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Effects of Background Noise on the Spoken Language of Young and Older Adults During Narrative Discourse

Erin LeCheminant
Brigham Young University

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A thesis submitted to the faculty of
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Master of Science

Tyson G. Harmon, Chair
Christopher Dromey
Douglas Petersen

Department of Communication Disorders

Brigham Young University

ABSTRACT

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Erin LeCheminant
Department of Communication Disorders, BYU
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This study examined how different background noise conditions affected the spoken language production of young (18-25) and older (60-85) adults when performing a story retell task. Participants included 10 female and 10 male young adult (YA) participants, as well as 10 female and 10 male older adult (OA) participants. Participants retold stories in a silent baseline and five background noise conditions (conversation, monologue, phone call, cocktail, pink noise). Speech fluency and language production measures (cohesive and coherent utterances, lexical-phonological errors, grammatically correct words, Moving Average Type Token Ratio (MATTR), speech rate, and disfluent words) were compared between groups and across conditions. Results reveal that background noise led to an increase in speech rate for the OA compared to the YA group. A main effect was also found for disfluent words, specifically between the phone call and conversation condition, as well as the pink noise and phone call conditions. The OA also experience background noise benefits in relation to speech fluency (conversation and phone call conditions) and lexical production (conversation condition). The YA group experience background noise costs in relation to speech rate in the phone call condition. These findings suggest that background noise benefits discourse more for OA and interferes more for YA.

Keywords: age groups, language, divided attention, noise, distraction

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DESCRIPTION OF THESIS STRUCTURE AND CONTENT

This thesis, *Effects of Background Noise on the Spoken Language of Young and Older Adults During Narrative Discourse,* is written in a combined format that merges traditional thesis requirements with the format of a journal article. The preliminary pages of this thesis reflect requirements for submission to the university. The remainder of this thesis is structured like a journal article; it conforms to the style requirements necessary for submitting research reports to relevant journals.

The annotated bibliography is included in Appendix A. Appendix B contains information regarding the Institutional Review Board (IRB)-approved consent form.

Introduction

Daily communication between individuals is often disturbed by distracting stimuli from background noises, ranging from concurrent speech nearby, to the sound of a cell phone notification. These types of stimuli increase the likelihood of distraction when attempting to communicate verbally. Furthermore, background noise can also increase cognitive load, which may additionally affect language production. The purpose of the present study was to determine the effects of different types of background noise on language production for young versus older adults during a narrative discourse task.

Effects of Age on Language

Declines in language processing and production have been shown to occur with age (Bier et al., 2017; Kemper et al., 2003; Kemper et al. 2005; Kemper et al., 2011; Kemper et al. 2009; MacPherson, 2019; Marini et al., 2005; Wright et al., 2014). For example, older adults, specifically those between the ages of 60-88, have shown poorer language comprehension (Wright et al., 2014), speech efficiency (Harmon et al., 2021), lexical errors, morphosyntactic production (Marini et al., 2005), and coherence (Glosser & Deser, 1992; Marini et al., 2005; Wright et al., 2014) when compared with young adults. Many of these changes seem to relate to natural declines in cognitive processing (Glosser & Deser, 1992) or general cognitive slowing (Marini et al., 2005; Salthouse, 1996) associated with aging.

In relation to language comprehension, Wright et al. (2011) found that older adults had significantly worse story comprehension skills than young adults and that their story comprehension related to their overall cognitive functioning. Comprehension was measured using a total of sixty participants, thirty young adults and thirty older adults. Each participant was asked 15 multiple choice comprehension questions targeting areas of story detail, setting detail, and inferencing after viewing and telling a story based on two wordless picture books. Results indicated that the older adult population demonstrated decreased story comprehension skills as they answered a lower percentage of the 15 comprehension questions accurately. A relationship was also found between scores on cognitive testing completed prior to the experiment and performance on the story comprehension task. Specifically, the older adults who presented with higher scores on standardized tests of cognition generally performed the story comprehension task with higher accuracy.

Speech efficiency has also been shown to be lower in older, rather than younger, adults. In comparison to young adults, when performing a speaking task while concurrently engaged in a secondary motor task, older adults perform with less efficiency (Harmon et al., 2021), require more time (Kemper et al., 2003; Kemper et al., 2005), and produce more words (Wright et al., 2014) than their young adult counterparts. Wright et al. (2014) studied the effects of aging on story production. A group of 80 cognitively healthy young (40 participants) and older (40 participants) adults were shown two wordless picture books then asked to tell the story depicted without reference to the images. Although no group differences were found in story propositions (i.e., setting, event/problem, plans, consequences, resolutions, internal responses, and endings), samples from the older adult group contained more words. In other words, older adults spoke with less efficiency but provided a similar amount of information when compared with the young adult group.

In addition to differences in language processing and speech efficiency, differences in lexical and morphosyntactic production, local and global coherence, and lexical and thematic informativeness are common between older and young adults during narrative production. Research indicates a negative linear trend in relation to age and the level of effort required in producing narratives, ultimately revealing a pattern of decreased language production as the age of the individual producing it increases. Marini et al. (2005) analyzed micro- and macro-linguistic measures, along with measures of informativeness in relation to age. Specifically, micro-linguistic measures consisted of ratios of semantic paraphasias (lexical), phonological selection (lexical), nouns/verbs (lexical), paragrammatic productions (morphosyntactic), and syntactic complexity (morphosyntactic). Macro-linguistic measures included local and global coherence. Sixty-nine participants were asked to produce a narrative while viewing a single-picture stimuli and two cartoon picture sequences (each with six images). Participants were able to utilize these images throughout their narrative production, potentially reducing the need for short term memory and, therefore, decreasing cognitive demands. Results indicated that, compared to the young adult group, older adults produced a greater number of semantic paraphasias, suggesting reduced lexical-semantic processing, along with more local coherence and global coherence errors and decreased lexical and thematic informativeness. Along with the effects of age, the attentional demands of the communication environment can also impact language production.

Attentional Demands

Cognitive demands affect one's ability to focus on singular or multiple stimuli (MacPherson, 2019). Several theories have been developed in an attempt to explain this phenomenon. The resource-capacity model suggests that the brain is comprised of a finite number of cognitive resources that can either be utilized for an individual demand or shared across concurrent tasks. Once the resources are depleted, the brain's ability to attend to multiple tasks at once is disrupted and we begin to see deficits in the tasks being carried out. This is known as task interference. A second theory is that the brain, in an attempt to process various stimuli simultaneously, experiences a bottleneck effect and consequently, a diminished level of attention is given to each of the various stimuli and/or tasks contributing to the cognitive load, as the brain cannot process so many stimuli at once (Dromey & Benson, 2003; Wickens, 1981).

The resource-capacity model of attention can also be used to address attentional complexity. According to this model, for a stimulus to require complex attention, it must draw on a greater quantity of processing resources in order to allocate the same level of attention to the primary task as would be required for a single, undisrupted, task (Cahana-Amity & Albert, 2015). Attentional demands are often described as ranging on a spectrum from less to more cognitively demanding (Lapointe & Erickson, 1991; Murray, 2000; Pashler, 1994; Villard & Kiran, 2015). The least demanding is considered sustained attention: the ability to attend to a single task for a prolonged time period. Sustained attention is experienced less often than other attention types due to the rarity of circumstances where a person's attention is not being influenced by additional stimuli. Consequently, sustained attention was not the primary focus of the current work. Divided and selective attention are more cognitively demanding and will be discussed in greater detail below.

Divided Attention

Divided attention is the most complex of the three attentional demands. Divided attention refers to the ability to process and/or respond to multiple stimuli simultaneously, thereby allocating a greater quantity of cognitive resources all at once (Cahana-Amitay & Albert, 2015). For example, writing while talking requires divided attention, as the brain must process language in two forms concurrently. As the number and/or complexity of stimuli increases, more cognitive resources are necessary for task completion (Cahana-Amitay & Albert, 2015).

Both older and young adults alike have been found to experience declines in performance when faced with increasing attentional demands. Young adults have been found to primarily experience declines in accuracy and older adults have been found to primarily experience greater decrements in fluency (Kemper et al., 2003; Kemper et al., 2005; Kemper et al., 2001; Kemper et al., 2009).

Kemper et al. (2003) and Kemper et al. (2005) analyzed the language production of young (18-28) and older adults (70-80) while simultaneously performing additional tasks. Participants from both studies completed tasks including walking, talking, carrying items, finger tapping, and ignoring noise. Tasks were performed singularly and in combinations of two to induce divided attention. Results were measured across three dimensions: fluency, propositional density, and grammatical density. More specifically, fluency for the purposes of both studies was comprised of percentage of utterances containing lexical fillers, percentage of grammatical sentences, mean length of utterance (MLU), and words-per-minute (WPM). Grammatical complexity comprised of mean clauses per utterance (MCU), and developmental level (D-level). Finally, propositional density (P-Density) was calculated using the average number of propositions per 100 words, as well as using a type-token ratio (TTR) to determine the ratio of the number of different words to the total number of words. Through analysis of these results, both studies found that older and young adults alike experience a decline in performance when faced with dual-task conditions. Young adults were found to use a restricted, more simplistic style of speech that resembled the baseline complexity of older adults, in that it was shorter and utilized less complex grammar and content. On the other hand, older adults' speech style did not decline in the same fashion as the young adults did, as their speech samples were already at the baseline of complexity, presumably due to their age. Thus, their decline in performance was observed in speech rate, as they slowed their speech to accommodate for the increased use of cognitive resources (Kemper et al., 2003; Kemper et al., 2005).

Similarly, Kemper and colleagues conducted an additional series of studies in which older (65-85) and young adults (18-34) were trained on a pursuit rotor task to establish proficiency, and then given a three-minute speaking prompt to complete orally, such as ‘Please describe someone you admire or someone who has influenced your life,’ while continuing to track an on-screen target (Kemper et al., 2011; Kemper et al., 2009). Kemper et al. (2009) specifically analyzed identical measures to Kemper et al. (2003) and Kemper et al. (2005). Additional measures were used in Kemper et al. (2011) which pertained to the spoken language task. However, despite the difference in measures between Kemper et al. (2009) and Kemper et al. (2011), results were largely the same. Both studies indicated that older adults speak with more simplistic language at baseline when compared to young adults. Due to this baseline performance, it was found that older adults did not reduce the content or complexity of their spoken language when engaged in dual tasks due to a floor effect. Rather, a declination was seen in speech rate, as older adults slowed down possibly to accommodate for increased cognitive demands and/or resource allocation during dual tasks. Likewise, young adults also experienced decrements to their language production in dual tasks. However, their declines were reflected in changes to their speech complexity, which resulted in similarities to the older adult's baseline speech pattern using shorter, slower, and more simplistic sentences. Harmon et al. (2019) reported similar findings when studying cognitively healthy adults and adults with aphasia. Results indicated that even in healthy adults, speech rate was influenced by a simultaneous noise discrimination task, specifically distinguishing between high and low tones while retelling a short story.

Selective Attention

Selective attention is the ability to attend to a single task while simultaneously filtering out additional stimuli. Selective attention is best illustrated using the example of the Stroop task (Stroop, 1935). In this task participants are instructed to name words printed in varying colors such as “purple,” “pink,” “red,” etc. This is considered a sustained attention task. However, the task becomes a more complex selective attention task when participants are asked to name the color in which the word was printed while ignoring the word itself. Thus, if the word “purple,” was printed in blue, the target word would be blue. Consequently, greater cognitive capacity and/or better resource allocation is required. These attentional demands are important to consider in relation to the impacts of aging on language production.

Compared with young adults, older adults are more susceptible to distractions originating from stimuli that carry no discernable message and/or do not require a response (Morrison et al., 2020). Within the context of selective attention, differences have been found between young and older adults (Harmon et al., 2021; Kemper et al., 2003; Kemper et al., 2005; Wasiuk et al., 2020) possibly due to how the two age groups allocate their cognitive resources. Wasiuk et al. (2020) investigated a group of healthy young adults and older adults with sensorineural hearing loss (SNHL) to study the effects of fundamental frequency on the ability to distinguish between target and masked speech. Masked speech can include either energetic masking or informational masking. Informational masking carries comprehensible information that the brain can decipher, such as spoken conversation (Wasiuk et al., 2020). Energetic masking is any noise that draws attention away from the target signal due to the neural overload the brain experiences while trying to decipher what comprises the target signal and what is energetic masking. However, energetic masking itself carries no information and is consequently incomprehensible.

Both types of masking require selective attention as the listener must select a target on which to focus. In the case of this study, Wasiuk et al. (2020) utilized only two-talker informational masking with varying fundamental frequencies (f0), meaning that masking involved two people speaking simultaneously. Under this condition participants were asked to decipher target sentences from nine different combinations of energetic masking. Results confirmed that older adults with SNHL are less successful in utilizing f0 cues to determine the difference between masked and target speech when compared to the healthy, young adult population. A portion of these differences can be attributed to the difference in hearing loss vs. no hearing loss. However, attentional resources also play a contributing role in the deficits older adults with SNHL presented with as their attentional resources are at greater risk of being depleted more quickly due to age (Wasiuk et al., 2020). Consequently, when more than one stimulus draws from the pool of resources, these resources are depleted more quickly, ultimately yielding decreased task performance (Dromey & Shim, 2008).

Kemper et al. (2003) compared performance on a monologue task, elicited using pre-determined question prompts, among older and young adults while simultaneously ignoring background noise in two conditions: speech noise (i.e., a lively debate between two people) and environmental noise (i.e., noise from a school cafeteria). Findings revealed that both young adults and older adults experienced greater decrements to their performance within the areas of content, complexity, and fluency when forced to ignore speech as opposed to noise. Within these constructs, older adults experienced greater costs on WPM, MCU, D-Level, and P-Density, while young adults had greater costs on grammatical errors and mean length per utterance.

