%
Ron didn't tell his elder or son about it.	18%	79%	3%	100%
Sally sold all her silver or jewelry last month.	6%	88%	6%	100%
Steve pitched the ball to center or left last week.	50%	41%	9%	100%
We won't have any winter or wet weather this year.	82%	12%	6%	100%
our	**15%**	**62%**	**24%**	**100%**
Susan said those are our black socks from the attic.X	15%	62%	24%	100%
Total	**52%**	**33%**	**14%**	**100%**

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