In studies involving a wider variety of background noise stimuli, research has shown that speech, specifically individuals having a lively debate, is consistently the most performance altering of all the noise and speech stimuli. Harmon et al. (2021) determined that of the five tested conditions (debate, movie, contemporary music, classical music, and pink noise), the debate had the most negative impact on 4/10 areas of measurement (speech rate, disfluency rate, lexical errors, and grammatically correct words). In the same study, results also indicated that speech acoustics themselves were negatively influenced by the addition of background noise. However, this study did not evaluate the differences in performance according to age.

Purpose

The present study seeks to expand upon the current published work to determine the effects of age on language production in the context of background noise, specifically in relation to selective attention. Current work has evaluated broad aspects of language production in the presence of additional stimuli and tasks. Studies have also been conducted to determine how age impacts other aspects of communication such as speech movements (Dromey & Scott, 2016; Dromey & Shim, 2008; Lu & Cooke, 2008, 2009), and story comprehension (Wright et al., 2011; Wright et al., 2014). The present study seeks to address the paucity of research on how background noise affects language production and to determine how these effects are influenced by age. We plan to do so by focusing predominantly on a selective attention task, while also introducing a unique series of background noise simulations as distractors for the participants, both young and old.

Specifically, the current work aims to answer the questions:

1. Does age affect language production in the presence of background noise?
2. Is there a specific background noise condition that more heavily impacts language production both generally and across age groups?

3. Does type of noise (energetic vs. informational) affect language production both generally and across age groups?

It is our hypothesis, after synthesizing the current published work, that the older adult group will demonstrate a more simplistic style of speech at baseline in the control (silent) condition when compared to the young adult group. This will consist of less grammatically complex sentences (exclusion of function words, omission of content, and number of bound morphemes), shorter phrases, and increased macrolinguistic errors, similar to the results found by Kemper et al. (2003) and Kemper et al. (2005). When faced with the background noise conditions, it is our hypothesis that the older adult group will speak with a reduced rate and experience a greater number of paraphasias and dysfluencies when compared to their baseline performance and to the language production of the young adult group. We further hypothesize that the young adult group will produce less complex grammar and content, as well as shorter phrases when faced with background noise conditions, similar to the baseline language of the older adult group. Additionally, we hypothesize that of the background noise conditions (silent, pink noise, single individual speaking, conversation between multiple speakers, a one-sided cell phone conversation, and cocktail speech), the conversation between multiple speakers will have the greatest negative impact on both age groups' performance on the language production task. And lastly, we hypothesize that informational masking will have a greater impact on language production generally, but specifically on older adults.

Method

Participants

Participants included 20 young adults (10 female and 10 male), ages 18-25 years and 20 older adults (10 female and 10 male), ages 60-85 years. Years of education ranged from 14-19 years for the older adults and 13-18 years for the younger adults. Table 1 reports mean and standard deviation of age and education for each group. All participants spoke English as their primary language, had no history of stroke or TIA as indicated through a score of 0 on the Questionnaire for Verifying Stroke-Free Status (QVFSF), and passed a bilateral pure-tone hearing screening at 500, 1000, 2000, and 4000 Hz at 30 dB. Participants were recruited from the BYU Stroke and Brain Injury Registry, flyers, and word of mouth. The study procedures were approved by Brigham Young University's Institutional Review Board in February 2021 and an addendum expanding age ranges of recruited older adult participants was approved by the university's Institutional Review Board in May 2021.

Instrumentation

Data collection took place in the Aphasia Research Lab located at Brigham Young University's Comprehensive Clinic. Language samples were collected in a sound attenuating booth to reduce auditory distractions and enhance the quality of acoustic recordings. The background noise recordings were presented to participants through Sennheiser HD600 open back headphones to prevent masking of participants' own speech, while simultaneously allowing for clean audio recordings of participants' spoken language. Speech samples were recorded to Adobe Audition software using a boom microphone, which was located approximately 50 cm from each participant's mouth during recording.

Procedures

All participants completed one session lasting no more than 90 minutes. Each session began with the participant reviewing the consent form and completing the QVSFS with a trained research assistant providing information and answering questions about the study and its procedures. Participants then completed a visual attention task, followed by all experimental conditions. The sessions were concluded with each participant answering questions in a semi-structured interview conducted by the trained research assistant.

Experimental Conditions

During the experimental protocol, participants retold short stories during six conditions. The conditions were as follows: (a) a silent baseline condition, (b) the speech of a person reading aloud a non-fiction book, (c) the speech of a lively conversation recorded between multiple speakers, (d) one side of a cell-phone conversation, (e) restaurant background noise, and (f) pink noise. The reading stimulus was an excerpt from a commercially available audiobook, the lively conversation was an excerpt taken from a commercially available dramatized story podcast, and the one-sided phone conversation was recorded by a research assistant in the Aphasia Lab. All recorded speech samples used for the background noise conditions were 100% intelligible. To ensure continuity, pauses longer than 200 ms were removed from the audio book and lively conversation recordings. The cocktail noise condition included unintelligible multi-talker speech combined with sounds commonly found in a restaurant, bar, or other noisy environment. These conditions were presented in a randomized order.

During data collection sessions a script was used to ensure standardization across administration procedures for all research assistants. A total of six research assistants conducted the sessions. Within each condition, participants completed a story retell task. Six stories were randomly selected from the Story Retell Procedure (Doyle et al., 1998) and presented in a randomized order. These stories have previously been shown to be balanced for content and complexity (i.e., number of words, number of sentences, number of subordinate clauses and mean sentence length, ratio of clauses to T-units, listening difficult, and number of unfamiliar words: McNeil et al., 2007). Before beginning, the examiner stated, “I will now play several stories for you. After each story, I will ask you to retell the story with as much detail as you remember. Sometimes, you will hear other noises while you are retelling the story. Are you ready for the first story?" Participants then indicated whether they were ready to proceed, at which point the examiner played the first short story through the open back headphones independent of any of the background noise conditions. When the story concluded, the examiner asked the participant to, "Please retell that story with as much detail as you remember." The examiner then played the previously randomized background noise stimulus throughout the duration of the retell. At the conclusion of each story retell, participants were asked to fill out a brief questionnaire detailing their stress and effort during the previously completed retell. The same process was repeated for the remainder of the stories and stimuli. Data from both the questionnaires, as well as the recorded speech acoustic data, will be reported elsewhere.

Orthographic Transcription and Error Coding

Audio samples were recorded using Adobe Audition then orthographically transcribed verbatim. Each transcription was reviewed and corrected by a trained research assistant. Transcriptions were then segmented into C-units (i.e., syntactic units consisting of an independent clause and a dependent clause, in addition to any modifiers). When defining the C-units, inter- and intra-rater reliability were ensured using the step-by-step procedures for C-unit segmentation outlined in Wright et al. (2011). Research assistants then used the segmented orthographic transcriptions to code the language samples for phonological, lexical, grammatical, and macro-linguistic errors based on the Codes for Human Analysis of Transcriptions (CHAT) format (MacWhinney, 2000). When documenting and coding errors, research assistants referenced a detailed list of codes to maintain consistency across all research assistants.

Furthermore, research assistants also completed required training, demonstrating mastery of a standard set of 15 practice transcriptions through comparison to the master transcriptions scored previously through collaboration between a master's level research assistant with over three years of language analysis experience, and the thesis chair, an experienced speech-language pathologist and aphasiologist. Once 100% agreement on assigned practice transcriptions was achieved, research assistants could then begin coding new files. Following coding, a student with over two years of language analysis experience then reviewed each coded transcription for accuracy and verified or corrected any differences in coding through collaboration with the thesis chair and an additional experienced coder. Using this approach, the accuracy of the coding was prioritized over the agreement between raters, and this is consistent with the approach used in previous research (Fromm et al., 2017; Harmon et al., 2021). Once all discrepancies were resolved, the coded transcriptions were then ready for analysis.

Dependent Variables

The dependent variables for this study consisted of those related to speech fluency, lexical production, grammatical production, and macrolinguistic production. These variables are summarized in Table 2 and explained below.

Speech Fluency. Speech fluency measures accounted for the speed at which speech was produced as well as interruptions to the overall flow of speech. This construct was divided into two individual components. First, speech rate measured the number of words per minute in each sample. Words excluded from this count consisted of fillers, partial words, repetitions of words, or word revisions. Second, the disfluency ratio consisted of the percentage of false starts and simple repetitions (repeated sound, syllables, and words) per word.

Lexical Production. Lexical production was divided into two dependent variables: lexical-phonological errors and MATTR. When calculating lexical-phonological errors, the number of false starts, phonological paraphasias, neologisms, semantic paraphasias, passe-partout words (e.g., vague words or general referents), simple repetitions, and fillers were tallied and divided by the total number of verbalizations, and then multiplied by 100 to generate a percentage. The Moving-Average Type-Token Ratio (MATTR) is a measure of lexical diversity, which was obtained using the Computer Analysis for Psychological Research (Covington, 2007; Covington & McFall, 2010). Type-token ratios are calculated using MATTR across consecutive, nonoverlapping word segments from a given language sample, and then averaging them. This in turn removes the influence of variability in sample size and is consequently a reliable means of measuring lexical diversity given the variability of sample sizes in the present study. For the present study, the window length was set at 37 words to account for the shortest sample in the dataset.

Grammatical Production. Grammatical production was calculated and quantified using the percentage of grammatically correct words. This was done by first determining the total number of grammatical errors, such as number of substitutions of a function word, bound morphemes, content omissions, and omissions of function words. This total number was then divided by the total number of words, inverted to represent the ratio of grammatically correct words, and then multiplied by 100 to generate a percentage.

Macrolinguistic Production. Macrolinguistic production was measured as the percentage of cohesive and coherent utterances produced during a given language sample. Specifically, the number of macrolinguistic errors (i.e., coherence errors, aposiopesis, ambiguous referents, missing referents, and tangential utterances) were tallied. This total number of macrolinguistic errors was then divided by the total number of utterances and inverted to reflect the ratio of coherent and cohesive utterances. This ratio was then multiplied by 100 to generate a percentage.

Statistical Analysis

Results of the present study were analyzed in a two-step process. The first step was using a two-sample t-test to analyze group differences in the silent baseline condition across all measures. Data met assumptions of homogeneity of variance and normality with the exceptions of the older adult data not being normally distributed for the disfluent words, lexical-phonological errors per verbalization measures, and cohesive and coherent utterances measures and the young adult data not being normally distributed for the grammatically correct words and cohesive and coherent utterances measures. Because the assumption of homogeneity of variance was met and we had a sufficient sample size, we proceeded with the analysis. The second step was investigation of the effects of background noise on the studied groups. This was done using a relative change score to determine the difference in performance between each noise condition and the baseline silent condition. To determine this score, calculations were completed by dividing the difference in value between noise and silent conditions, for any dependent variables, by the silent condition value, and then generating a percentage by multiplying the calculated value by 100 (Harmon et al., 2021; Kemper et al., 2005). The scores were then inverted for both the lexical-phonological and disfluency measures to ensure that negative values reflect deterioration in language across the background noise conditions, and that positive values reflect increased performance in the same background noise conditions. These relative change scores will be referred to as background noise effects for the duration of this study.

The background noise effects calculated were analyzed further with two-way mixed-effects analysis of variance (ANOVA) or, in the case of cohesive and coherence utterances, which did not meet assumptions of normality or homogeneity of variance, a Friedman test. The between-subject factor (Group) accounted for differences between the age populations (older adults vs. young adults). The within-subject factor (Condition) accounted for differences across the different background noise conditions. Participants were included as a random effect factor. Further testing was completed using Tukey's Honestly Significant Difference. ANOVAs were also followed up with independent sample t-tests in order to determine whether performance was affected significantly due to the result of each individual background noise condition. The alpha level for all tests was set at .05.

All statistical analyses were completed using R 4.0.2 (R Core Team, 2020). Mixed-effects ANOVAs were completed on models built using the lme function within the nlme package (Pinheiro et al., 2017), and pairwise comparisons were made on the model using the emmeans package (Lenth, 2017).

Results

Findings from the present study indicated differences in how language for older and young adults is affected when talking in the presence of background noise. Some distinction between the effects of different background noise conditions were also observed. Figures 1 and 2 illustrate background noise effects.

Baseline Language Production

Regarding the baseline language production for both the older and young adult groups, no significant differences between groups for all dependent variables (speech rate, disfluent words, lexical-phonological errors, MATTR, grammatically correct words, and cohesive and coherent utterances) were found in the silent baseline condition ($p > .05$). Table 3 reports data across all group and dependent variable combinations.

Effects of Background Noise on Language Production

In relation to background noise effects, a two-way ANOVA showed significant main effects for group across one measure of language production: speech rate. Specifically, older adults were found to change the rate at which they spoke in the presence of background noise more than their young adult counter parts, $F(1, 151) = 5.82$, $p = .017$. Additionally, a main effect of condition was found for disfluent words, $F(4, 151) = 4.74$, $p = .001$. Post-hoc testing showed significant differences between the phone call and conversation conditions ($t[151] = 3.91$, $p = .001$), as well as the pink noise and phone call conditions ($t[151] = -3.20$, $p = .014$). One sample t-tests further elucidated several changes relative to the silent baseline condition. Because the primary goal of this study was to investigate these changes in conjunction with age, these results are emphasized below.

Speech Fluency

Speech Rate

Significant background noise benefits were found for the older adult group during the phone call ($t[20] = 2.32$, $p = .031$) and conversation ($t[20] = 2.22$, $p = .038$) noise conditions, indicating that they increased their rate of speech in these conditions. However, young adults were found to experience a statistically significant background noise cost to their speech rate in the phone call condition ($t[18] = -2.12$, $p = .048$), meaning that their rate of speech decreased from baseline.

Disfluent Words

Results indicated that for the young adult group, the change in disfluencies was near to significant during the phone call condition, but did not reach statistical significance (t[18] = -2.01, p =.059). No other statistically significant changes from 0 were found in relation to disfluent words.

Lexical Production

Lexical-Phonological Errors

In relation to lexical-phonological errors, significant background noise benefits were found for the older adult group during the conversation condition (t[20] = 2.36, p =.029). No other statistically significant changes from baseline were found for the OA group. Additionally, the young adult group showed no significant background noise effects across conditions.

Moving-Average Type-Token Ratio

In relation to MATTR, no statistically significant changes from zero were found across all condition and group combinations.

Grammatical Production

No statistically significant changes from zero were found across all condition and group combinations for grammatically correct words.

Macrolinguistic Production

No statistically significant changes from zero were found across all condition and group combinations for cohesive and coherent utterances.

Discussion

The effects of concurrent tasks on language production have been studied across a variety of populations (Harmon et al., 2021; Harmon et al., 2019; Kemper et al., 2003; Kemper et al., 2005; Kemper et al., 2011; Kemper et al., 2009; Morrison et al., 2020; Wasiuk et al., 2020), tasks (Bier et al., 2017; Dromey & Shim, 2008; Glosser & Deser, 1992; Kemper et al., 2003; Kemper et al., 2005; Kemper et al., 2011; Kemper et al., 2009; Lu & Cooke, 2008), and settings (Aubanel et al., 2011; Bier et al., 2017; Lu & Cooke, 2008). However, there is currently a lack of research surrounding the effects of background noise on language production, particularly in relation to different age groups. The current work aimed to compare the speech fluency, lexical production, grammatical production, and macrolinguistic production of neurotypical young and neurotypical older adults when retelling stories under various background noise conditions. Findings suggest some differences in how young and older adults respond to speaking in noise.

Distinctions in How Background Noise Affects Young and Older Adults

We hypothesized that older adults would experience more decrements to their spoken language as the result of background noise than young adults. This hypothesis was based on previous research that investigated similar conditions to those used in the current study (Kemper et al.; Kemper et al., 2005; Kemper et al., 2011; Kemper et al., 2009). Kemper and colleagues (Harmon et al., 2019; Lu & Cooke, 2008) reported that under varying tasks and/or background noise conditions, older adults consistently reduced their rate of speech while young adults consistently experienced decrements to their grammatical complexity during discourse production. Although distinctions between young and older adult groups were also found in the present study, they were different from our original hypothesis as well as the general trends found across the previous research.

Specifically, young and older adult groups were distinct in how background noise conditions affected their speech rate with young adults generally maintaining or decreasing and older adults generally increasing their rate of speech. In relation to specific conditions, the young adults significantly reduced their rate of speech during the phone call condition. Older adults, on the other hand, significantly increased their speech rate during the phone call and conversation conditions. They also decreased their lexical-phonological errors in the conversation condition. Opposite our hypothesis, therefore, older adults were differentiated from young adults due to general background noise benefits rather than costs.

Although our findings were not in line with our initial hypothesis, several potential factors might explain these results. These include (a) differences in attentional capacity/resource allocation for young v. older adults, (b) potentially greater acclamation to speaking in background noise for older adults, and (c) older adults being more attuned to the needs of a listener when retelling a story.

Attentional Capacity and Resource Allocation

Historically, older adults have been shown to demonstrate greater interference to their spoken language than young adults when participating in selective attention tasks (Kemper et al., 2003; Kemper et al., 2005; Kemper et al., 2011; Kemper et al., 2009; Morrison et al., 2020; Wasiuk et al., 2020). Specifically, older adults demonstrated greater decrements in speech rate, mean clauses per utterance, developmental level, and propositional density when producing spoken language while listening to speech stimuli, whereas young adults only suffered greater decrements in mean length per utterance and grammatical errors under the same conditions (Kemper et al., 2003; Kemper et al., 2005). Older adults also decreased their rate of speech while participating in divided attention tasks (Kemper et al., 2011; Kemper et al., 2009). The current study directly focused on selective attention tasks, much like those found in Kemper et al. (2003), Kemper et al, (2005), and Wasiuk et al. (2020). However, results of the current study differed from those found previously. During the selective attention task of producing spoken language while concurrently ignoring the presence of background noise, the older adults generally demonstrated overall benefit to their spoken language, while young adults experienced overall interference.

Previous research has related the greater decrements in spoken language experienced by older adults during divided and selective attention tasks to their attentional resources being depleted more quickly (Kemper et al., 2003; Kemper et al., 2005; Wasiuk et al., 2020). According to a resource-capacity model, greater interference in response to attentional demands could be indicative of decreased attentional capacity or greater difficulty allocating attentional resources. Kemper et al. (2003) included two conditions that were similar to background noise conditions used in the present study. Specifically, their cafeteria noise was comparable to the current work's cocktail speech condition and their concurrent speech was comparable to the current work's monologue condition. In the current work, the monologue condition was comprised of a single person reading a continuous monologue throughout the participant's story retell while in Kemper et al. (2003), the concurrent speech condition consisted of a single, monotone reader of the same sex as the participant, reading a passage, which the participant heard while producing spontaneous speech in response to a prompt. Despite similarities in these noise conditions, methodological differences included participants in the Kemper et al. (2003) article being required to listen to one of the two noise conditions, and then after 30 seconds of listening, respond to a question prompt shown to them, producing at least 50 utterances in the process. This difference may have contributed to differing results. For example, it is possible that participants were more distracted by the noise when they were given a period of time to attend to it prior to performing a speech task leading to the possibility of greater interference. Additionally, retelling a story as opposed to generating speech in response to a prompt may reduce higher-level language planning because the content and structure of the discourse was already provided.

Despite Kemper et al. (2003) showing greater interference when speaking in two noise conditions than was found in the present study, some trends were similar to our results. Specifically, Kemper et al. (2003) found that in the "Ignoring Speech" condition their older adult participants suffered less of an adverse effect numerically than young adults across all the measured dependent variables, except for speech rate. Relatedly, the older adults demonstrated a numerical benefit under the "Ignoring Speech" condition, indicating that, like the current work, the older adults seemed to benefit from the presence of noise, as opposed to suffering from it. Additionally, differences between results of the current work and Kemper et al. (2003) may also be related to statistical power, as Kemper's work was conducted with a substantially larger sample size having 77 young adults, and 91 older adults.

Wasiuk et al. (2020) used a two-talker mask throughout their study which was comparable to the current study's cocktail speech condition. In the current work, when producing language under the cocktail speech condition, both the young and older adults were found to maintain their linguistic production, resulting in no statistically significant differences between the baseline and experimental language productions. Wasiuk et al. (2020) measured the differences in speech recognition threshold, a measure of the minimum intensity level at which a listener can recognize at least 50% of speech, for both young and older adults when the speech was masked by flat, normal, and exaggerated concurrent speakers. Results from this study indicated that the older adults studied had a higher speech recognition threshold when the target and masked speaking styles were matched, and even more so when both were exaggerated. The young adults were found to have similar results in that their speech recognition threshold was higher when the target and masker speech were matched. However, the young adults showed that there was no significant difference between the flat, normal, or exaggerated styles as seen with the older adults. These results indicate that in the presence of cocktail speech noise, unlike the present work, both young and older adults suffered decrements to their performance. Had the current work measured speech acoustics, perhaps similar results may have been yielded.

Although attentional capacity or allocation of attentional resources likely contributed to our results, we must acknowledge that across the six background noise conditions utilized in this study, the attentional capacity required to ignore the noise likely varied from participant to participant due to any number of extenuating factors: personality, background, occupation, or other personal factors. Furthermore, we also know that selective attention tasks, such as those in the current work, are less attentionally demanding than divided attention tasks used in other studies similar to our own (Kemper et al., 2003; Kemper et al., 2005; Kemper et al., 2011; Kemper et al., 2009), further contributing to the possible differences in results across age groups. Nonetheless, due to the benefit in performance that was seen in the current work across two dependent variables for the older adults, perhaps their attentional resources were not "depleted more quickly" than those of the young adults. Nor were they sacrificing speech rate in order to maintain a baseline level of performance in language production. Instead, it may be the young adults who have yet to determine the balance in allocating appropriate attentional resources to both ignoring concurrent stimuli while accurately producing spoken language efficiently.

Acclamation and Experience

As previously discussed, results from one sample t-tests indicated that while producing language in the presence of a lively conversation, the older adult participants were found to decrease the number of lexical-phonological errors when compared to the silent baseline condition. Additionally, in the lively conversation and one-sided phone call conditions, the older adults also increased their speech rate when compared to the silent baseline condition. Based on anecdotal evidence collected in conjunction with this experiment, we found that older adults frequently reported that as they aged, they found it easier to tune out most background noise. When asked, which, if any, of the background noise conditions were the most difficult for them to ignore, older adults frequently stated that they couldn't recall any of the background noise conditions because they all were easy to ignore. Future research should investigate participants' subjective response to speaking in noise using qualitative analysis. Results suggest that to some extent, older adults may have indeed been able to better tune out background noise, particularly in the conversation and phone call conditions, leading to quantitatively better language (i.e., decreased lexical errors and increased speech rate). We speculate that this is, at least in part, due to the greater life experience of older adults, and the time they have had to acclimate to the presence of additional noise in their everyday lives. Additionally, it is unlikely that these differences in performance were the result of decreased hearing abilities in the older adult group as all participants demonstrated hearing thresholds below 30 dB.

Differences in Level of Interest and Engagement in Discourse

When compared with young adults, older adults have been found to, at baseline, have superior narrative discourse due to more robust vocabularies, and greater skills as conversationalists than young adults, which has been shown to result in better listener attention and engagement (Glisky, 2007). In line with this finding, it may be that older adults experienced less interference to their narrative discourse than young adults because they were attempting to keep the listener engaged. Harmon et al. (2021) suggested that their young adult participants modified their spoken language in ways that might better maintain listeners' attention and engagement in the face of background noise. Specifically, participants were found to increase their vocal intensity and lexical diversity, as well as reduce pauses while producing spontaneous speech in response to a written prompt during a variety of background noise conditions. In the current study, the older adults demonstrated behaviors consistent with those of the young adults in Harmon et al. (2021). For example, in the current work, older adults increased their speech rate while simultaneously reducing the number of lexical-phonological errors in the presence of the lively conversation condition. This is consistent with the notion that these improvements were made in order to compete with the distracting background noise in order to maintain listener interest and engagement. Similarly, under the phone call condition, the older adults were found to increase speech rate, likely for similar reasons.

However, this begs the question, why did the young adults not show the same changes in their language production in the current study as were shown in Harmon et al., 2021, especially considering that two pairs of background noise conditions were similar (dialogue from a movie and conversation, and pink noise conditions)? First, it should be noted that, for these conditions, speech rate findings were comparable with neither study showing significant changes. Similarly, in both studies the disfluency measure showed no significant change under the pink noise conditions. Furthermore, neither pair of comparable conditions showed significant changes in lexical-phonological errors, grammatical production, or macrolinguistic production. On the other hand, differences in results between the two studies were found for disfluencies and lexical diversity. Specifically, Harmon et al. (2021) found significant disfluency ratio differences under the movie condition whereas no significant change in disfluencies was found in the present study during the conversation condition. One potential explanation for this could be differences in the specific stimuli used. The noise stimulus used for the movie condition was a segment of dialogue taken from a scene of a movie that would have been familiar to most young adult participants whereas the stimulus used in the conversation condition was taken from dramatized story podcast that participants were likely not familiar with. Decreased familiarity with the stimulus may have caused it to be less distracting leading to less of an impact on spoken language. Future research should investigate how familiarity with noise stimuli impacts how listeners respond. Harmon et al. (2021) also found increased pause time ratios for both the movie and pink noise conditions. It may be that this measure of fluency was more sensitive to change than those included in the present study. Had the current study included pause time ratio as a measure of fluency, we may have seen similar results given the similarities between results for the other two measures of fluency (i.e., speech rate and disfluencies). In relation to lexical diversity, Harmon et al. (2021) found changes in both movie and pink noise conditions whereas the current study showed that young adults generally maintained lexical diversity. This difference could be the result of differences in how language samples were elicited. In the previous study, young adults produced spontaneous language samples in response to prompts, which required them to generate novel content. Because this task was less constrained than the story retell task used in the present study, it may have provided them greater leeway to diversify their vocabulary in order to maintain listener engagement.

In summary, although both older and young adults may make adjustments to their discourse to maintain listener engagement when background noise is present, findings from the present study suggest that these adjustments could be more robust for older adults particularly during a narrative discourse task.

Informational and Energetic Noise

Within the current study, no relationship was found between informational vs. energetic noise in relation to group effects. However, given the previous research, we anticipated that there may be a greater decline in performance for the older adults when producing language under the pink noise condition (energetic noise; Kemper et al., 2003). Rather, we found that neither population was significantly affected by the presence of energetic noise, but more so by the presence of informational noise (phone call, and lively conversation). Similarly, Harmon et al. (2021) found generally less impact in background informational noise conditions and Kemper et al. (2003) found that older adults were found to be less affected than the young adults in regard to sentence length and grammatical complexity in the presence of informational noise. The current work corroborates these findings given that the older adults were again found to benefit from the presence of informational noise in relation to both speech rate and lexical diversity errors. But what quality about informational noise yields itself to improvement for the older adults? We anticipate that, given the informational nature of the noise, the older adults may have found it necessary to allocate a greater proportion of their cognitive resources to the story retell, therein ignoring the stimuli more successfully, overall resulting in an improved performance.

Even though generally older adults tended to make some improvements when speaking in noise, whereas young adults tended to maintain/decrease their spoken language, across groups the phone call condition did lead to more disfluencies than other conditions, specifically pink noise and conversation. While there is no definitive answer as to why this may be, we suspect that one contributing factor could be due to the intermittent nature of informational noise present in a one-sided phone call, which may have required more attention from the listener. This was not the case in the conversation condition given that continuous informational noise was present. For a similar reason, we anticipate that the pink noise also yielded similar results in the sense that it required less cognitive resources of the participants to ignore the stimuli, as compared to the intermittent information from the phone call condition.

Limitations and Future Directions

It's important for researchers and clinicians alike to sufficiently understand the effects that background noise has on language production in order to continuously provide appropriate and relevant treatment in settings and conditions that can be generalized for their patients. The current study looked to add to the already existing literature (Harmon et al., 2021; Kemper et al., 2003; Kemper et al., 2005; Kemper et al., 2011; Kemper et al., 2009; Lu & Cooke, 2008) surrounding the effects of background noise, with a specific focus on the differences across varying age demographics. Future research should look to refine and address the limitations in the current study to further understand how background noise affects language production across the life span.

First, it should be noted that the current work looked at only a small sample size in relation to other studies of similar nature (Kemper et al., 2003; Kemper et al., 2005; Kemper et al., 2011; Kemper et al., 2009), with a total of 40 participants, and only 20 in each age group. Should sample sizes be increased, this would in turn raise the statistical power of the study, and possibly reveal additional statistically significant results that we were otherwise unable to discern. Additionally, by increasing the sample size, future research may also be able to account for variations in race, vocation, socioeconomic status, focus of study, as well as any additional population differences that may be pertinent to consider when comparing performance across the life span. Second, the age range which was used for the older adult group was broad, spanning from 60-85 years. While this range was necessary to recruit the desired number of participants of both sexes, it unfortunately leaves notable room for variation in the participants' ages and potentially their attentional capacity. Ideally, this age range would be narrowed, or like in Marini et al. (2005), additional age groups could be created, representing an old adult group, as well as an older adult group, allowing the data to be more specific to the ages studied. Third, future studies may find it beneficial to focus on a single linguistic construct, perhaps fluency as this is where the current work yielded distinct differences in performance. Although our rationale for the large number of dependent variables used in the present study was to conduct a multilevel language analysis, measuring a single construct would again increase the statistical power and could potentially make findings more focused in nature. Lastly, an additional, or different language task could be considered to analyze how different types of language are affected under the same noise conditions, similar to work conducted by Harmon et al. (2021) or Kemper et al. (2003). A narrative discourse task was used in the current study, but perhaps a spontaneous language sample, or another elicitation technique may lead to different results than those found here. Or more specifically, future research could investigate the impact of background noise in a conversational task in order to eliminate a perceived difference in interest with the narratives used in the narrative discourse task. Older adults were informally observed to find humor in the narratives used, while the young adults lacked the same physical reactions, which may have contributed to the differences in overall performance.

Despite the limitations noted, the current study provides quantitative data representing the challenges faced by both young and older adults when attempting to produce language amidst background noise. Should the current work be confirmed by future research it may lead to need for further conversation and research surrounding the use of varying noise types while in session with patients engaged in speech therapy, and as to what types of therapy best benefit from the use of methods such as these.

Conclusion

This study found that different types of background noise resulted in language production costs for the young adult population, but also what could be interpreted as language production benefits for the older adult population. These findings suggest that background noise may interfere with language production more for young adults than older adults. Future research should continue exploring the effects of background noise on the language production of all populations to facilitate further development of appropriate clinical practice in relation to this common interference.

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Tables

Table 1

Participant Demographic Information

	Young Adults (YA)	Older Adults (OA)
N	10 Male, 10 Female	10 Male, 10 Female
Age (years)	22.9 (1.33)	67.4 (5.41)
Years of Education (years)	15.8 (1.44)	16.4 (1.46)

Table 2

Summary of Dependent Variables

Construct	Dependent Variable	Definition
Speech Fluency	Speech rate	Words per minute
	Disfluent words	Number of false starts and simple repetitions per word multiplied by 100
Lexical Production	Lexical-phonological errors	Proportion of lexical-phonological errors (i.e., false starts, incorrect word productions, simple repetitions, and fillers) per verbalizations, inverted, and multiplied by 100.
	MATTR	Moving-average type-token ratio, which analyzes lexical diversity using the type-token ratio while accounting for variability in sample length (Covington & McFall, 2010).
Grammatical Production	Grammatically correct words	Proportion of morphosyntactic errors (i.e., function word omissions or substitutions, bound morpheme substitutions, and content omissions) per word, inverted, and multiplied by 100.
Macrolinguistic Production	Cohesive and coherent utterances	Proportion of macrolinguistic errors (i.e., incomplete, ambiguous, tangential, incongruent, repeated, and filler utterances) per utterance, inverted, and multiplied by 100.

Table 3

Descriptive Statistics for all Dependent Variables

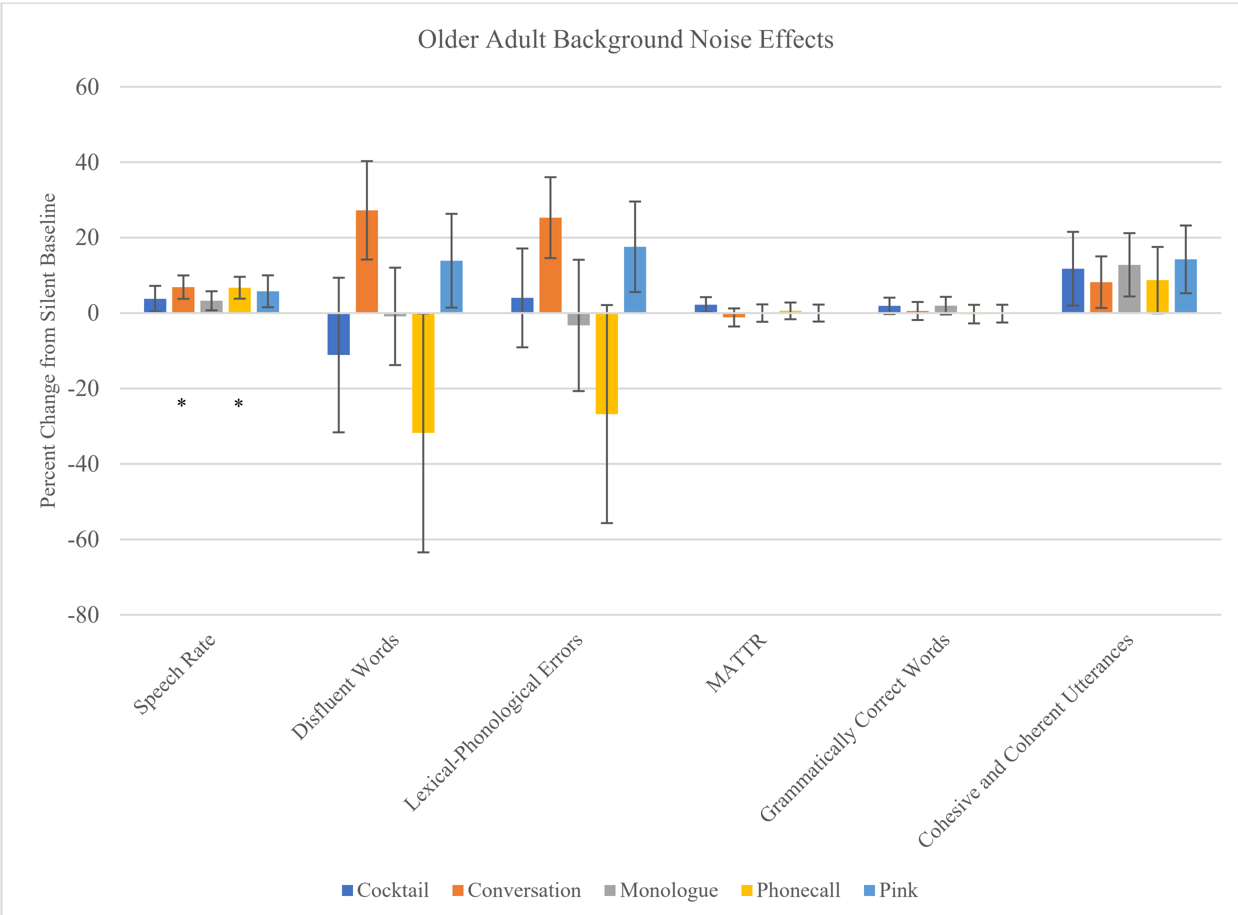
		Cocktail		Conversation		Monologue		Phone call		Pink		Silent	
		OA	YA	OA	YA	OA	YA	OA	YA	OA	YA	OA	YA
Speech Rate	*M*	133.89	136.40	137.7	134.33	132.56	134.86	137.25	125.8	136.29	132.39	129.78	134.10
	SE	5.37	6.69	4.97	6.19	4.86	4.32	4.14	6.07	6.02	6.34	4.31	4.82
Disfluent Words	*M*	0.08	0.10	0.05	0.08	0.08	0.09	0.08	0.10	0.10	0.10	0.09	0.08
	SE	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Lexical-Phonological Errors	*M*	5.07	5.60	4.16	5.41	5.01	5.14	5.79	5.80	4.65	5.13	6.07	5.24
	SE	0.933	0.676	0.906	0.909	0.977	0.539	0.951	0.618	1.23	0.707	1.07	0.602
MATTR	*M*	0.60	0.58	0.58	0.56	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
	SE	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Grammatical Production	*M*	99.4	99.6	99.2	99.6	99.3	99.2	99.2	99.3	99.2	99.5	99.2	99.2
	SE	0.142	0.135	0.172	0.102	0.165	0.181	0.204	0.157	0.198	0.135	0.150	0.226
Macrolinguistic Production	*M*	94.7	93.2	93.4	98.3	95.6	97.5	92.5	93.6	97.0	96.4	90.1	95.9
	SE	1.97	4.80	2.36	6.74	1.44	1.15	2.43	1.80	0.89	1.24	3.49	1.74

Note. OA = older adult; YA = young adult; MATTR = moving average type token ratio

Figures

Figure 1

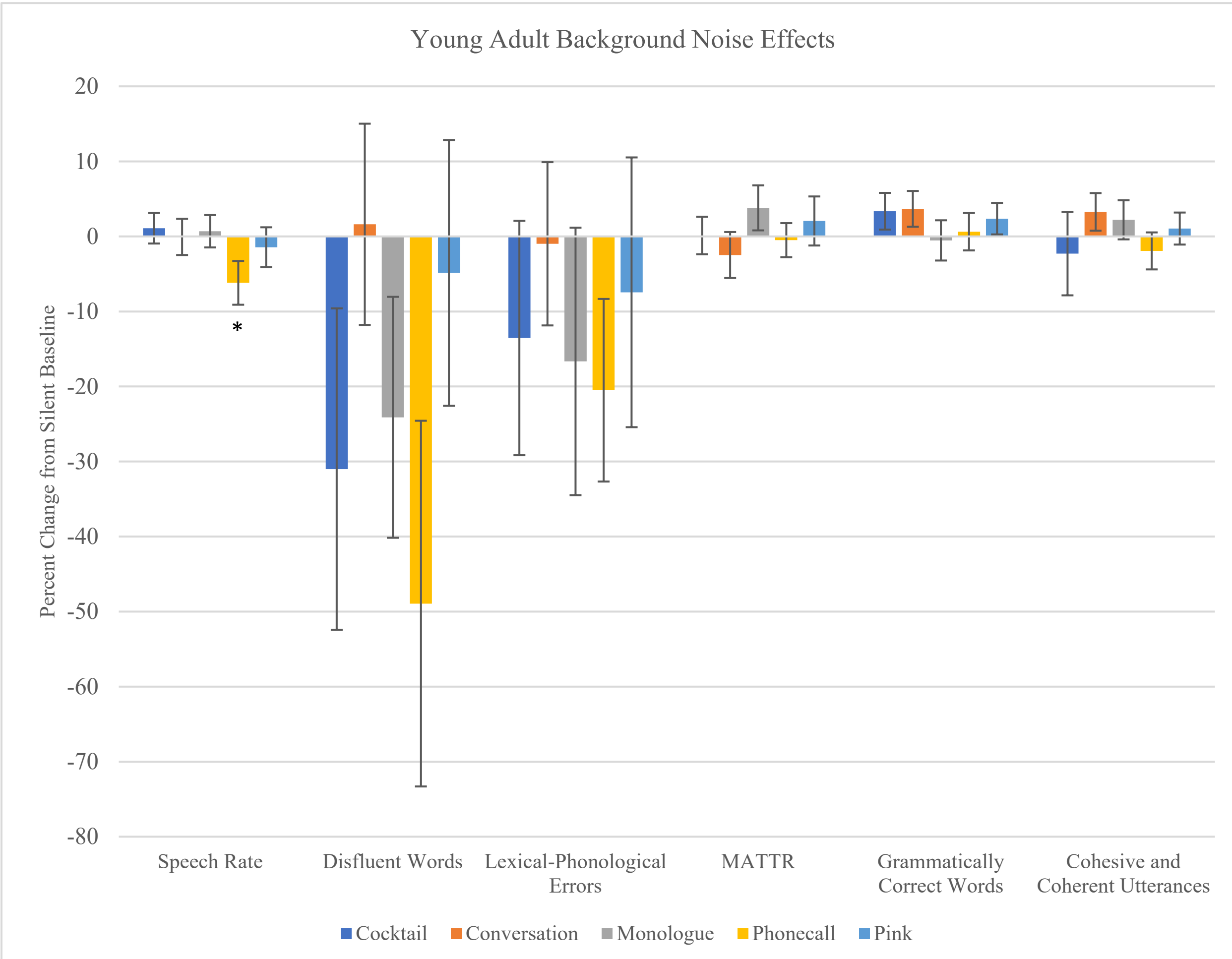
Background Noise Effects for the Older Adult Group Across all Dependent Variables



Note. The Grammatical Production data has been multiplied by 10 to improve visualization of changes. * = statistically significant results.

Figure 2

Background Noise Effects for the Young Adult Group Across all Dependent Variables



Note. The Grammatical Production data has been multiplied by 10 to improve visualization of changes. * = statistically significant results.

APPENDIX A

Annotated Bibliography

Aubanel, V., Cooke, M., Villegas, J., & Lecumberri, M. L. G. (2011, August). Conversing in the presence of a competing conversation: Effects on speech production. In *Proceedings of the Twelfth Annual Conference of the International Speech Communication Association: Interspeech 2011, Florence, Italy,* (pp. 2833-2836).

Objective: This study aims to determine the effect of background noise/competing speech on spontaneous, natural conversation.

Method: Six female Spanish speakers (three pairs) were recorded as a single pair conversing for five minutes before adding in a second pair conversing simultaneously for five minutes. At this point the first pair was asked to leave and the second pair conversed for five minutes independently. Data was collected and using Praat, energy, fundamental frequency, and frequency of the first formant were analyzed, and speech rate was analyzed using the number of vowel per second derived from the word-level transcription.

Results: In the presence of background conversation, more dysfluencies and mis-timings were seen. There were also more interruptions seen, both for when the other speaker was speaking, and when the other speaker wasn't speaking but hadn't yielded their turn to speak yet. Fundamental frequency and the first formant frequency both decreased with the addition of background conversation. Speech rate also increased with the addition of background conversation.

Conclusions: Speech was modified in a variety of ways when an additional conversation was introduced in the background. These changes were particularly seen in the fundamental frequency and speech rate for all pairs of speakers. These findings indicate that there "is a clear indication that factors other than energetic masking are at play in determining the level of speech modifications in natural conversations." Overall, this study concluded that speaking with other conversations occurring simultaneously within the vicinity causes the speaker to make significant speech modifications.

Relevance to the current work: This study is similar to the current work in how it analyzed the effect of additional background noise/speakers on the speech of concurrent talkers/listeners. This is similar to the background noise condition of the lively conversation used in the current study. They also used a silent condition, just like the current study.

Bier, B., Lecavalier, N. C., Malenfant, D., Peretz, I., & Belleville, S. (2017). Effect of age on attentional control in dual-tasking. *Experimental Aging Research*, *43*(2), 161-177. https://doi.org/10.1080/0361073X.2017.1276377

Objective: This quantitative study looks to analyze age-related differences in young and older adult populations in their ability to control the amount of attention they give to individual tasks in divided attention tasks, and also to determine whether divided attention results from a reduction in resources that are available for dual-tasking or not.

Method:

Experiment 1: Twenty-one young and 21 older adults participated in both focused and dual attention tasks. The focused attention tasks involved tracking a square on a screen and repeating back a series digits in auditory form. The dual attention task required the participants to perform both tasks simultaneously.

Experiment 2: Twenty-one young and 23 older adults participated in the same tasks as in the first experiment. However, the goal of this procedure, specifically for the visual task, was to obtain three different speeds of varying difficulty. This included performance/correct tracking at 90% (easy), 70% (moderate), and 50% (difficult). Performance corresponded with the percentage of time spent on a given target in a 15-second tracking period.

Results:

Experiment 1: Older adults were able to recall a smaller digit span of M = 5.5 as compared to the young adults who had a larger digit recall span of M = 6.2. Older adults also required a slower moving target to hit performance accuracy on the tracking task that was comparable to the young adults.

Experiment 2: In this experiment, the digit span capacity was comparable to the young adults M = 6.05 vs M = 6.38. Older adults did obtain higher visual tracking thresholds when compared to the young adults, meaning that they required slower moving targets to hit a similar performance as the young adults.

Conclusions: After comparing the results of both experiments, it's clear that older adults are unable to control their attention as a function of external demands, even when given specific emphasis on varying instructions, as in these experiments. Young adults demonstrated an ability to comply with the instructions they were given which ultimately forced them to change where their attention was going. Additionally, there were no age-related difference found in relation to demand because both age groups demonstrated similar patterns of dual-task cost changes that correlated with the levels of difficulty of the tasks.

Relevance to the current work: This study is similar to the current study in its use of two age populations, specifically young and older adult groups. While there was no focus on speech/language like the current study has, there was the use of dual attention tasks, which the current study does use to analyze how language is affected in the presence of background noise.

Brungart, D. S., Simpson, B. D., Ericson, M. A., & Scott, K. R. (2001). Informational and energetic masking effects in the perception of multiple simultaneous talkers. *The Journal of the Acoustical Society of America*, *110*(5 Pt 1), 2527-2538. https://doi.org/10.1121/1.1408946

Objective: This paper quantitatively evaluates three different experiments that examine the differences that vocal characteristics and overall levels of simultaneous talkers have on a target phrase in a "multi-talker speech signal."

Method:

Experiment 1: Five male and four female participants with normal hearing were asked to listen to a previously recorded audio which asked them to select squares on a grid to determine if they heard the speaker correctly or not. This was done while listening to either one, two, or three additional speakers speak on the recording simultaneously. Each of these listeners had participated in previous experiments using the same speech materials.

Experiment 2: Three males and five females were asked to listen to the same audio as in experiment 1, except this time the target-masker configurations were different because every stimulus presentation contained three different talkers presented at different dB levels. Each participant participated in a total of 1200 trials split into seven blocks.

Experiment 3: Six participants were asked to listen to the same audio as in experiments 1 and 2. However, this time nine different target-masker configurations were used. These included two-talker, three-talker, and four-talker configurations in which the RMS power (overall level) of each competing talker was normalized to the RMS level of the target talker.

Results:

Experiment 1: The results of the different voice configurations were largely consistent across the two, three, and four-talker conditions. Unsurprisingly, the listener did best when the target voice was qualitatively different from the making voices. Thus, when the target voice was qualitatively similar to the masking voices, performance decreased. Performance was also influenced by the target-to-masker ratio (TMR). When the TMR was higher, performance decreased. However, when the TMR was lower, performance differences were much more noticeable between same-sex and mixed-sex masking configurations. Signal-to-noise ratio (SNR) was also calculated, and it was found that with a positive SNR performance increased in correlation with the number of talkers.

Experiment 2: Performance declined the most with the addition of a same-sex masker B, specifically when the level of the same-sex masker A was lower than the level of the target voice. Listeners are more susceptible to the distraction from an odd-sex talker than from a same-sex talker when listening to the quieter of the two same-sex voices.

Experiment 3: As a trend, performance improved when the listeners were provided with prior information about the characteristics of the target voice. Improvement was seen the most in different-sex and mixed-sex configurations than in same-sex ones. Improvements were also more largely seen in three and four-talker configurations than in two-talker ones.

Conclusions: Overall, performance is typically best in multi-talker situations when the target voice is qualitatively different from the masker's voice, when there are fewer competing talkers, and when there is prior knowledge about the target talker's voice.

Relevance to the current work: This study analyzed how a listener's ability to accurately perform on a task changed as additional maskers/talkers were introduced into the background with varying vocal characteristics. However, they varied their listening conditions using the dB level at which they were presented, something the current study is not doing. This study also used listeners who were healthy and with normal hearing.

Cooke, M., & Youyi Lu. (2010). Spectral and temporal changes to speech produced in the presence of energetic and informational maskers. *Journal of the Acoustical Society of America*, *128*(4), 2059–2069. https://doi.org/10.1121/1.3478775

Objective: The purpose of this study was to analyze the effects of energetic and informational masking on speech production for individuals talking in pairs or alone.

Method: Eight native British English speakers were selected from staff and students at the University of Sheffield to participate in the study. Participants were grouped into pairs with a person of the same gender and asked to solve Sudoku puzzles either alone or in their assigned pairs, while language samples were collected from those interactions. During the process, participants were also subjected to various background noise conditions, specifically quiet, competing speech, speech-shaped noise, and speech-modulated noise.

Results: For each language sample collected, PRAAT was used to measure word duration, root-mean-square, energy, and mean fundamental frequency. Results showed that in the presence of both a task and background noise, there was no significant change in any of the measures. In both tasks, SSN had the greatest increases across all measures, while SMN and CS resulted in smaller changes in energy, mean fundamental frequency, and spectral tilt. In the task involving pairs, there was a significant increase in F0 and intensity, and a decrease in spectral tilt. F0 increased significantly when there was a communication factor present in the activity (pairs). In the Sudoku task, speaking rate was faster.

Conclusions: All background noises yielded common Lombard effect results: increases in speech level and fundamental frequency, along with a flattening of spectral tilt (more energy at higher frequencies).

Relevance to the current work: This study utilized similar background noise conditions such as quiet, competing speech, and noise to analyze how language change for participants while participating in dual attention tasks. The dual task was similar to that of the current study in that it requires significant cognitive effort to recall details of a story/solve a puzzle, but they differ in that this study utilized the presence of a partner for one of the competing variables.

Davis, M. S., Fridriksson, J., Healy, E. W., & Baylis, G. C. (2007). Effects of MRI scanner noise on language task performance in persons with aphasia. Journal of Medical Speech -

Language Pathology, 15(2), 119+.

https://link.gale.com/apps/doc/A165578856/HRCA?u=anon~3a8d73fa&sid=googleScholar&xid=f97b0371

Objective: The purpose of this study was to determine the effect of the various types of noise from an MRI scanner on language processing in both people with aphasia and healthy individuals.

Method: Sixteen native English speakers were recruited to participate in a mock MRI while performing two language tasks. Eight of the participants had stroke-induced aphasia while the other eight participants were healthy individuals acting as control participants. The first language task consisted of picture-word matching using a list of high frequency nouns. 120 picture-word pairs were presented across each of the various noise conditions: silent, sparse noise, and continuous noise. The second language task consisted of determining if the presented word was a word or nonword. 60 words and 60 nonwords were presented during each noise condition: silent, sparse noise, and continuous noise.

Results: Results indicated that there was a difference between groups in terms of reaction time and accuracy with reaction time and accuracy being slower and lower for PWA than for the control group. However, the scanner noise had no effects on either group of participants' abilities to respond to the language tasks.

Conclusions: While PWA did score lower on the language tasks than their healthy counterparts, it was determined that the scanner noise from an MRI machine, of any variety (sparse or continuous), had minimal to no effect on the ability to responds to language tasks for both PWA and healthy controls.

Relevance to the current work: This study compared two different groups of people, a healthy adult population, and an adult population with aphasia, to determine if there were differences in their ability to accurately and efficiently respond to two different language tasks. Background noises similar to those used in the current study were also present.

Desjardins, J. L., Bangert, A., & Gomez, N. (2020). What does language have to do with it? the impact of age and bilingual experience on inhibitory control in an auditory dichotic listening task. *Journal of Speech, Language, and Hearing Research*, *63*(5), 1581-1594. https://doi.org/10.1044/2020_JSLHR-19-00238

Objective: The purpose of this study was to determine the effects of bilingualism/age on the ability to ignore irrelevant information while performing an auditory forced-attention dichotic listening task.

Method: Sixty-one participants were recruited for this study. 31 younger adults ages 18-25, with 15 of them being English monolingual, and 16 Spanish-English bilinguals, and 30 older adults ages 47-62, with 15 of them being English monolingual, and 16 Spanish-English bilinguals. The first test administered was a nonverbal inhibition task to determine performance in the visual domain. Participants were required to watch the screen and press buttons according to where a stimulus appeared on the screen of a Dell computer. A second test was administered in which the participants listened to a CV stimulus and then selected on a computer screen which CV they had just heard. This consisted of three trial conditions: non-forced, forced-right, and forced-left.

Results: Results of this study indicate that in the response inhibition task, there was no significant difference seen across age groups, nor language(s) spoken in their ability to inhibit irrelevant visual information during the task. During the same task, no overall general processing advantage was found when comparing monolingual vs. bilingual groups either. Similar results were also found in the auditory inhibition task in that there was no there was no significant difference seen across age groups, nor language(s) spoken in their ability to inhibit irrelevant auditory information during the task.

Conclusions: There is no significant difference between monolingual and bilingual speakers, regardless of age, in the ability to inhibit irrelevant information during both visual and auditory forced attention tasks.

Relevance to the current work: This study used both an older adult and young adult population to compare the varying effects of a focused attention task on the ability to attend to a specific task. This is similar in that there are two different age groups, and that they're required to participate in a task while attempting to ignore other occurring conditions. The main task described is also very similar to the visual attention task participants in the current study complete prior to the background noise portion of the study.

Dromey, C., & Scott, S. (2016). The effects of noise on speech movements in young, middle-aged, and older adults. *Speech, Language, and Hearing*, *19*(3), 131-139. https://doi.org/10.1080/2050571X.2015.1133757

Objective: This quantitative study looked at how speech movements were affected across various age categories (young, middle-age, and older) under five different noise conditions (silence, one person reading aloud, two readers, six readers, and pink noise).

Method: Sixty participants were recruited for this study with 10 men and 10 women in each age category (20-30, 40-50, and 60-70). Each participant was hooked up to a head-mount strain gauge system which measured their lip and jaw movements while repeating the phrase, "In Panama most people prefer to travel by bus, bike, or boat," under each of the five listening conditions. Data was collected on target phrase duration, lower lip displacement and velocity, upper lip/lower lip correlation, lower lip spatiotemporal index, velocity peaks, and SPL.

Results: Results indicated that duration was significantly shorter for the 1-talker condition than for the silent condition. The data showed no significant results for differences in displacement of the lower lip in any noise conditions, nor was there a change between the upper lip/lower lip correlation across any of the noise conditions. The peak velocity for each of the noise conditions was greater than in the silence condition, and the number of velocity peaks was lower in the noise conditions than in the silence condition. Intensity increased across all of the noise conditions. Lower lip STI was significantly lower during the noise conditions than during the silent condition. Overall, there was no difference across age groups or sex for any of the data collected.

Conclusions: This study concludes that when listening to various noise conditions, speakers are only minimally influenced by these distractions. The changes measured can be attributed to the Lombard effect, considering that the speech rate was the only change attributed to the noise conditions.

Relevance to the current work: The background noise conditions in this study are incredibly similar to the background noise conditions used in the current study (silence, a single talker, dueling talkers, pink noise, and cocktail speech). Various age groups were also compared for performance, ranging from young to older adults. The task of repeating a specific sentence varies in that it is the same stimuli each time, and the data analyzed looked at effects on speech movements, rather than on the language produced.

Dromey, C., & Benson, A. (2003). Effects of concurrent motor, linguistic, or cognitive tasks on speech motor performance. *Journal of Speech, Language, and Hearing Research, 46*(5), 1234–1246. https://doi.org/10.1044/1092-4388(2003/096)

Objective: The purpose of this study was to determine the effect of distractor tasks on speech movements using one motor task that required little cognitive effort, one task that required significant cognitive effort, and one task that was linguistically challenging.

Method: Ten young adult male and 10 young adult female participants with a median age of 22.7 were selected to participate in the present study. Using a head-mounted strain gauge system, lip and jaw movements were recorded while the participants spoke under four different conditions: speech-only, speech + a motor task, speech + a linguistic task, and speech + a cognitive task. In each task, participants repeated the phrase, “Mr. Piper and Bobby would probably pick apples.”

Results: Data showed that during the motor task participants had reduced lip displacement due to the cognitive demand of the task. During the linguistic task, higher STI values were reported which indicates that speech movements were less repeatable. During the cognitive task, a shorter duration was recorder per utterance indicating that participants spoke much faster when under a high cognitive load. Data also indicated that women had an easier time dividing their attention during divided attention tasks than men.

Conclusions: Based on the results from the data, the authors concluded that linguistic and cognitive loads have a direct impact on aspects of speech such as speech movements.

Relevance to the current work: Divided attention tasks were the focus of this study, requiring participants to speak while performing a variety of motor, linguistic, and cognitive tasks. This is similar to the current study's work in that current participants are asked to speak while listening to different background noise conditions which could alter the cognitive load demanded of speakers when recalling details of a story. However, speech movements were analyzed rather than changes in language.

Dromey, C., & Shim, E. (2008). The effects of divided attention on speech motor, verbal fluency, and manual task performance. *Journal of Speech, Language, and Hearing Research, 51*(5), 1171–1182. https://doi.org/10.1044/1092-4388(2008/06-0221)

Objective: This study looked to quantify the effects of divided attention tasks on speech in young adults. Data was collected while participants performed speech motor, verbal fluency, and manual tasks.

Method: Twenty participants were selected for the study, ten men and ten women. Participants attended two sessions for the study, one to become familiarized with the tasks so as to avoid any learning effects during the data collection, and one where their speech movements were recorded while performing the tasks using a head-mounted strain gauge system. The speech motor task required participants to repeat the phrase, "Peter Piper picked a peck of pickled peppers" a total of 14 times. The verbal fluency task required participants to say as many words as possible in 60 seconds, all beginning with a designated letter. The manual motor task required participants to place metal pegs and washers into a peg board for a total of 60 seconds. These tasks were completed back in isolation and in conjunction with another for the three tasks.

Results: A decrease in lower lip movement was recorded during the concurrent conditions, indicating that there was an increase in attentional demands, taking away from the movement of the articulators. Similar data was collected for velocity, showing a reduced peak velocity when participants were performing the concurrent manual tasks. STI, or the consistency of speech movements, was recorded to be higher when participants performed the motor task with their less dominant hand. SPL also increased when comparing isolated to concurrent tasks.

Conclusions: When comparing speech only tasks to concurrent divided attention tasks, speech is affected in a way that represents changes in attentional demands. More attention is given to the task at hand as opposed to the precise movements of the articulators, resulting in decreased displacement and velocity of the articulators.

Relevance to the current work: Three different tasks were used in this study, randomized and performed in varying orders/sequences, to determine the effects of divided attention on the speech movements in a young adult population. The current study also uses randomization to determine the order of balanced stories and listening conditions to measure the effects of dual attention on language production in older and young adults. The two studies are also similar in that the tasks participants are performing require cognitive load to be used for two different stimuli simultaneously.

Glosser, G., & Deser, T. (1992). A comparison of changes in macrolinguistic and microlinguistic aspects of discourse production in normal aging. *Journal of Gerontology*, *47*(4), P266-P272. https://doi.org/10.1093/geronj/47.4.P266

Objective: This study looked at comparing how age affects the macro and microlinguistic aspects of language in adults. This was done by informally interviewing participants and analyzing their discourse.

Method: Twenty-seven participants volunteered for this study, with 14 being middle-aged (43-61), and 13 being elderly (67-88). All participants were native English speakers and had no underlying medical conditions that could affect the validity of the study. Participants were interviewed for between 10-20 minutes individually, answering prompts and questions such as describing themselves, their family, etc. The interviewer spoke for as limited a time as possible aside from further prompting.

Results: Discourses were analyzed on syntactic, lexical error, discourse cohesion, and thematic coherence measures. Absolute scores for the elderly group showed that all syntactic measures were lower than those of the middle age group. However, the MANOVA showed no statistically significant difference. The same was true for lexical errors and discourse cohesion. However, the ANOVA did reveal that the elderly group did score significantly lower on thematic coherence when compared to their middle age counterpart.

Conclusions: Analysis of the data indicated that there may be a slight reduction of syntactic complexity in spontaneous discourse for the elderly group. A deficit was also found in the thematic coherence of the spontaneous discourse for the elderly group. Consequently, older adults presented with deficits in macrolinguistics, but their microlinguistics were well preserved when compared to the middle age group of participants.

Relevance to the current work: This study looked at how language production is altered with age by comparing spontaneous conversation in two age groups, a middle age and older adult group. This is similar to the current study in its use of different age groups, as well as the analysis of language. However, the language sample in this study was fairly unstructured, allowing participants to speak about vague topics at length, while the current study uses structured stories as the language sample collected.

Harmon, T. G., Jacks, A., Haley, K. L., & Bailliard, A. (2019). Dual-task effects on story retell for participants with moderate, mild, or no aphasia: Quantitative and qualitative findings. *Journal of Speech, Language, and Hearing Research*, *62*(6), 1890-1905. https://doi.org/10.1044/2019_JSLHR-L-18-0399

Objective: The purpose driving this study was to determine the impact of a dual task on various aspects of speech (content, speed, and effort) in people with aphasia ranging from mild-moderate, as well as a control group with no aphasia. This was done using a story retell task, coupled with a concurrent dual attention task.

Method: This study was two-fold in that it has a quantitative and qualitative side. Thirty-three participants were selected for this study, 21 of which had aphasia secondary to a stroke, brain injury, or multiple sclerosis, and twelve were control participants with no history of aphasia. Prior to participating in the dual attention task, participants with aphasia underwent a test battery to gain baseline data of their language, verbal working memory, cognitive abilities, and confidence in their ability to communicate. Participants with aphasia were then split into two groups: those with moderate aphasia, and those with mild aphasia.

The participants all completed a "narrative discourse task" under two separate conditions, single and dual task. All participants listened to and retold two stories, one in the single condition and the other in the dual condition. The dual condition consisted of participants retelling the story immediately after listening to it told, while simultaneously listening to randomly played tones and pressing corresponding buttons to indicate if the tone was high or low. Participants then filled out subjective rating forms after each story retelling to indicate their perceived effort while retelling the stories.

Results: Results of this study indicated that in general, participants with moderate aphasia had the lowest accuracy and speed scores. However, participants with mild aphasia reported the greatest effort when retelling the stories in the dual task condition. More specifically, participants with moderate aphasia had the greatest dual costs for accuracy, but participants with mild aphasia had the greatest dual costs for speed. Participants with moderate aphasia also experienced dual costs in efficiency as well. Participants with mild aphasia did not have any effects to their efficiency.

In regard to the interviews/questionnaires post story retell, all but one participant's data was transcribed and analyzed by the researchers. Participants with aphasia reported feelings of frustration, irritation, nervousness, and often lost the desire to keep trying on the dual tasks. They also reported that it was difficult to concentrate on both tasks, and often had to let one slide in order to fully focus on the other. This resulted in negative perception of their own abilities to perform the tasks. The control participants, however, reported minimal impact to their ability to perform either task in the dual task condition.

When interviewed, participants with aphasia, specifically mild aphasia, reported a few strategies which they used to complete the dual task. These included, moving forward, getting it over with, slowing down, and rehearsing. People with moderate aphasia, as well as the control participants, reported no such strategies.

Conclusions: The study concludes that for people with aphasia, communicating while competing with another task is difficult and results in costs to their language/speech. Results also showed that people with aphasia view themselves negatively when they're unable to complete these tasks without incredible effort and increased mistakes. The dual task had minimal effort on the control group.

Relevance to the current work: The current work looks at how older and young adults' ability to communicate is affected by background noise when retelling stories under various listening conditions. Subjective rating forms, along with semi-structured interviews, are also used to determine the participants perceived effort. This study looked at how dual tasks affect the ability of people with aphasia and neurotypical people to communicate, as well as what their perceived effort was when completing the tasks.

Harmon, T. G., Dromey, C., Nelson, B., & Chapman, K. (2021). Effects of background noise on speech and language in young adults. *Journal of Speech, Language, and Hearing Research*, *64*(4), 1104-1116. https://doi.org/10.1044/2020_JSLHR-20-00376

Objective: Determine how a variety of background noises affects various aspects of speech and language.

Methods: Researchers examined 40 neurotypical young adults speaking in 6 different listening conditions (five background noise conditions and one silent baseline). Data analyzing speech acoustics, speech fluency, and language production were compared across all conditions. Participants were interviewed to determine which conditions were most distracting.

Results: All noise conditions resulted in some effect on the participants' ability to monologue when compared to the silent listening condition. Speech fluency showed a decrease in pausing and increased disfluencies. Speech acoustics showed increased intensity and fundamental frequency.

Conclusions: "The present study revealed that different types of background noise led to both compensatory responses and interference effects on speech and language in young adult speakers." Some changes were seen across all noise conditions, others displayed trends, i.e. "interference in language production was most prominent for noise conditions that had a high degree of linguistic interference." Background noise was determined to have the potential to negatively impact spoken language in healthy, young adults.

Relevance to the current work: This study is very similar to the current study in that the effects of background noise on speech and language were analyzed amongst neurotypical young adults. Participants also participated in an interview to discuss their personal experience.

Kemper, S., Herman, R. E., & Lian, C. H. T. (2003). The costs of doing two things at once for young and older adults: Talking while walking, finger tapping, and ignoring speech or noise. *Psychology and Aging, 18*(2), 181-192. https://doi.org/10.1037/0882-7974.18.2.181

Objective: The purpose of this study was to further evaluate the relationship between age/cognitive ability and language/linguistic ability. Data was collected while a group of older adults and a group of young adults performed various concurrent tasks.

Method: Seventy-five young adults (18-28 yoa) and 75 older adults (70-80 yoa) were selected for participation in the study based on a basic hearing screening, the results of the Short Portable Cognitive Status Questionnaire, and self-reporting of health conditions that might interfere with the study. These participants were then given a series of cognitive tests "designed to assess individual and age-group related differences in verbal ability, working memory, inhibition, and processing speed." Participants were then required to complete nine different tasks: talking alone, walking alone and while talking, complex finger tapping alone and while talking, simple finger tapping alone and while talking, talking while ignoring concurrent speech, and talking while ignoring concurrent noise. Tapping tasks were simple (taps per minute) and complex (completing four-tap sequences per minute). Ignoring speech involved ignoring concurrent speech and ignoring cafeteria noise. Language samples were collected using a series of prompts requiring the participant to discuss various people, places, things, etc. For this study, fluency, grammatical complexity, and prepositional density were assessed.

Results: On all tasks, for older adult's dual task costs for MLU were smaller than for younger adults. Overall, older adults had a higher dual task cost for WPM than the young adults. Similarly, overall, younger adults had a higher dual task cost for grammatical complexity than the older adults.

Conclusions: Older adults and young adults both make adjustments in order to maintain the content of their speech. However, how they compensate for the demanding nature of dual tasks differs in the sense that older adults slow their rate of speech, while young adults alter the context of their language.

Relevance to the current work: This study looked at how language and linguistic complexity were affected during concurrent tasks for both young and older adults, specifically while listening to background noise as one of the conditions. The age groups that were used are similar to the current study in that one was 18-28 and the other was 70-80. This study also had the participants self-report their previous medical history in order to determine eligibility.

Kemper, S., Herman, R. E., & Nartowicz, J. (2005). Different effects of dual task demands on the speech of young and older adults. *Aging, Neuropsychology, and Cognition*, *12*(4), 340-358. https://doi.org/10.1080/138255890968466

Objective: This study compares how young and older adults' language is affected when providing a language sample and concurrently performing a variety of tasks. The hypothesis is that older adults use restricted speech which is grammatically less complex than the young adult population.

Method: Twenty-six young adults and 37 older adults answered elicitation questions while simultaneously performing three different tasks. The language samples were analyzed for fluency, grammatical complexity, and content.

Results: Baseline differences in walking and talking indicated that older adults did in fact use a restricted speech style and that they were less fluent than young adults on two of four measures, specifically MLU and WPM. Older adults' speech was also less complex than young adults. Young adults experienced negative changes in percentage of utterances without fillers, and MCU and D-Level. When carrying groceries and climbing steps, older adults demonstrated negative changed in all fluency measures except percentage of grammatical sentences. Young adults demonstrated negative changes for MCU and D-Level, as well as P-Density.

Conclusions: The results confirm the hypothesis that young and older adults present with different strategies when asked to perform a dual task. Young adults demonstrate restricted speech composed of shorter and less complex utterances. Older adults demonstrated a slower walking pace, as well as a slower speaking rate. Older adults also used greater fillers when experiencing more obstacles, like walking upstairs or carrying groceries.

Relevance to the current work: This study both compared an older population of healthy adults to a younger population of healthy adults, as well as analyzed language patterns while simultaneously performing additional tasks. Tasks included walking and talking, carrying groceries and climbing steps. The cognitive demand is similar to the current study, but not exactly the same. This is considered a dual attention task, while the current study uses a focused attention task.

Kemper, S., Hoffman, L., Schmalzried, R., Herman, R., & Kieweg, D. (2011). Tracking talking: Dual task costs of planning and producing speech for young versus older adults. *Aging, Neuropsychology, & Cognition*, *18*(3), 257–279. https://doi.org/10.1080/13825585.2010.527317

Objective: The purpose of this study was to answer the following three questions: “Is speech planning costly for both young and older adults?” “Is speech production costly for both young and older adults?” and “Is speech output costly for both young and older adults?”

Method: The data for this study was collected previously, in 2008, using a group of 80 paid participants. Participants first engaged in a tacking task in which they used a computer mouse to control a pointer and track a bullseye target moving around the screen to establish a baseline speed. Participants then began the task, tracking the bullseye for one minute before being given a prompt in the center of the screen to which they were to respond orally. They then spoke about the prompt ('please describe someone you admire and someone who has influenced your life') for three minutes while still tracking the target.

Results: Results showed that when the propositional density of a sentence increased, the task error increased and the time on target decreased immediately before the utterance (speech planning). Results also indicated that while there was no significant difference in the cost on rotor tracking across age groups, there was a difference between those with better working memory capacity vs. those with less working memory capacity. In other words, the better the working memory, the more time on target. Speakers with larger vocabularies also experienced greater tracking error. During the production of the utterance, time on target decreased while tracking error increased with the content and propositional density. Thus, the more complex the utterance (grammar, vocabulary, etc.), the less attention was paid to the tracking task during production (speech production). During pauses, it was found that time on target was not affected, no matter what the prior utterance consisted of. However, during utterances, as indicated previously, the most complex they were, the greater the task errors were (is output costly). This was especially true for older adults.

Conclusions:

Question 1: Yes, speech planning is costly for both age groups. However, young adults were affected more greatly by complex speech planning than the older adults were.

Question 2: Yes, speech production is also costly for both age groups. It was found that when older adults used more complex language, speech production costs increased.

Question 3: Yes, speech output is costly, particularly for older adults, which indicates that it takes them longer to recover between utterances when the previous utterance was more complex.

Relevance to the current work: This study's main focus was determining the effects of dual attention tasks on speech, specifically speech planning, production, and output. This was done using a speech task while participants tracked a bullseye on the screen using a computer mouse. The method is what is similar to the current study. The questions studied do not necessarily match up with what the current study is looking at.

Kemper, S., Schmalzried, R., Herman, R., Leedahl, S., & Mohankumar, D. (2009). The effects of aging and dual task demands on language production. *Aging, Neuropsychology, and Cognition*, *16*(3), 241-259. https://doi.org/10.1080/13825580802438868

Objective: This qualitative study compares how young and older adults' language is affected when providing a language sample and concurrently performing a rotor task.

Method: Forty young adults and 40 older adults were trained on a digital pursuit rotor tracking task. After training was completed, participants were prompted with a question to read aloud and respond to after one revolution or one minute of rotor tracking.

Fluency, grammatical complexity, and content of the language samples collected were analyzed for both age groups.

Results: Results were collected for four main issues: “the effects of concurrent language production on tracking performance, baseline comparisons of language production, the effects of concurrent pursuit rotor tracking on language production, and individual differences in language production and dual task demands (pg 249).” Concurrent language production was equally affected for both young and older adults. Young adults used longer utterances and spoke at a faster rate than older adults, but they also used more fillers. Both young and older adults spoke with a slower rate when participating in the dual task.

Conclusions: As a whole, language production was similarly affected for both young and older adults. However, young adults used more fillers, long sentences, and complex sentences. They also shifted to restricted speech, much like what older adults used in the baseline conditions. Older adults use slower, shorter speech with less complexity. Overall, young adult’s speech is affected more greatly with the dual tasks, while older adults’ speech is moderately protected from the effects of dual task.

Relevance to the current work: This study both compared an older population of healthy adults to a younger population of healthy adults, as well as analyzed language patterns while simultaneously performing additional tasks. The additional tasks, talking while doing rotor tracking, is similar to the current study’s task in that participants will also be talking, describing stories previously listened to, and doing so while listening to background noises that demand their attention simultaneously.

Lu, Y., & Cooke, M. (2008). Speech production modifications produced by competing talkers, babble, and stationary noise. *Journal of the Acoustical Society of America*, *124*(5), 3261– 3275. https://doi.org/10.1121/1.2990705

Objective: This study looked at determining the effects of energetic masking and informational masking on noise-induced speech production.

Method:

1. Eight native British English speakers (four men and four women) were selected to each produce the same set of 50 sentences under 11 different masking conditions (single talker and speech-shaped noise at 89 dB SPL, single talker/speech-shaped noise at 82 dB SPL, single talker/speech-shaped noise at 96 dB SPL, and quiet). Speakers were presented with a sentence on a computer screen and then had approximately three seconds to produce the sentence. Acoustic properties analyzed for each utterance were as follows: sentence duration, rms energy, mean fundamental frequency, spectral center of gravity, sentence start time, number/duration of short pauses, and voiced-to-unvoiced energy ratio.

2. Tweleve native British English speakers were selected to listen to the previously recorded utterances and identify the letter and digit keywords using a simplified keyboard.

3. Tweleve native British English speakers listened to the previously recorded audio and were asked to identify keywords in utterances when the sound was presented in competing speaker noise conditions. They also listened to and identified keywords in audio recorded under quiet conditions, but added to other speech material, as well as

audio recorded in competing speech and then added to additional competing speech audio.

Results:

1. Results showed that the most significant effects of the various noise conditions were on energy and fundamental frequency. The mean sentence duration also increased by 2.4-7.6% when there was masking from 1.64s under the quiet condition. The number of short pauses also increased in the single talker condition. Furthermore, results indicated that for almost all parameters, if there was an increase in stationary noise, there was a slightly smaller increase for single talker noise.

2. Listeners were able to identify key words with a mean score of 42% in speech-shaped noise conditions. In noise-induced speech, the mean identification score was between nine-25% higher than speech-shaped noise.

3. Listeners were able to identify more keywords in audio recorded in single-competing talker conditions added to single talker conditions better than in the audio recorded in quiet conditions and added to single talker conditions.

Conclusions: Findings showed that when speech is produced in the presence of noise, increases in fundamental frequency, spectral CoG, and energy are the main effects. As the numbers of talkers increased in the masking noise, these three variables increased concurrently. Noise induced speech was also found to be more intelligible in stationary noise than in quiet conditions. Consequently, it was determined that speakers “attempt to compensate for the EM effect of the noise on their own speech.”

Relevance to the current work: This study utilized a dual attention task to determine its effects on speech production in the presence of noise. The method is similar to the current study's in that background noises/tones were utilized to require participants to split their attention two different ways during the study. This study was three parts; however, the current study consists of only one phase.

MacPherson, M. K. (2019). Cognitive load affects speech motor performance differently in older and younger adults. *Journal of Speech, Language & Hearing Research, 62*(5), 1258–1277. https://doi.org/10.1044/2018_JSLHR-S-17-0222

Objective: The purpose of this study was to analyze the effect of cognitive load coming from a speech production task on speech motor performance in healthy young and older adults.

Method: Twenty-four adult participants (12 older and 12 younger) were selected to participate in the study. All were native English speakers, passed hearing screenings, and presented with age-appropriate cognition. The experiment required participants to produce sentences that used a modified version of the Stroop paradigm in two different conditions: congruent and incongruent. The congruent condition included color words written in their corresponding color, while the incongruent condition included color words written in a different color. Participants were asked to read the sentences with the color of the text, not the color of the word. Each participant produced each sentence a minimum of eight times.

Results: For both young and older adults, lip variability was greater in the incongruent condition than the congruent, as well as during-Stroop as opposed to pre/post-Stroop. For older adults, lip variability was significantly greater in pre/post-Stroop than for young adults. For both young and older adults, in both Stroop conditions, the during-Stroop segment was significantly longer than the pre/post-Stroop segments.

However, incongruent was significantly longer for both age groups, but it was harder for the older adults than the young adults. There was no difference in accuracy between age groups in the congruent segment, but in the incongruent segment, the older adults were significantly less accurate than the young adults.

Conclusions: The effects of cognitive load on young and older adults is significant across all variables studied. However, the effects of increased cognitive load was significantly greater for older adults than for young adults, which likely stems from differences in cognitive processes due to age.

Relevance to the current work: This study analyzed how cognitive load affects speech motor performance across young and older adults. The method was similar given the age groups and the focused attention task that required participants to focus heavily on the words/colors they were reading. This cognitive load is similar to the current study in that participants are trying to do one thing while attending/not attending to something else.

Marini, A., Boewe, A., Caltagirone, C., & Carlomagno, S. (2005). Age-related differences in the production of textual descriptions. *Journal of Psycholinguistic Research*, *34*(5), 439-463. https://doi.org/10.1007/s10936-005-6203-z

Objective: This main purpose of this study was to compare how linguistic performance changes in healthy younger and healthy older adults when producing a narrative. This was done by splitting 69 participants into five age groups and having them tell a series of short stories in order to collect language samples for analysis.

Method: Sixty-nine healthy adults were selected for participation and split into five age categories: a very young group (20-25), a young adult group (25-39), a middle age group (40-59), a young elderly group (60-74), and an old elderly group (75-84). All participants were asked to produce three narratives based on pictures provided by the researchers. One image was a single picture, "Picnic," from the Western Aphasia Battery, and the other two were cartoon stories, each with six pictures ("flowerpot," and "quarrel"). Narratives were analyzed for microlinguistic and macrolinguistic features.

Results:

Microlinguistics: Results from the microlinguistic analysis showed that the old elderly group produced more paraphasias, had decreased syntactic complexity, and more pragmatic errors than the other four age groups. There was no difference in the use of nouns/verbs across the five groups.

Macrolinguistics: Results from the macrolinguistic analysis showed that the old elderly group had a poorer performance in local coherence, and global coherence than the other four age groups.

Level of Informativeness: In relation to lexical informativeness, the older elderly group performed poorer than the young and very young groups, but not the middle-aged and young elderly groups. The older elderly was also significantly different than the young and very young groups in relation to thematic informativeness. There was also an overall gradual, linear decrease across all age groups in level of lexical informativeness.

Conclusions: Linguistic performance declines with age in relation to narrative production, according to the results of this study. Syntactic complexity, paragrammatic production, errors of local coherence, lexical informativeness, and thematic informativeness all varied linearly across age groups, while semantic paraphasia's, degrees of local and global coherence varied non-linearly, and production of words, phonology, noun to verb ratio, and global coherence errors did not change at all.

Relevance to the current work: This study's method is similar to the current study's in the use of various age groups for healthy adults. This study also analyzed how language changes across age. There was no use of different background noise conditions or other focused/dual attention tasks, but the same language components will be analyzed in the current study.

Meekings, S., Evans, S., Lavan, N., Boebinger, D., Krieger-Redwood, K., Cooke, M., & Scott, S.K. (2016). Distinct neural systems recruited when speech production is modulated by different masking sounds. *The Journal of the Acoustical Society of America*, *140*(1), 8-19. https://doi.org/10.1121/1.4948587

Objective: The purpose of this study was to determine the neural response in speakers when speaking in varying masking conditions while undergoing an fMRI.

Method: Fourteen participants, six females and eight males, participated in two fMRIs which consisted of a total of 135 trials. Participants participated in four experimental tasks: reading silently, hearing nothing; reading silently, hearing sounds; reading aloud while hearing nothing; and reading aloud while hearing sounds. The various masking conditions were four-fold: continuous white noise, speech modulated noise, rotated speech, and intelligible speech. Speech samples were chosen from the BKB sentence list and read by a male and female talker. The sentences read aloud by the participants were presented on a screen in various colors to indicate whether they read aloud or in their head.

Results: Results showed that there was no effect of masking on spectral center of gravity, mean harmonic-to-noise ratio, or median pitch. Intensity was greatly affected by masking condition as it increased with the increase in energetic masking. There was also an increase in mean duration during masking conditions as opposed to quiet conditions.

fMRI results showed that speech production activated the auditory and sensorimotor cortical fields, while perception of sounds activated the dorsolateral temporal lobes. There was greater activation in the bilateral postcentral gyri in the two speaking conditions than in the listening condition. Overall, there weren't any regions of the brain that responded more to energetic masking.

Conclusions: Participants increased the RMS amplitude of their voice when speaking in the masking conditions as opposed to the quiet conditions. However, there was no increase in amplitude across the various masking conditions themselves. Talkers also change their voices overall more in white noise as opposed to any other listening condition. Findings demonstrated that masking sounds have a dominant cortical effect of information masking during speech production.

Relevance to the current work: This study analyzed the neural changes of talkers when speaking under a variety of masking conditions. There was no use of different age groups, but participants were asked to read sentences either out loud or in their heads, depending on the corresponding number, and background noises were played for both scenarios. The background noises utilized are similar to the current work in that they consist of white noise, modulated noise, rotated speech and intelligible speech.

Morrison, C., Kamal, F., Campbell, K., & Taler, V. (2020). The influence of different types of auditory change on processes associated with the switching of attention in younger and older adults. *Neurobiology of Aging*, *96*, 197-204.

https://doi.org/10.1016/j.neurobiolaging.2020.09.012

Objective: This study compared the performance of young and older adults on a visual task while being presented with six different auditory stimuli that were intended to be ignored. This was measured using EEG.

Method: Data from 32 participants, 16 younger adults (22.07) and 16 older adults (72.84), was collected while participants sat in a sound booth, observing a silent, subtitled video and were presented with various auditory stimuli that was intended to be ignored. Participants were outfitted with EEG electrode caps to monitor neuronal activity, along with an ocular electrode to monitor vertical eye movements and blinks. The six auditory stimuli generated for this study by changing a key feature/features of the original audio: either a 10 dB increase in intensity, a 20 dB increase in intensity, a 100 Hz increase in frequency, a 100 ms decrease in duration, a white noise burst, or a novel environmental sound (coughing, dog barking, piano, car driving, etc.).

Results: Results showed that the amplitude of N1 did not differ amongst the older or younger adults at either the frontal or central regions. However, the P2 at 150-190 ms for older adults was significantly larger at both the frontal and central regions than for younger adults. Older adults also had larger deviant related negativity amplitudes for the environmental/white noise deviants than any of the other four deviants. Younger adults, though, had larger DRN for frequency and duration deviants than the older adults did. Younger adults also presented with larger DRN amplitude at the central regions.

Conclusions: Older adults presented with larger DRNs for white noise/environmental noise. These results indicate a decline in functioning for the frontoparietal network responsible for establishing the priorities for the allocation of attention. They also suggest that early auditory processing of the salient, unattended stimuli was successful.

Relevance to the current work: This study looked at how background noise affects the attention of older vs. younger adults during a visual attention task. Brain activity was monitored throughout to determine the overarching effects. The method is similar in that both studies utilize a visual attention task, as well as an older and younger adult population. However, the current study is focused primarily on language production as opposed to the response from the brain when different background noises are introduced. The background noises were not entirely similar to the current study's, but some are, such as the environmental sound and white noise.

Summers, W. V., Pisoni, D. B., Bernacki, R. H., Pedlow, R. I., & Stokes, M. A. (1988). Effects of noise on speech production: Acoustic and perceptual analyses. *The Journal of the Acoustical Society of America*, *84*(3), 917-928. https://doi.org/10.1121/1.396660

Objective:

1. The purpose of this study was to research the effects of background/masking noise on the speech production of individuals.

2. This experiment looked at analyzing how background/masking noise affects the perception of sound for individuals listening.

Method: 1. Two participants were recruited for this study, both of them male, and both of them blinded to the purpose of the study. Both participants were given a list of 15 words that were part of the Air Force speech recognition vocabulary and asked to read them throughout the course of the experiment. The words were read under four different noise conditions: silent, 80 dB, 90 dB, and 100 dB of white noise.

2. Forty-one undergraduate students were asked to listen to a series of words that were recorded both in quiet and with 90 dB of masking noise playing (the recordings from the previous experiment), while listening to various levels of masking simultaneously.

3. Thirty-nine participants participated in this portion of the experiment with 10 under a -15 dB S/N condition, nine under a -10 dB condition, and 10 under a -5 dB condition.

Results:

1. Fundamental frequency, amplitude, and duration of speech increased for both participants when background noise was playing. Vowels produced under masking conditions had a flat spectrum, with most of their energy occurring in the high frequency range. First formant frequencies were affected by noise for only one of the speakers, going higher for vowels in noise, than in quiet.

2. Results indicated that words recorded/produced in the 90 dB masking condition were easier to identify than words recorded/produced in the silent condition.

3. Results indicated that speaker SC was easier to identify than speaker MD, and accuracy of identification decreased as the signal to noise ratio decreased. Utterances produced with a greater dB of masking were more accurately identified than utterances produced in silent conditions.

Conclusions: This study indicated that when talking under various masking conditions, speakers not only altered the volume at which they speak, but also the prosodic and segmental acoustic-phonetic qualities as well. Results also indicated that speakers were easier understood/recognized when speaking under some form of masking condition, as opposed to quiet conditions.

Relevance to the current work: This study looked at how masking conditions affect speech/speech intelligibility across speakers and listeners. This study was three-fold in that different groups of participants were used to listen to audio under different background noise conditions. Recordings of the participants repeating the words were made, similar to the current study. However, they were analyzed on their different speech components, rather than on language.

Wasiuk, P. A., Lavandier, M., Buss, E., Oleson, J., & Calandruccio, L. (2020). The effect of fundamental frequency contour similarity on multi-talker listening in older and younger adults. *The Journal of the Acoustical Society of America*, *148*(6), 3527-3543. https://doi.org/10.1121/10.0002661

Objective: The purpose driving this study was to analyze the utilization/importance of fundamental frequency on the ability to improve speech recognition in both younger and older adults, specifically older adults with varying degrees of sensorineural hearing loss.

Method: In this study, two separate experiments were conducted. The first included 22 older adults between the ages of 61-75, all with sensorineural hearing loss. The second included 44 young adults between the ages of 18-31, all with normal hearing. The young adult group was split into two with the first group listening to unshaped speech stimuli, and the second listening to the same spectrally shaped stimuli the older adults listened to.

The experiment required participants to listen to a series of sentences, coupled with three nine different background noise conditions. After listening to these sentences, they were told to repeat back only what the target speaker had said, ignoring all other background noise.

The various listening conditions were as follows: target speakers using flat, normal, and exaggerated tones, and background speakers using flat, normal, and exaggerated tones.

Results:

Older Adults: Results indicated that there was no significant difference in SRT for flat masker, but that for the normal and exaggerated maskers there was a significant difference. For the exaggerated maskers, older adults were able to distinguish more effectively the target speaker from the maskers. In normal speech, there was significantly less SRT than the other masking conditions.

Young Adults: Young adults displayed greater SRT when there was a greater difference in speaking style of the masker compared to the target speaker. This pattern was found across all three masking conditions. This was true regardless of spectral shaping or not.

Conclusions: Three different conclusions were reached:

Older adults are less adept to using fundamental frequency to discern between speech they're trying to understand and speech they're trying to tune out.

"Predicted differences in EM… can explain differences between groups when target/masker f0 contour depth is matched, but not when there is a mismatch between target and masker f0 contour depth. (pg. 3540)"

The pure tone threshold was a greater predictor of performance on this task for older adults than their cognitive test results.

Relevance to the current work: This study's method is similar to the current work in how it uses two different age groups (younger and older adults), and how they are asked to listen to sentences while background noise was being played simultaneously, and then asked to repeat back the sentences. This is slightly different from the current work due to the fact that the background noise is played during the initial listening of the sentences, while the current work has background noise playing during the story retell.

Wright, H. H., Capilouto, G. J., Srinivasan, C., & Fergadiotis, G. (2011). Story processing ability in cognitively healthy younger and older adults. *Journal of Speech, Language, and Hearing Research, 54*(3), 900–917. https://doi.org/10.1044/1092-4388(2010/09-0253)

Objective: This study examined the direct/indirect relationships between comprehension and production, as well as memory and attention, in young and older adults when telling stories from wordless picture books.

Method: Sixty participants were selected for this study, 30 of which were young adults (20-29), and 30 of which were older adults (70-89). Participants were screened for the following prior to participation: aided or unaided normal vision, aided or unaided hearing within functional limits, no depression, normal cognitive functioning, no history of stroke/TBI/neurogenic disorder, and English as their first language.

In the narrative task, participants looked at and told stories for two wordless picture books called, "Picnic," and "Good Dog Carl." Participants were given an example story, told by the test administrator, given a short prompt for what to do, and then given unlimited time to look at the book and then tell the story. After the story telling, participants were then asked to answer 15 multiple choice questions (without access to the books) to measure comprehension of the story they told.

Results: Scoring was done using a binary system to measure whether participants had included all relevant story structures: setting, problem/event, plans, internal response, attempts, consequences, resolutions, and endings. Scoring was also done based on responses to the comprehension questions.

Results showed that older adults produced significantly longer stories than the young adults. Young adults performed significantly better on comprehension in both stories than did the older adults. Amongst the older adults, they comprehended the story “Picnic,” when compared to “Good Dog Carl.” As a general trend, older adults with better episodic/working memory and attention abilities performed best on the comprehension tasks, as well as produced a greater proportion of story propositions.

Conclusions: Cognitive ability in older adults significantly contributed to overall success in story production and comprehension. Young adults significantly out-performed the older adults across all measures of comprehension and story production.

Relevance to the current work: This study required participants, both young and older adults, to produce stories based on wordless picture books in order to measure comprehension and production. The older adult and young adult age groups are similar to the current work due to their age ranges (20-29 and 70-89). The language measures analyzed were also similar to the current work as they compared across both groups, as well as within groups.

Wright, H. H., Koutsoftas, A. D., Capilouto, G. J., & Fergadiotis, G. (2014). Global coherence in younger and older adults: Influence of cognitive processes and discourse type.

Aging, Neuropsychology, and Cognition, *21*(2), 174-196.

https://doi.org/10.1080/13825585.2013.794894

Objective: This study measured the influence of cognitive processes on discourse global coherence in several different discourse tasks. Results were collected from both young and older adults who were deemed to be cognitively healthy.

Method: Eighty participants were selected for this study from a pool of data. The young adult group was comprised of 40 people between the ages of 20-39, while the older adult group was comprised of 40 people between the ages of 70-87. Participants were confirmed to have the following: aided or unaided normal vision, aided or unaided hearing within functional limits, no depression, normal cognitive functioning, no history of stroke/TBI/neurogenic disorder, and English as their first language. Participants attended two sessions, the first one involving a series of cognitive assessments to determine the participants current cognitive abilities to establish correlations in later data analysis. The second session involved the participants completing a series of discourse tasks. These involved the following: eventcasts (two single pictures and two six-frame, sequential picture scenes), storytelling ("Picnic" and "Good Dog Carl"), Recounts (three different personal events), and procedural (how to make a peanut butter and jelly sandwich).

Results: Discourses were analyzed using a four-point rating scale and compared to the cognitive test results from the first session conducted. Initial results indicated that recounts yielded significantly lower coherence ratings than the other four discourse types. The other discourse types had no significant differences between them. Results also showed that when comparing the older to young adults, older adults scored significantly lower on global coherence for recounts. Episodic memory and STROOP scores were determined to be positively correlated with global coherence.

Conclusions: As a whole, young adults scored better on global coherence than the older adults did. Older adults results indicate that when recounting personal events, they were more likely to stray from the overall topic.

There were no relationships found between cognitive processes and maintenance of global coherence in younger adults, and only a few relationships between the two for older adults, as stated previously.

Relevance to the current work: This study looked at how discourses changed with cognitive ability/age in both young and older adults. The method is similar given its use of storytelling. However, the stories told in this study were generated by the participants given prompts. The current study uses predesigned, balanced stories that the participants listen to and retell. The use of different age groups is similar, however.

APPENDIX B

Consent/Institutional Review Board Approval

Memorandum

To: Tyson Harmon

Department: BYU - EDUC - Communications Disorders From: Sandee Aina, MPA, HRPP Associate Director

Wayne Larsen, MAcc, IRB Administrator Bob Ridge, Ph.D., IRB Chair

Date: March 07, 2022 IRB#: X2020-101

Title: The Effects of Background Noise on the Spoken Language of People with Aphasia

Brigham Young University IRB approved the continuation of the research study referenced in the subject heading. The approval period is through 04/05/2023**.** All conditions for continued approval during the prior approval period remain in effect. These include, but are not necessarily limited to the following requirements:

1. A copy of the consent forms is found in the study management folder in iRIS. No other forms should be used. Each research subject must sign the form prior to initiation of any protocol procedures. In addition, each subject must be given a copy of the signed consent form unless the documentation of consent was waived by the IRB.
2. Any modifications to the approved protocol must be submitted, reviewed, and approved by the IRB before modifications are incorporated in the study.
3. In addition, serious adverse events must be reported to the IRB immediately, with a written report by the PI within 24 hours of the PI's becoming aware of the event. Serious adverse events are (1) death of a research participant; or (2) serious injury to a research participant.
4. All other non-serious unanticipated problems should be reported to the IRB within 2 weeks of the first awareness of the problem by the PI. Prompt reporting is important, as unanticipated problems often require some modification of study procedures, protocols, and/or informed consent processes. Such modifications require the review and approval of the IRB.

Instructions to access approved documents, submit modifications, report complaints, and adverse events can be found on the IRB website under iRIS guidance: https://orca.byu.edu/IRB/Articulate/Study_Management/story.html.

A few months before the expiration date, you will receive a prompt from iRIS to renew this protocol. There will be two reminders. Please complete the form in a timely manner to ensure that there is no lapse in the study approval. Please refer to the IRB website for more information.

Consent to be a Research Subject

Introduction

This research study is being conducted by Tyson Harmon, Ph.D., CCC-SLP and Dr. Christopher Dromey, Ph.D., CCC-SLP at Brigham Young University. The purposes of this study are to (1) determine the impact of background noise conditions on spoken language and (2) learn about the communication experiences of people recovering language after a stroke or brain injury from their own perspective. You were invited to participate in this study as a pilot or control participant.

Procedures

Your participation in this study will involve a single session lasting 1.5 to 2 hours. During the session, you will be asked to complete an attention test. You will also complete a questionnaire intended to verify that you have not experienced a stroke or other neurological damage.

During the experimental task, you will listen to a variety of short stories and retell them in background noise conditions. You will also answer questionnaire and interview questions about your experiences retelling these stories. This session will be held on BYU campus (John Taylor Building room 110).

Audio/video Recordings

During the session audio and video recordings will be obtained so that we can complete more detailed analysis after the session. Please indicate what uses of these recordings you are willing to permit, by initialing next to the uses you agree to and signing at the end. This choice is completely up to you. We will only use the recordings in the ways that you agree to. In any use of the audio/video, you will not be identified by name.

__________ Audio and video recordings can be studied by the research team for use in the research project.

__________ Short excerpts of audio and/or video recordings can be used for scientific publications, conferences, or meetings.

__________ Short excerpts of audio and/or video recordings can be used in university classes.

Risks/Discomforts

Risks associated with this study are minimal. Because some of the tasks may be difficult, you may become anxious or embarrassed. You might also become tired or frustrated. We will make every effort to be sure you are as comfortable as possible during the testing. You can take a break or discontinue your participation at any time. If the session is too long, the length and number of sessions can be changed according to your needs.

Benefits

Although there will likely be no direct benefit to you for participating in this study, your participation will provide us with information that might generally improve assessment and treatment of people with aphasia.

Confidentiality

All data collected for the purposes of this study will be kept confidential and will only be reported without personally identifiable information. Any personally identifiable information will be stored separate from research data in a locked cabinet in the researcher's office.

You will be given a number that will identify you for this study. All data obtained from you will be associated with this number instead of your personally identifiable information. Any paper forms or test protocols will be kept in locked cabinets in a locked research lab at BYU. Any electronic forms or files (e.g., audio files) will be kept on a secured, password protected server. Only those directly involved with the research will have access to these data.

Compensation

You will receive $15.00 cash after completing the session.

Participation

Participation in this research study is voluntary. You have the right to withdraw at any time or refuse to participate entirely.

Questions about the Research

If you have questions regarding this study, you may contact Tyson Harmon, Ph.D., CCC-SLP by phone at 801-422-1251 or email at tyson_harmon@byu.edu.

<u>Questions about Your Rights as Research Participants</u>

If you have questions regarding your rights as a research participant contact IRB Administrator at (801) 422-1461; A-285 ASB, Brigham Young University, Provo, UT 84602; irb@byu.edu.

Statement of Consent

I have read, understood, and received a copy of the above consent and desire of my own free will to participate in this study.

Name (Printed): Signature: Date: