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Measuring the Effects of Selective and Divided Attention Conditions on Language Production: Comparing Across Age Groups for Aphasia Assessment

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ABSTRACT

Measuring the Effects of Selective and Divided Attention Conditions
on Language Production: Comparing Across
Age Groups for Aphasia Assessment

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This study was divided into two parts. Study 1 examined the spoken language production of neurologically healthy adults (NHA) in selective and divided attention conditions during a story retell task. NHA participant groups consisted of 21 younger (26–54), 19 older (55–69), and 20 elderly (70–85) adults. Study 2 investigated how the language production of four people with aphasia (PWA) compared to their respective NHA group. All participants retold stories in a silent baseline condition, three background noise conditions (cocktail party, conversation, phone call), and one dual-task condition (tone discrimination). Language production measures (speech rate, disfluent verbalizations, language efficiency, lexical diversity, lexical-phonological errors), tone-discrimination accuracy and response time, and perceived effort and stress were compared across groups and conditions. Results of Study 1 revealed that the language of elderly adults was significantly less efficient and had more disfluent verbalizations than that of both younger and older adults, and the language of older adults was significantly less efficient and had more disfluent verbalizations than that of younger adults. The tone discrimination accuracy and response time of elderly adults was significantly lower than that of younger adults. Older and elderly adults showed greater levels of perceived stress than younger adults. Across groups, lexical diversity decreased and lexical-phonological errors and disfluent verbalizations increased during the dual-task and phone call conditions. Costs to tone discrimination accuracy, response time, perceived effort, and perceived stress were found in the dual-task condition across groups. These findings suggest that some, but not all, measures of spoken language production are impacted by aging, and that selective and divided attention interferes with spoken language production for NHA. Results of Study 2 show that the four PWA were distinguished from their respective NHA adult group for all dependent variables in at least one condition. Percent lexical-phonological errors, percent disfluent verbalizations, and speech rate were the dependent variables that distinguished PWA from NHA the most. However, the language production, tone-discrimination response, perceived effort, and perceived stress of each PWA were unique to the individual. These findings suggest that lexical-phonological errors, percent disfluent verbalizations, and speech rate may be useful measures for discerning individuals with mild aphasia from NHA speakers in a variety of conditions.

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

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

DESCRIPTION OF THESIS STRUCTURE AND CONTENT

This thesis, *Measuring the Effects of Selective and Divided Attention Conditions on Language Production: Comparing Across Age Groups for Aphasia Assessment*, is written in a hybrid format that combines traditional thesis requirements with journal publication formats. The preliminary pages of the thesis reflect requirements for submission to the university. The remainder of this thesis is formatted like a journal article, conforming to length and style requirements for submitting research reports to relevant journals. The annotated bibliography is included in Appendix A. Appendix B contains the consent form for neurologically healthy adults and Appendix C contains the consent form for people with aphasia. Appendix D provides the Post-Narrative Questionnaire and Appendix E provides the data collection protocol script that was used in this study. The stamped IRB Letter of Approval to Conduct Research is included in Appendix F.

Introduction

Aphasia is an acquired language disorder, characterized by its impact across various language modalities that can negatively affect everyday communication. Everyday communication often occurs in distracting contexts, which may be difficult for people with aphasia (PWA). Two specific examples of this include expressive communication when background noise is present (e.g., selective attention; Nelson et al., 2023) or while performing a task concurrently (e.g., divided attention; Harmon et al., 2019; Murray et al., 1998). The resource-capacity model of attention (Wickens, 1981, 2008) has been used in divided attention studies to conceptualize interactions between different types (e.g., linguistic, non-linguistic) of tasks for both neurologically healthy adults (i.e., adults who have no history of stroke, TIA, or other neurological symptoms or disease; NHA) and PWA. For NHA, research has shown that selective and divided attention interferes with language performance, and that these changes differ with aging (Kemper et al., 2003, 2005, 2009, 2010, 2011; LeCheminant, 2022). Additionally, compared with NHA, PWA have greater difficulty dividing their attention for both linguistic tasks and non-linguistic tasks (Murray, 2012; Murray et al., 1998; Villard & Kiran, 2015, 2016), as well as when presented with background noise with both linguistic and non-linguistic content (Nelson et al., 2023). This study draws upon past research to investigate (a) how selective and divided attention conditions impact spoken language for NHA across a cohesive span of age groups and (b) how the spoken language of four participants with aphasia compare with their age-matched neurologically healthy group.

The Resource-Capacity Model of Attention

The resource-capacity model of attention posits that finite cognitive resources, which are divided into distinct resource pools, influence task performance. Wickens (2008) described three pools of differential resources that are drawn upon for task performance. These may include resource pools designated for verbal/linguistic (i.e., speech and language), perceptual (e.g., auditory), and action/motor (i.e., manual motor) tasks. This division of resources allows for tasks from different pools to be completed simultaneously with more efficiency. When multiple tasks are being completed simultaneously, it is necessary to understand how resources are used by the attention system through evaluation of task demands (i.e., the quantity of resources required) and the overlap of resources required (i.e., coming from the same or different resource pools; Wickens, 2008). Each pool of differential resources has a specific capacity that can be used for tasks within that pool. Some single tasks do not require the full extent of resources and would then leave a residual capacity in their resource pool. However, other single tasks may demand more resources than the capacity of their resource pool, which would lead to an overload capacity. The resources required for a given task is the task demand. How task demands interact within different resource pools to cause residual or overload capacity is important for interpreting results from divided attention studies (Wickens, 2008). This has led to the resource-capacity model of attention to be referenced across much of the literature investigating how attentional demands impact speech and language performance (Bailey & Dromey, 2015; Harmon et al., 2019; Kemper et al., 2003, 2005, 2009, 2010, 2011; Nelson et al., 2023). Of particular interest in the present study is the interaction between resource pools, especially those for (a) speech and language and (b) auditory perception. It should be noted that speech and language could be conceptualized as separate resource pools due to the motor component required for speech production. However, for the purpose of this study, speech and language will be conceptualized as a single resource pool because the experimental task includes the production of *spoken* language, which includes both language retrieval and language production.

When multiple tasks are performed concurrently, their performance will be more efficient when the tasks require resources from separate pools than they would if they require shared resources (Wickens, 1981). For example, Bailey and Dromey (2015) found that when completing a speech task (i.e., sentence repetitions) and linguistic task (i.e., semantic decision) concurrently, participants saw greater interference to both tasks than they did when completing a speech task and manual-motor task (i.e., Purdue Pegboard Test) concurrently. From the perspective of the resource-capacity model, the speech and linguistic task were both drawing resources from the speech and language resource pool, which would exceed the capacity of this resource pool more quickly and, therefore, cause an overload capacity. The speech task and the manual-motor task, on the other hand, draw from different pools of resources, which would allow more efficient concurrent performance because the tasks did not overload either resource pool. Wickens' three pools of differential resources also impacts how resources can be allocated. This division of resources allows for multiple tasks to be efficiently completed simultaneously when the resources are drawn from separate resource pools. However, if a task in one pool left a residual capacity while another task led to capacity overload in a separate pool, the overloaded task would be unable to draw from the leftover resources because of the separation of resource pools (1981). Therefore, even if the entirety of cognitive resources has not been allocated, if all the resources from a specific pool have been used and an additional task requires resources from that pool, no resources remain for allocation.

Consistent with the resource-capacity model, task demands and resource allocation have also been used to describe different types of attention as they apply to clinical populations. These types of attention have been organized according to their demands or the suspected resources required. Focused attention, a direct response to stimuli, is understood to be the least demanding form of attention and therefore, require the fewest cognitive resources. Sustained attention involves attending to a specific stimulus for a period of time, holding onto that information and manipulating it. Selective attention is focusing on a specific stimulus in the midst of distraction, whether internal or external. Alternating attention requires a mental flexibility to switch between tasks that have differing cognitive loads. Divided attention is the most demanding form of attention, requiring behavioral responses to two or more different tasks simultaneously. It has also been argued that divided attention actually involves rapid alternation of attention, rather than a true division of resources (Sohlberg & Mateer, 2001). Understanding the cognitive resources required for different forms of attention is useful in conjunction with the resource-capacity model. Of particular importance for this study are selective and divided attention, and therefore these two forms of attention will be described in further detail in relation to how they impact people with and without aphasia.

Attention and Aphasia

PWA comprise one population in which attention has been studied within the resource-capacity model. Aphasia is an acquired language disorder that is characterized by its impact across various language modalities that can negatively affect everyday communication. In addition to the language impairment that characterizes aphasia, many PWA demonstrate difficulties with attention as indicated by multiple standardized measures. Most studies have investigated attention from a resource-capacity perspective; however, other attentional frameworks have also been addressed. In relation to the resource-capacity model, it has been found that PWA show significantly lower performance than NHA on measures related to sustained attention (Lee et al., 2020; Murray, 2012), selective attention, divided attention, and perceptions of attention deficits from caregivers (Murray, 2012). Unlike the previously mentioned studies, LaCroix and colleagues (2020) investigated relationships between attention and aphasia using a functional neuroanatomical model of attention networks, which is a division of selective attention into three subtypes: alerting, orienting, and executive control. The authors found that PWA showed significantly slower reaction times and lower accuracy on the Attention Network Test (Fan et al., 2002) than a control group (LaCroix et al., 2020). In addition to measuring attention using standardized tests, studies have investigated attentional abilities in PWA using experimental conditions (e.g., tone identification, tone counting). Results of these studies confirm that PWA show decreased accuracy and reaction time for switching attention (Kuptsova et al., 2021) and divided attention (Erickson et al., 1996) as compared to neurologically healthy adults.

Attention and Language Interactions in People With and Without Aphasia

The division of resource pools in the resource-capacity model of attention is important in understanding how selective and divided attention may affect spoken language. From a resource-capacity model of attention perspective, it is likely that both selective and divided attention tasks are more achievable when the secondary stimulus or task requires resources from a pool that is separate from the resources required for the primary stimulus or task. When tasks require resources from different pools, both primary and secondary tasks can be performed more efficiently. Because of this, in conjunction with the aims of the present study, we will review the literature within the context of language performance in conditions of (a) selective attention with stimuli that do and do not include linguistic content and (b) divided attention with nonlinguistic stimuli.

In the context of selective attention, less overlap of resources would occur when completing a language production task in background noise containing nonlinguistic content as compared to background noise containing linguistic content (LeCheminant, 2022; Nelson et al., 2023), which could lead to the language production task feeling easier in the background noise condition that contains nonlinguistic content. Indeed, this has been found for both NHA and PWA. In selective attention conditions with nonlinguistic background noise (e.g., cocktail party noise, pink noise) changes in language performance (e.g., narrative retell, lexical decision) often do not differ significantly from the baseline (i.e., silent) condition (Davis et al., 2007; LeCheminant, 2022; Nelson et al., 2023; Villard & Kidd, 2019). In contrast, when completing language tasks in background noise containing linguistic content, there are significant decreases in both receptive and expressive language performance (e.g., fluency, accuracy, efficiency, content, complexity, speech processing) in relation to the baseline (i.e., silent) condition (LeCheminant, 2022; Nelson et al., 2023; Villard & Kidd, 2019). Subjective reports from PWA also support these findings, with participants describing talking in the presence of background noise that included linguistic content as more difficult than talking in the presence of background noise that did not include linguistic content (Hegewald, 2022).

Within the resource-capacity model, it is expected that divided attention tasks will also show greater resource demands if a language production task is being completed with a secondary task that is linguistic as compared to a secondary task that is nonlinguistic. Though many divided attention studies involve secondary tasks that are nonlinguistic, including auditory tone discrimination, walking, finger tapping, pursuit rotor tasks, matching, etc. (Bailey & Dromey, 2015; Fernandes & Moscovitch, 2003; Harmon et al., 2019; Kemper et al., 2003, 2005, 2009, 2010, 2011; McNeil et al., 2005; Murray et al., 1998; Tun & Wingfield, 1994), few involve linguistic secondary tasks (see Bailey & Dromey, 2015; Fernandes & Moscovitch, 2003 for exceptions). For the purposes of this study, nonlinguistic divided attention tasks that involve auditory processing are of particular interest, as it is through the auditory mechanism that any linguistic secondary task would be processed. A common secondary task that involves auditory processing is a tone discrimination task where participants are asked to discriminate between high and low tones either by counting the number of high and low tones (Kuptsova et al., 2021) or by pressing a button when a tone is presented (Harmon et al., 2019; Murray et al., 1998). In a tone discrimination task, it has been found that both NHA and PWA show divided attention costs to their language production through decreased accuracy, efficiency, and speed (Harmon et al., 2019; Murray et al., 1998). Subjective reports obtained through both qualitative (e.g., interview) and quantitative (e.g., questionnaire) measures also indicate increased perceived effort in completing concurrent language production and tone discrimination tasks (Harmon et al., 2019).

In addition to understanding the impact of selective and divided attention on language production generally, how attentional demands affect spoken language for PWA compared to NHA has also been of interest. This has been investigated through experiments that require PWA to complete language tasks (e.g., spoken discourse production, lexical decision making) in both selective (e.g., background noise; Davis et al., 2007; Nelson et al., 2023) and divided attention (e.g., dual-task) conditions (Harmon et al., 2019). In these conditions, PWA generally show significantly more costs on their spoken language production (e.g., accuracy, efficiency, diversity, rate, cohesion) than their neurologically healthy adult counterparts (Harmon et al., 2019; Nelson et al., 2023). It has also been found that aphasia severity impacts language performance in these attentionally demanding conditions, with greater costs caused by attentionally demanding conditions in individuals with more severe aphasia. For example, in a study examining divided attention effects on story retell performance, Harmon et al. (2019) found that participants with moderate aphasia experienced greater divided attention costs for their accuracy, efficiency, and rate as compared to participants with mild aphasia. Combined with the aforementioned research indicating that people with more severe aphasia perform worse on standardized assessments of attention than those with less severe aphasia, these results indicate that both the presence and severity of language impairment may be compounded by increased attentional demands on language tasks.

Although attentional demands have general impacts on spoken language performance in NHA, aging also plays a role on these affects. Most studies, however, have compared young and older adult groups without regard to what occurs over the course of aging. Typically, it has been found that older adults show divided attention costs in their speech rate and fluency, while younger adults decrease their language content and complexity (Kemper et al., 2003, 2005, 2009, 2010, 2011). It has been suggested that these differences can be attributed to age-related differences in language production in the baseline condition (Kemper et al., 2003, 2005). Kemper et al. (2005) describe these differences as characterized by less complex and rich language produced by older adults as compared to younger adults. Because their language production is already less complex, older adults typically do not show decreased complexity and/or content until divided attention demands reach a high level of complexity (Kemper et al., 2003, 2005, 2010). Specifically, when presented with a simple divided attention condition, older adults maintained the complexity and content of their speech but sacrificed their fluency and time on task whereas young adults decreased their content and complexity (Kemper et al., 2005). When divided attention demands become more complex, however, older adults have been shown to decrease their language content and complexity (Kemper et al., 2010). Slightly different results have been found when investigating the impact of background noise (e.g., selective attention) on the language production of healthy adults across aging. LeCheminant (2022) found that older adults showed an increase of speech rate and fluency in informational background noise conditions, while young adults decreased their speech rate and fluency. This decreased speech rate and fluency for young adults is consistent with the findings by Kemper and colleagues (2003, 2005, 2009, 2010, 2011). Although research has identified differences between young and older adults when producing language while multitasking, few studies have investigated how changes occur over a cohesive span of age groups.

Two studies that have investigated divided attention effects on language performance over the course of aging are Bailey and Dromey (2015) and Tun and Wingfield (1994). Bailey and Dromey (2015) investigated how speech intensity and kinematics changed in single- vs. dual-task conditions for younger (20–28 years), middle-aged (40–50 years), and older (58–70 years) adults. Generally, they found that some divided attention costs increase gradually with age. For example, utterance duration generally was found to increase with age, with the older adults having the longest utterance duration indicating a slower rate of speech. In divided attention (i.e., dual-task) conditions, younger adults did not significantly differ in the percentage of accuracy measured in the semantic-decision and quantity-comparison tasks, while middle-aged and older adults did show a significant difference. This indicates that changes in accuracy on cognitive tasks while speaking may occur more gradually over time. Tun and Wingfield (1995) developed and used the Divided Attention Questionnaire (DAQ) to assess subjective reports of difficulty with divided attention across age groups. These groups included what they referred to as "young" (18–27 years), "young-old" (60–71 years), "old" (72–81 years), and "old-old" (82–91 years) adults. They found that the self-perceptions of divided attention ability show systematic changes as adults age, with differences between each age group indicating a subjective increase of difficulty in divided attention with aging. Further investigation of potential changes in this way could help identify when these differences become noticeable.

Attention and Language Assessment

Standardized assessments exist for measuring both attention and language functions independently. Many approaches to the assessment of both selective and divided attention have been used in the literature including questionnaires (Sohlberg & Mateer, 2001; Tun & Wingfield, 1995), experimental paradigms (Bailey & Dromey, 2015; Fernandes & Moscovitch, 2003; Kuptsova et al., 2021; Sohlberg & Mateer, 2001), and standardized tests (LaCroix et al., 2020; Lee et al., 2020; Murray, 2012; Sohlberg & Mateer, 2001). The ecological validity of attention assessment, especially standardized measures, is important to consider as some attention assessments have higher levels of ecological validity than others (Villard, 2021). One standardized attention test that was developed with ecological validity in mind is the Test of Everyday Attention (Sohlberg & Mateer, 2001). Similarly, ecologically validity is also important to consider in relation to standardized language tests. For example, Fromm et al. (2017) argued that the standardized nature of many language tests for aphasia make it difficult to understand the full impact that language functioning has on the lives of PWA. Though standardized tests exist for measuring both attention and language functions independently, they fall short of evaluating the overlapping influences of each on ecologically valid tasks. One purpose of this study is to begin to identify how language, attention, and the interactions between them can be assessed together in an ecologically valid manner.

Aims

People with aphasia have reported communication challenges when attempting to multitask and communicate in the presence of background noise. To adequately investigate the impact of these types of attentional demands on language production in aphasia, it is necessary to identify typical performance for healthy adults and then compare performance from PWA with this group. This thesis, therefore, reports on two studies. Study 1 aims to determine the effects of dual-task and select background noise conditions on story retell performance of NHA. Study 2 aims to use this sample to identify whether a few people with mild aphasia perform at an expected level when compared with their NHA peer group. The long-term goal of this research is to develop an assessment tool that measures spoken language performance of people with aphasia in ecologically valid contexts.

Study 1

Aim 1.1. Determine how selective and divided attention conditions affect the spoken language of healthy adults during a story retell task.

Hypothesis. The spoken language performance of healthy adults will decrease as condition complexity increases; with selective attention conditions (e.g., background noise) causing less interference than divided attention conditions (e.g., dual-task).

Aim 1.2. Determine how selective and divided attention conditions affect the perceived effort and perceived stress of healthy adults during a story retell task.

Hypothesis. Healthy adults will perceive more effort and stress with language production in the more attentionally complex conditions.

Aim 1.3. Determine how age affects the story retell performance of healthy adults under selective and divided attention conditions.

Hypothesis. Older adults will experience greater costs in selective and divided attention conditions than younger adults, with the prominence of the costs increasing as age increases (e.g., smallest costs being found for adults in the youngest group and the greatest costs for adults in the oldest group).

Study 2

Aim 2.1. Determine how selective and divided attention conditions affect the spoken language of four PWA during a story retell task compared with their age-matched NHA peer group.

Hypothesis. The spoken language performance of PWA will be at least 1 SD below the group mean of their respective age group, with the distinction increasing as condition complexity increases.

Aim 2.2. Determine how selective and divided attention conditions affect the perceived effort and stress of four PWA during a story retell task compared to the views of their age-matched healthy peer group.

Hypothesis. PWA will experience significantly higher levels of effort and stress than the healthy adults in their respective age group, with greater effort and stress being experienced in conditions that are more attentionally complex.

Method

Participants

Study 1

Participants included a total of 60 NHA from the following age groups: 21 younger adults (9 male, 12 female) aged 26–54 (mean 38.76, median 40), 19 older adults (10 male, 9 female) aged 56–69 (mean 61.95, median 62), and 20 elderly adults (10 male, 10 female) aged 72–84 (mean 75.65, median 74.5). Due to the greater prevalence of aphasia in older as compared to younger adults (Ellis & Urban, 2016), a larger range of ages was recruited for the younger adult group as compared to the older adult and elderly adult groups. Years of education ranged from 12 to 22 (mean 17.05, median 16) for the younger adult group, 12 to 34 (mean 17.3, median 16) for the older adult group, and 13 to 24 (mean 16.42, median 16) for the elderly adult group. A more detailed summary of demographics for each group can be found in Table 1. Participants were recruited through personal contact with research assistants, a registry of individuals who previously agreed to be contacted for research at Brigham Young University (BYU), posted fliers, and networking at events hosted at the BYU Speech and Language Clinic. The study was approved by the Institutional Review Board at BYU.

Study 2

Four PWA were recruited and compared with participants from Study 1. Demographics of each PWA can be found in Table 2. The Quick Aphasia Battery (QAB; Wilson et al., 2018), a standardized aphasia assessment, was administered at the beginning of the research procedure. The QAB was used to define the multidimensional profile of each participant's language functioning (see Table 3 for a full report of these scores). To be included in the current study, participants with aphasia had to (a) affirm an aphasia diagnosis by a qualified speech-language pathologist, (b) report interference to their daily life from their aphasia symptoms, and (c) present with evidence of some impaired language function on any part of the QAB. PWA03 and PWA04 scored in the non-aphasic range of the aphasia battery, but their data was included in the study because they met the above criteria. Data from an additional potential aphasia participant was collected but was omitted from analysis due to her not meeting all criteria.

All PWA were screened for both acquired apraxia of speech and dysarthria through the use of the motor speech subtest of the QAB (Wilson et al., 2018) and clinical observation throughout the assessment by the examiner and an experienced aphasiologist. PWA01, PWA02, and PWA03 demonstrated no evidence of motor speech impairment (i.e., apraxia of speech, dysarthria). PWA04 was classified as having mild dysarthria. Though PWA02 reported that it was more difficult to move his tongue to the right than to the left, indicating a minor dissymmetry of the tongue, he was classified as having a normal motor speech profile because there were no manifestations of speech production errors.

Data Collection Procedures

In Studies 1 and 2, all participants completed a data collection session that lasted one to one-and-a-half hours. At the beginning of each session, participants reviewed and signed a consent form. In Study 1, participants completed the Questionnaire for Verifying Stroke-Free Status (QVSFS; Jones et al., 2001) to confirm the absence of a history of stroke, transient ischemic attack, or other neurological disease. Data was only collected from participants who scored zero on the QVSFS. Three participants were recruited but did not complete the full data collection procedure. Two were disqualified because they did not score zero on the QVSFS, and one was disqualified due to not meeting the age requirement. In Study 2, PWA completed the QAB (Wilson et al., 2018) as administered by a trained research assistant. Participants in both studies then completed the Test of Everyday Attention (TEA; Robertson et al., 1994) subtests four, six, and seven, as administered by a trained research assistant. These subtests were chosen because they have been shown to measure selective and divided attention abilities, which most closely related to the tasks investigated in the present study. The TEA is a valid and reliable test that has been previously used successfully to measure attention in a large sample of PWA (Murray, 2012; Robertson et al., 1994). The QAB and the TEA were recorded using a Canon Vixia HFR21 video camcorder. After concluding the TEA, all participants completed a basic hearing threshold test for 500, 1000, 2000, and 4000 Hertz in a single wall sound booth. All participants in the younger adult group had average hearing thresholds of 20 dB HL or below in both ears. In the older adult, elderly adult, and PWA groups all participants passed with average hearing thresholds of 40 dB HL or below in both ears with the following exceptions: C03 (right 73.75 dB HL), D03 (right 70 dB HL, left 47.5 dB HL), D16 (left 50 dB HL), and PWA04 (left 72.5 dB HL). Additionally, participant D03 wore hearing aids throughout the session, which could have caused interference via the occlusion effect. See Table 3 for a full report of test scores for PWA and Table 4 for a summary of test scores for the NHA groups.

After the hearing threshold test, participants listened to pre-recorded short stories from the Story Retell Procedure (SRP; McNeil et al., 2001), which have been controlled for linguistic content and complexity. Stories were presented from a desktop iMac through Sennheiser HD 600 open-backed headphones. After listening, participants were asked to retell the story with as much detail as they remember while one of five conditions was presented. Because the iMac used to present the audio stories and stimuli did not state the decibel level of audio presentation, a conversion was made by a human listener who judged that the 19% presentation level of the cocktail party audio on the iMac was perceptually equivalent to 60 dB HL masking noise from a calibrated audiometer. The story, as well as any background stimuli, were presented at 60 dB HL through the desktop iMac with the following exceptions: C09, presented at 65 dB (21%) for all but the silent condition; D03, presented at 70 dB HL (32%) for the dual-task condition only; D13, presented at 67 dB HL (29%) for all conditions; D16, presented at 72 dB HL (35%) for all conditions; PWA04, presented at 73 dB HL (45%) for all conditions. The participants story retell response was then recorded using an AKG C-2000 boom microphone approximately 50 cm from the mouth with a Scarlett Focusrite 2i2 pre-amp via Adobe Audition Version 13.0.1 on a desktop lab computer. After participants completed each story retell, they responded to five self-rating questions on a 5-point Likert scale (see Appendix D). Prior to the first experimental condition, participants completed a practice story retell to ensure their understanding of the task as well as the calibration of all equipment.

Experimental Conditions

The following conditions were presented to each participant: (a) silent condition, (b) cocktail party noise, (c) the speech of a lively conversation recorded between multiple speakers, (d) one side of a cell-phone conversation, and (e) a tone discrimination task. The silent condition was the baseline condition, where the participant completed the story retell with no concurrent background noise or secondary task. The lively conversation was an excerpt taken from a commercially available dramatized story podcast. The one-sided phone conversation was recorded by a research assistant in the Aphasia Lab at Brigham Young University. The cocktail party noise included unintelligible multi-talker speech combined with other sounds that are commonly heard in noisy environments, such as a restaurant or bar. The tone discrimination task involved the participant listening for high (2000 Hz) and low (500 Hz) tones that were presented via MatLab R2021b (The MathWorks Inc., 2021) through the headphones and pressing a button corresponding with each (red for high, blue for low). Participants completed a one-minute practice tone-discrimination task prior to completing it with a simultaneous story-retell to ensure that they understood the instructions. Both stories and conditions were presented in a random order for each participant, with the exception of the tone-discrimination task, which was always presented last. Because it was a divided attention task, the tone-discrimination was suspected to be the most attentionally demanding condition and therefore the most likely to cause fatigue. Consequently, the tone-discrimination task was always presented last to combat effects of fatigue. During data collection sessions a specified protocol was used to ensure consistency (see Appendix E).

Orthographic Transcription and Error Coding

Following data collection, all audio files were orthographically transcribed verbatim using speech-to-text software. Trained research assistants then listened to the audio files to correct any transcription errors made by the speech-to-text software, ensuring the inclusion of all verbalizations such as false starts or fillers. These transcriptions were then segmented into C-units and analyzed by trained research assistants using the Codes for the Analysis of Human Transcripts (CHAT; MacWhinney, 2000). Research assistants referenced a detailed list of codes to document each type of error (Marini et al., 2005). All coded transcripts were checked by two master coders who had at least one year of previous CHAT coding experience to ensure accuracy for analysis across all language samples. For any disagreement between the two master coders, a third coder was consulted to resolve the discrepancy. The coded samples were then analyzed using CLAN (Computerized Language Analysis) software.

Dependent Variables

Language Measures. Language dependent variables include measures of language efficiency (i.e., percent information units), lexical production (i.e., lexical diversity [moving average type-token ratio], lexical-phonological errors), and fluency (i.e., speech rate [words per minute], percent disfluent verbalizations).

Language Efficiency. Percent information units (%IUs) was calculated to account for the proportion of accurate, intelligible, and relevant words produced. Using the story retell procedure (SRP) checklists, developed by McNeil and colleagues, %IUs was calculated by comparing the written transcripts of participants to the score sheet checklists of the SRP stories (McNeil et al., 2001). The original SRP score sheet checklists include both direct IUs (the word that was presented) as well as acceptable alternate IUs. Because alternate IUs are defined as legitimate synonyms, or acceptable semantic derivatives of the direct IU found in the story stimulus (including different tenses of verbs), it was decided that the list could be revised to account for regional and dialectal differences. Therefore, if a committee of three trained researchers achieved consensus agreement that a word produced was a legitimate synonym, it would be included as an alternate IU. This consensus was obtained by keeping record as scoring of the transcripts was completed. When coders encountered a transcript with an alternate IU they believed should be accepted, it was presented to the committee and only included as an alternate IU if consensus agreement was reached. The story retell transcripts were divided and scored by three trained raters. Inter-rater reliability was calculated for an overlap of 10 percent of samples between each rater. Ten percent of samples were also re-rated by the original rater for calculation of intra-rater reliability. All inter- and intra- reliability ratings were completed within one year of the original rating. Both inter- and intra-rater reliability were calculated using Pearson's correlation coefficient. Inter-rater reliability across the three raters was $r = .95$ or higher when rating 10 percent of files previously scored by the other two raters. Intra-rater reliability was $r = .95$ or higher when raters rescored 10 percent of previously scored files.

Lexical Production. Lexical production was measured through two dependent variables: lexical diversity and lexical-phonological errors. To measure lexical diversity, the validated measure of the Moving Average Type Token Ratio (MATTR; Fergadiotis et al., 2013) was used because it accounts for variability in text length. To do this, a window size of 69, the length of the shortest sample, was chosen to apply to all transcripts. The MATTR manual indicates that a smaller window size will reflect repetition, while a larger window size is more likely to reflect lexical diversity (Covington & McFall, 2010); because MATTR is being used as a measure of lexical diversity, the length of the shortest transcript was chosen because it is the largest window size that would apply to all transcripts in the data set. Lexical-phonological errors was calculated through the number of false starts, phonological paraphasias, neologisms, semantic paraphasias, passe-partout words (e.g., vague words or general referents), simple repetitions, and fillers being tallied and divided by the total number of verbalizations, then multiplied by 100 to generate a percentage.

Speech Fluency. Measures of speech fluency was divided into two dependent variables: speech rate and percent disfluent verbalizations. Speech rate was measured by words per minute for each sample. Words excluded from this count consisted of fillers, partial words, repetitions of words, or word revisions. The percent disfluent verbalizations was calculated from the percentage of false starts and simple repetitions (repeated sound, syllables, and words) per word.

Tone Discrimination Performance. The accuracy and response time of the tone discrimination task was also analyzed to determine the impact of the dual-task outside of language production. Accuracy was measured according to the number of accurately discriminated tones. Response time was measured according to the average number of milliseconds in which the participant responded during accurate responses only. Single-task accuracy and response time data were obtained during participants' practice trial. Because the single-task was also the practice trial, some participants required more time to successfully complete the tone discrimination task. All participants were given one minute of practice after comprehension of the task was ensured through three consecutive correct responses. The relative change in performance between single- and dual-task conditions was calculated for both accuracy and response time using a dual-task change score. This score was calculated by dividing the difference between the value of single- and dual-task performance divided by the value of single-task performance and then multiplying by 100 to express as a percentage (Harmon et al., 2019; Plummer et al., 2014). This calculation was obtained for both accuracy and response time. Because of technical difficulties, tone discrimination data for three participants (A09, C01, and C11) was omitted.

Questionnaire Responses. At the end of each story retell participants completed a questionnaire with 6 questions on a 5-point Likert scale. Their responses were analyzed to evaluate the participants' perception of effort and stress during the story retell task under each condition (Harmon et al., 2019). This questionnaire provided ratings for overall perceived stress, and perceived effort. Questionnaires for the silent condition were not obtained from participant C13 due to technical reasons.

Data Analysis

Study 1

Data from NHA was analyzed using two-way mixed effects ANOVAs. The condition factor accounted for the five conditions (silent, cocktail party noise, the speech of a lively conversation recorded between multiple speakers, one side of a cell-phone conversation, and a tone discrimination task) and the group factor accounted for the three age groups (younger adults, 26–54 years; older adults, 55–69 years; and elderly adults, 70–85 years). Participant and hearing status were included as random effect factors. Statistically significant main or interaction effects were followed with post-hoc testing using Tukey's Honest Significant Difference (HSD). Prior to conducting the ANOVAs and Tukey's HSD, data were checked for normality, homogeneity of variance, and sphericity. Lexical-phonological errors, percent disfluent verbalizations, tone discrimination accuracy, and perceived effort did not meet these assumptions and, therefore, were analyzed using non-parametric statistics. A family-wise error rate of .05 was used for all statistical tests with adjustments made for multiple comparisons.

Study 2

Data from participants with aphasia were compared to their age-matched NHA group using descriptive statistics. Specifically, each individual PWA score was compared to their respective age group using *z*-scores.

Results

Study 1

Both condition and group effects were found for language efficiency, lexical diversity, lexical-phonological errors, and percent disfluent verbalizations. There were also significant condition and group effects for tone discrimination accuracy and response time. Significant condition effects were found for questionnaire responses for both overall stress and perceived effort. See Table 5 for descriptive statistics for all groups and conditions.

Language Efficiency

A two-way mixed-effects ANOVA showed main effects of group ($F[2, 79] = 23.77$, $p < .001$, $\eta^2 = .38$) and condition ($F[4, 164] = 3.14$, $p = .016$, $\eta^2 = .07$) and no interaction effect. Post-hoc testing for group showed significantly better language efficiency for both younger ($t[79] = 6.86$, $p < .001$, $d = 1.54$) and older ($t[79] = 4.16$, $p < .001$, $d = .94$) adult groups than the elderly adult group, as well as better language efficiency for the younger than the older adult group ($t[79] = 3.01$, $p = .01$, $d = .68$). Post-hoc testing for condition indicated that across groups, language efficiency was significantly lower in the dual-task condition than in the cocktail party condition ($t[79] = 3.45$, $p = .008$, $d = .78$). Figure 1 illustrates these results.

Lexical Production

Lexical Diversity (MATTR). A two-way mixed-effects ANOVA showed main effects of condition ($F[4, 164] = 3.26$, $p = .013$, $\eta^2 = .07$) and no main effect of group or interaction effect. Post-hoc testing for condition showed that across groups, lexical diversity significantly decreased in the phone call condition compared to the cocktail party condition ($t[79] = 3.56$, $p = .006$, $d = .80$). Figure 2 illustrates these results.

Lexical-Phonological Errors. A one-way Kruskal-Wallis rank sum test showed no significant group effect ($\chi^2 = 20.18$, $p > .05$, $\varepsilon^2 = .01$). A Freidman test showed a significant condition effect across groups ($\chi^2 = 20.18$, $p < .001$, $w = 0.09$). Post-hoc testing indicated that across participant groups there were more lexical-phonological errors produced in the phone call condition compared with the silent ($p = .006$) and conversation ($p = .006$) conditions, as well as in the dual-task condition compared to the conversation condition ($p = .037$). Figure 3 illustrates these results.

Speech Fluency

Speech Rate (WPM). A two-way mixed-effects ANOVA showed no significant main effects of group or condition or interaction effects.

Percent Disfluent Verbalizations. A one-way Kruskal-Wallis rank sum test showed a significant group effect ($\chi^2 = 15.27$, $p < .001$, $\varepsilon^2 = .05$). A post-hoc Dunn test showed that both the older ($p = .002$, Cliff's delta = .28) and elderly ($p = .002$, Cliff's delta = .26) groups produced significantly more disfluencies than the younger group. A Friedman test showed a significant condition effect across groups ($\chi^2 = 16.93$, $p = .002$, $w = .07$). Post-hoc testing indicated that across participant groups there were more disfluencies produced in the phone call than the silent condition ($p = .002$). Additionally, the elderly adult group ($\chi^2 =19.08$, $p < .001$, $w = .24$)

produced significantly more disfluencies in both the phone call (p = .002) and dual-task (p = .006) conditions than the silent condition. Figure 4 illustrates these results.

Tone Discrimination Performance

Accuracy. A one-way Kruskal-Wallis rank sum test showed a significant group effect (χ^2 = 7.12, p = .028, ε^2 = .06). A post-hoc Dunn test indicated that the elderly adult group showed lower accuracy than the younger adult group (p = .023, Cliff's delta = .27). A Friedman test showed significant condition effect across groups, indicating significantly lower accuracy in the dual-task compared to the baseline single task condition (χ^2 = 9.14, p = .002, w = .07).

Response Time. A two-way mixed-effects ANOVA showed both main effects of group (F[2, 26] = 3.41, p = .048, η^2 = .21) and condition (F[1, 41] = 37.07, p < .001, η^2 = .47) and no interaction effects. Post-hoc testing for group found that the response time of the elderly group was significantly longer compared to the younger group (t[26] = 2.499, p = .049, d = .98). Post-hoc testing for condition found that across participant groups, the response time was significantly longer in the dual-task than the baseline single task condition (t[26] = 6.108, p < .001, d = 2.40). Table 6 illustrates results for both accuracy and response time.

Questionnaire Responses

Overall Stress. A two-way mixed-effects ANOVA showed main effects of group (F[2, 78] = 12.04, p < .001, η^2 = .24) and condition (F[4, 164] = 6.82, p < .001, η^2 = .14) and no interaction effects. Post-hoc testing for group found that the overall stress of the younger group was significantly lower than the older (t[78] = 3.18, p = .006, d = .72) and elderly (t[78] = 4.84, p < .001, d = 1.10) groups. Post-hoc testing for condition indicated that there were significantly higher levels of stress perceived in the dual-task condition than the silent (t[78] = 4.77, p < .001, d = .94) and cocktail party (t[78] = 4.14 p < .001, d = 1.08) conditions.

Effort. No significant group effects were found in a one-way Kruskal-Wallis rank sum test ($\chi^2 = 2.70$, $p > .05$, $\varepsilon^2 = .01$). A Friedman test showed significant condition effects across groups ($\chi^2 = 21.04$, $p < .001$, $w = .09$). Post-hoc testing for condition indicated that across participant groups, more effort was perceived in the dual-task condition than the silent condition ($p = .002$). Figure 5 illustrates the results for both effort and overall stress.

Study 2

The language production of four PWA was compared to their age-matched NHA group (see Figure 6 and Figure 7). PWA were distinguished from their respective NHA groups for all dependent variables in at least one condition. The dependent variables with the most consistent differences across PWA and the greatest magnitude of differences between PWA and the NHA groups were percent lexical-phonological errors, percent disfluent verbalizations, and speech rate. See Table 7 for a full list of *z*-scores comparing the language production of PWA to their respective NHA groups.

Language Efficiency

The language efficiency of all PWA was greater than 1 SD below their respective NHA group mean with the following exceptions: PWA01 in the cocktail party and dual-task conditions and PWA04 in the silent, cocktail party, phone call, and dual-task conditions.

Lexical Production

The lexical diversity of PWA was more than 1 SD below their respective NHA group for PWA01 in the silent, conversation, and dual-task conditions, PWA02 in the cocktail party condition, and PWA04 in the silent and cocktail party conditions. The lexical diversity of PWA03 was greater than 1 SD above the younger adult group mean for the silent condition and greater than 2 SDs above the younger adult group mean for the cocktail party and dual-task conditions. Additionally, all PWA produced greater than 3 SDs more lexical-phonological errors than their respective NHA groups.

Speech Fluency

The speech rate of all PWA was greater than 1 SD below their respective NHA groups with the following exceptions: PWA03 in the cocktail party and dual-task conditions. All PWA produced greater than 3 SDs more disfluent verbalizations than their respective NHA groups.

Tone Discrimination Performance

There were no significant differences in the accuracy of any PWA from their respective NHA groups. The reaction time of PWA01 was greater than 1 SD above the older adult group mean in the baseline condition. The reaction time of PWA03 was greater than 1 SD above the younger adult group mean in the dual-task condition. See Table 8 for a full list of z-scores comparing the tone discrimination performance of PWA to their respective NHA groups.

Questionnaire Responses

Questionnaires for the silent condition were not obtained from PWA02 due to a technical error. The overall stress perceived by PWA02 was greater than 1 SD above the younger adult group mean for the conversation and phone call conditions. The overall stress perceived by PWA03 was greater than 1 SD above the younger adult group mean for all conditions except the conversation condition, and greater than 2 SDs above the group mean for the phone call condition. The perceived effort of PWA02 was greater than 1 SD above the younger adult group mean for the conversation and dual-task conditions. The perceived effort of PWA03 was greater than 1 SD above the younger adult group mean for the cocktail party, conversation, phone call, and dual-task conditions and greater than 2 SDs above the younger adult group mean for the silent condition. The perceived effort of PWA04 was greater than 1 SD above the older adult group mean for the dual-task condition. See Table 9 for a full list of *z*-scores comparing the questionnaire responses of PWA to their respective NHA groups.

Discussion

People with aphasia (PWA) have reported that speaking in attentionally demanding conditions (e.g., background noise or while completing another task) is more difficult than speaking without these attentional demands. Additionally, empirical evidence shows that the performance of PWA on spoken language tasks during attentionally demanding conditions is lower than that of their NHA counterparts (see Harmon et al., 2019; Linnik et al., 2016; Murray, 2012; Nelson et al., 2023; etc.). However, language therapy for people with chronic aphasia often occurs in more controlled environments (e.g., therapy rooms), which does not account for these increased attentional difficulties. We completed two studies with the aims of (1) investigating what effects dual-task and select background noise conditions have on the story retell performance of neurologically healthy adults (NHA) and (2) using this sample to investigate whether a few people with mild aphasia perform at an expected level in these conditions when compared with their peer group.

Study 1

In Study 1, we investigated how selective and divided attention conditions interfered with spoken language production for NHA speakers, and if this interference was impacted by age. Using the resource-capacity model of attention as a framework (Wickens, 1981, 2008), we hypothesized that selective and divided attention conditions would impact the spoken language of NHA more when the conditions required resources from the same pool rather than separate pools, with older and elderly adult speakers experiencing more interference in the attentionally demanding conditions than younger adult speakers. The results of Study 1 differed from our hypothesis. These results indicate that some, but not all, measures of spoken language production are impacted by aging, and that selective and divided attention interferes with spoken language production for NHA, without interaction of interference between age and attentional demands.

Aging Impacts Spoken Language Production

Significant differences with large or very large effect sizes between the elderly group and one or both of the other groups suggest that aging alone commonly results in certain costs to spoken language. The most salient costs found in the present study were related to the speed at which information was portrayed (i.e., language efficiency, percent disfluent verbalizations). This is consistent with the concept of cognitive slowing, which indicates that it is normal and natural for cognitive processing to generally slow as individuals get older (Salthouse, 1996). Combined evidence from previous research and the present study suggests that cognitive slowing may be manifest in decreased response time or speech efficiency. For example, like in the present study, Bailey and Dromey (2015) found that both linguistic and cognitive task performance of middle-aged (40s) and older (60s) adults were significantly slower than those of younger adults (20s). Similarly, Kemper et al. (2003, 2005, 2009, 2010, 2011) found that older adults showed slower speech rate and lower speech fluency compared to younger adults in divided attention conditions. The similar decrease in the language efficiency of older adults as compared to younger adults without significant differences in disfluent verbalizations may indicate that cognitive slowing occurs gradually, with certain language measures are impacted before others as aging occurs.

Despite differences in speech efficiency and disfluent verbalizations, the present study found no significant group differences for speech rate or lexical diversity. The lack of group differences in speech rate was surprising, as previous studies have found that older adults have a slower speech rate than younger adults (Kemper et al., 2003, 2005, 2009, 2010, 2011). Though there were not significant differences in speech rate found in the present study, the speed at which information was transmitted did show costs through other linguistic measures (e.g., language efficiency, percent disfluent verbalizations) as previously discussed. The lack of significant differences across groups for lexical diversity may indicate that there are some areas in which aging does not negatively impact spoken language performance. Further, there is some evidence indicating that despite cognitive slowing, the mental lexicon continues to grow rather than decline with aging due to increased exposure to words (Brysbaert et al., 2016). There is, therefore, potential for older adults to see benefits to their language, as they may use a greater variety of words to tell the same story because of their more extensive lexicon. Although the language of older and elderly adults was less efficient than that of younger adults, there were some areas (e.g., speech rate, lexical diversity) in which language was not as adversely impacted by age.

In addition to measured costs in spoken language performance for elderly and older adults, there was also an increased perception of overall stress, as measured by significant differences and large or very large effect sizes, for both the elderly and older adult groups as compared to the younger adult group. The combination of these findings supports our hypothesis that spoken language in attentionally demanding situations becomes more difficult with age. However, though the older and elderly adults did experience higher levels of perceived stress, they did not indicate greater levels of effort as compared to the younger adults. It is possible that this lack of increased perceived effort may indicate a gradual change over time, which could lead these differences to be imperceptible to the speaker. Another factor that may influence the perception of effort is the experience individuals have with difficult speaking situations such as having a conversation in a busy restaurant or talking while trying to complete another task. These previous experiences would likely affect participants' perceptions of the experimental conditions. Anecdotal evidence presented in LeCheminant (2022) supports this, as most older adults described background noise conditions as easy to ignore. It is possible that older and elderly adults did not perceive greater levels of effort due to their previous experience with demanding speaking situations.

Attentional Demands Impact Spoken Language Production

The finding that the dual-task (a) led to the greatest number of significant differences in linguistic production, (b) interfered with secondary task completion, and (c) led to increased perceived stress confirms that divided attention was more attentionally demanding than selective attention conditions. The similar interference in both primary (i.e., spoken language) and secondary (i.e., tone discrimination) tasks shows bidirectional interference, indicating that each task was negatively impacted by completion of the other. This is similar to the findings of Harmon et al. (2019), who also found bidirectional interference using a similar dual-task paradigm with comparable outcomes. This bidirectional interference indicates a division of cognitive resources, likely because the concurrent tasks both required conscious effort. Using the resource-capacity model of attention, the dual-task condition was conceptualized as requiring resources from the speech and language pool (e.g., story retell) and the auditory perception pool (e.g., tone discrimination). It is likely that there is some overlap of these resource pools, as spoken language production does require the use of the auditory feedback loop, which would access the auditory perception pool. Because this was the only divided attention task used in the present study, it is possible that there are some types of dual-tasks that would be less demanding (e.g., tasks that require little to no overlap of resources, such as walking while talking) or more demanding (e.g., tasks that require majority or full overlap of resources, such as writing while talking). Another factor to consider is the manual-motor component that was required by the tone discrimination task. Though we originally conceptualized the dual-task as only accessing the two aforementioned resource pools, the tone discrimination task also included a manual component (i.e., pressing buttons), which may have led to greater interference due to drawing upon three rather than two resource pools. Confirmation of this, however, would require experimental comparison of divided attention tasks that draw upon two vs. three resource pools.

In addition to the bidirectional interference that participants experienced in the dual task condition, neurologically healthy adults across groups showed greater interruption to the flow of information (i.e., decreased lexical diversity, increased lexical-phonological errors, and increased disfluent verbalizations) during the phone call condition. These results confirm previous findings wherein the same phone call condition led to more disfluent words, lexical-phonological errors, and changes in speech rate than the silent baseline condition (LeCheminant, 2022). Within the resource-capacity model of attention, completing a spoken language task with linguistic background noise would be more difficult than with non-linguistic background noise. It was, therefore, expected that the phone call and conversation conditions would be more difficult than the cocktail party condition. We have hypothesized that the phone call condition is the most attentionally demanding of the background noise conditions presented in the present study due to the intermittent nature of the auditory-linguistic input, which may recapture the attention of participants and therefore make this type of noise more difficult to ignore as compared to the cocktail party or conversation background noise. Therefore, participants may acclimate more easily to the noise in the conversation condition than the phone call condition. Another possibility is that individuals imagined what the speaker on the other side of the phone call might be saying. Should this be the case, the phone call condition could contain divided attention components, which could influence the interpretation of these results.

Another interesting finding from the present study was that for language efficiency and lexical diversity, there were significant differences found between the cocktail and dual-task and cocktail and phone call conditions respectively, with no significant differences noted in the silent baseline condition for these dependent variables. This indicates that, contrary to our hypothesis, the cocktail condition was the least attentionally demanding condition rather than the silent condition, at least for these two dependent variables. One possible explanation for this is that cocktail noise, which can be classified as energetic noise, can provide some benefit for NHAs because it allows the speaker to focus less on their language production, which may lead to less scrutiny of language production errors. Because language efficiency and lexical diversity are highly linguistic measures, decreased scrutiny of language production may therefore increase the efficiency and diversity of a speaker's language. Future studies could further investigate this phenomenon.

Study 2

After the completion of Study 1, we tested four participants with mild aphasia to compare their spoken language performance to their age matched NHA groups. PWA experience deficits across different combinations of language domains and modalities. These deficits are often, but not always, noticeable to a listener. Standardized aphasia assessments commonly used for aphasia classification, such as the Western Aphasia Battery (WAB: Kertesz, 2006), are not sensitive to individuals with mild aphasia presentation, yet these individuals often continue to experience difficulty with spoken language (Fromm et al., 2017). This study was an attempt to identify how the spoken language profile of individuals with mild aphasia differ from NHAs as a first step toward the creation of a supplemental assessment tool. It is well known that PWA show interference to their language production, though there is variability in how this interference manifests (*Aphasia*, n.d.; Glosser et al., 1988). Moreover, a growing body of work (Harmon et al., 2019; Murray et al., 1998; Nelson et al., 2023; Rogalski et al., 2010) indicates that that the language production of PWA further declines in attentionally demanding conditions, such as a noisy environment (i.e., selective attention) or while completing a second task simultaneously (i.e., divided attention). We hypothesized that the spoken language performance of the four participants with mild aphasia would be at least 1 SD below their respective group mean, with the difference between the PWA and the NHA increasing as the attentional demands of the condition increased.

Spoken Narrative Discourse of PWA

Across conditions, four PWA showed differences in language production at least one SD below their age-matched NHA groups in language efficiency, speech rate, percent disfluent verbalizations, and percent lexical-phonological errors, which supports our first hypothesis. Though the four PWA generally showed differences in their spoken language production, there was variability for some of the dependent variables, with each PWA showing relative strengths and weaknesses in comparison to other PWA. For example, the lexical diversity of PWA03 was higher than the younger adult group, rather than lower like the other PWA. One possible explanation for this increased lexical diversity is that during the narrative retell tasks, PWA03 seemed to struggle to stay on topic and would frequently produce tangential utterances. Macrolinguistic discourse analysis could help determine whether tangential utterances were, indeed, significantly more frequent for this participant than others. A second example is the weakness in language efficiency that both PWA02 and PWA03 showed relative to other PWA tested. Specifically, for all but one condition for PWA03, the language efficiency of both PWA02 and PWA03 was greater than two SDs below the younger adult group mean. This may indicate that language efficiency is a more distinguishing factor for PWA who are younger than for PWA who are older. As previously discussed, there were significant differences in language efficiency between the younger and older adults. Therefore, it is possible that there is more room for loss for PWA in the younger adult group, which may lead language efficiency to be a more distinguishing variable for PWA who are younger. Further research with greater statistical power is necessary to determine the extent of which this is true. Should this be the case, language efficiency could be an effective variable in the diagnosis of aphasia for adults who are younger, but less effective for adults who are older. Another consideration that may impact language efficiency for PWA is their language comprehension abilities. For example, PWA01 and PWA02 both demonstrated severe deficits with sentence comprehension, as measured by the QAB (see Table 3). Though the overall language profile for all four PWA was very mild or mild, there is a possibility that the specific comprehension deficits impacted the accuracy and relevance of the story retell performance for PWA01 and PWA02.

Two measures in which all four PWA were distinguished from the NHA group were percent lexical-phonological errors and percent disfluent verbalizations. We found that regardless of condition, all four PWA produced a high number of these types of errors, while the NHA produced few to none. The literature regarding discourse in aphasia often finds some differences in speech rate between PWA and NHA (Marini et al., 2011), which is a measure that is often used in assessment of discourse in aphasia (Brisebois et al., 2022; Gordon & Clough, 2022). Though the speech rate of PWA tested in this study was greater than 1 SD below the speech rate of age-matched NHA groups across almost all conditions, this difference was not as strong at distinguishing PWA from NHA as the high density of lexical-phonological errors and disfluent verbalizations were. Similar to our measure of lexical-phonological errors, Linnik et al. (2022) used a measure of "word-level errors," which they found are common in discourse of PWA and rarely produced by NHA. They also found that structural disfluencies, such as false-starts and corrections, are excessive in the discourse of PWA as compared to NHA (Linnik et al., 2022). Therefore, lexical-phonological errors and disfluent verbalizations could both be useful measures for discerning individuals with very mild aphasia from NHA speakers.

Though it has been previously found that PWA show significantly higher levels of effort and stress as compared to neurologically healthy adults during narrative discourse (Harmon et al., 2019; Hegewald, 2022), we found that there was some variability in the difference of their perception as compared to the NHA groups. For example, across conditions PWA01 did not show differences in his perception of effort and stress compared to the older adult group, and PWA04 only expressed more effort in the dual-task condition. On the other hand, compared to the younger adult group PWA02 and PWA03 perceived higher levels of effort and stress in most of the conditions. One potential explanation for this difference in perception of effort and stress could be the participants' experience with similar language production tasks. Another, similar, explanation could be their experience with language therapy since their onset of aphasia. PWA01, for example, was receiving language therapy at the time he completed the session, while PWA02 and PWA03 were not. Because spoken language tasks are commonly used in aphasia assessment and treatment (Gordon et al., 2020; Stark, Dutta, Murray, Bryant, et al., 2021; Stark, Dutta, Murray, Fromm, et al., 2021) it is possible that PWA who were currently receiving treatment were more comfortable with these tasks than PWA who were not receiving treatment at the time data was collected. Another potential explanation for these differences in perception between PWA could be the difference in time post-aphasia onset. PWA01 and PWA04 were both less than two years post-stroke, while PWA02 and PWA03 were 22 and 9 years post-stroke respectively. It is possible that individuals further post-stroke may have more negative experiences speaking in attentionally demanding situations, which could lead them to be more nervous about their performance and therefore exert more effort and feel more stress while completing the task. A third possibility is chronological age, as PWA02 and PWA03 both fell into the younger adult group while PWA01 and PWA04 were a part of the older adult group. As found in Study 1, younger adults showed lower levels of perceived stress than older adults, which may then lead to a greater difference between PWA and the younger adults as well. Though the present study was unable to confirm specific explanations for these findings, they highlight the individuality of language production for PWA in a variety of situations.

Use of Attentionally Demanding Conditions in Discerning Aphasia

Previous research has suggested that integration of background noise into therapy for PWA may allow them to be more prepared for everyday communication environments (Nelson et al., 2023). We further hypothesized that the use of these conditions could be informative in assessment. However, because the present study had only four participants with aphasia, our ability to analyze the effect select background noise and dual-task conditions had on language production for PWA was limited. Generally, each of these four participants with aphasia demonstrated unique individual responses across conditions (see Table 7). For example, in the dual-task condition PWA02 slowed his speech rate even further in relation to the younger adult group, while the speech rate of PWA03 did not slow in relation to the younger adult group in the dual-task condition but did slow in the phone call condition. PWA04, on the other hand, slowed her speech rate more than the older adult group in the cocktail, conversation, and dual-task conditions. These individualized responses, paired with the known language profiles of each PWA (see Table 3), indicate the need for variety in outcome measures and conditions used when testing PWA. Future research with greater statistical power could confirm if there are specific selective or divided attention conditions that lead to more interference in the language production of individuals with mild aphasia. However, as highlighted by the unique responses each PWA tested in this study showed, future research focused on continuing to identify individual differences of PWA is also warranted.

Limitations and Future Directions

The sample of NHA and PWA in the present study was collected from a small geographic location and all participants were white and non-Hispanic. We recognize that the homogenous demographic of participants will impact the findings of this study. Future research should expand this sample to include participants from other racial and ethnic backgrounds, as well as other geographical areas. This could corroborate and validate the present findings, leading to useful information in the assessment of PWA who come from other racial, ethnic, or geographic backgrounds.

Three of the four PWA tested in the present study had previously participated in a study with similar procedures (i.e., Nelson et al., 2023). All three PWA participated in the present study over one year after their completion of the previous study. It is possible that there were retest effects that impacted their performance in the present study due to their previous participation. Expanding the sample of participants with aphasia would help overcome this limitation.

Two participants (PWA02 and PWA04) tested in the present study had right hemiparesis, meaning that when they pressed the buttons during the tone-discrimination task they only used their left hand. There is a possibility that this could have impacted their performance, as many other participants used both hands to complete the tone-discrimination task. However, observation of the data found that this did not seem to impact their performance in comparison to other PWA (see Table 8). Nevertheless, future studies utilizing a similar button pressing dual-task could control for this difference by instructing all participants to use their left hand only.

The changes in volume that occurred for some participants to account for their hearing loss could have impacted how the conditions influenced the participants' story retells. In future research using auditory stimuli, including hearing status as a qualifying factor for participation in the study may prevent this type of confounding factor. However, individuals with aphasia often experience some type of hearing loss, whether age related or related to their stroke. Therefore, the disqualification of these participants may not be the best solution. Rather, including hearing status as a random effect factor in analysis provided information regarding how hearing status contributes to the dependent variables measured.

Conclusions

This thesis was divided into two studies. Study 1 found that aging leads to some costs to language production, with these costs occurring gradually with age across multiple dependent variables. Across all NHA, the dual-task (i.e., divided attention) condition caused the most interference to spoken language with the phone call condition being the background noise to cause the most interference. The understanding of both condition and age effects on spoken language performance can be helpful for future research focusing on the application of these factors in the assessment of language production for disordered populations. Future research could work to expand the sample to include more racial, ethnic, and geographical diversity, as this would be the next step toward creating a normative sample for assessment purposes. Study 2 found that for four participants with mild aphasia, measures of lexical-phonological errors and disfluent verbalizations were used in higher quantities by all PWA than NHA. This indicates that lexical-phonological errors and disfluencies are particularly sensitive to identifying individuals with aphasia, and future research focusing on the clinical application of these spoken language measures would be useful to increase the diversity of measures used to assess and treat individuals with aphasia. Additionally, research investigating the individual presentation of aphasia symptoms including individualized responses of PWA to varying attentionally demanding conditions would be beneficial for the future of aphasia assessment and treatment.

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Tables

Table 1

Demographics of Neurologically Healthy Adults

Group	Biological Sex		Age			Education (years)		
	Male	Female	*M*	*SD*	Range	*M*	*SD*	Range
Younger	9	12	38.76	9.75	26–54	17.04	2.22	12–22
Older	10	9	61.95	3.12	56–69	16.42	2.93	12–34
Elderly	10	10	75.65	3.29	72–84	17.26	4.59	13–25

Note. All participants were White/Non-Hispanic

Table 2

Demographics of People with Aphasia

Participant	Biological Sex	Age	Education (years)	MPO
PWA01	Male	56	16	20
PWA02	Male	47	16	267
PWA03	Female	47	16	111
PWA04	Female	62	14	15

Note. MPO = months post aphasia onset. All participants were White/Non-Hispanic

Table 3

Test Scores of People with Aphasia

Ppt.	Hearing Status		QAB									TEA Raw Scores			
	Right (dB HL)	Left (dB HL)	WC	SC	WF	GC	SMP	Rp	Rd	O	Sev.	ST 4 Acc.	ST 4 Tim.	ST 6	ST 7
PWA01	-3.75	-8.75	10.00	3.75	6.75	8.75	7.50	8.33	9.17	7.59	M.	8	5.26	4.16	5.26
PWA02	0	6.25	10.00	2.92	8.00	9.00	10.00	8.33	10.00	7.91	M.	6	3.91	2.70	0.70
PWA03	-5	-1.25	10.00	7.92	8.75	9.50	7.50	10.00	10.00	8.97	VM [a]	10	3.75	2.69	2.15
PWA04	18.75	18.75	10.00	10.00	8.00	10.00	10.00	10.00	10.00	9.46	VM [a]	10	4.90	6.19	1.83

Note. Ppt. = Participant; QAB = Quick Aphasia Battery; TEA = Test of Everyday Attention; WC = Word Comprehension; SC = Sentence Comprehension; WF = Word Finding; GC = Grammatical Construction; SMP = Speech Motor Programming; Rp = Repetition; Rd = Reading; O = Overall; Sev. = Severity; ST = Subtest; Acc. = Accuracy; Tim. = Timing. M = Mild. VM = Very Mild. Subtest 4: Elevator Counting and Subtest 7: Dual Task Telephone Search measured sustained attention. Subtest 6: Telephone search measured visual selective attention/speed (Robertson et al., 1994).

[a] Participants in the very mild aphasia group tested in the non-aphasic range on the QAB but were included in the present study because they affirmed an aphasia diagnosis, experienced interference in their daily life from aphasia symptoms, and presented with some impaired language function on the QAB.

Table 4

Test Scores of Neurologically Healthy Adults

Group		Hearing Status		TEA Raw Scores			
		Right (dB HL)	Left (dB HL)	Subtest 4 Accuracy	Subtest 4 Timing	Subtest 6 [a]	Subtest 7 [a]
Younger	*M*	5.95	6.19	9.10	3.54	2.98	0.88
	SD	6.31	4.94	1.22	0.55	0.72	1.82
	Range	-2.5–20	-1.25–18.75	5–10	2.5–4.88	2.21–5.05	-1.5–7.76
Older	*M*	17.57	16.38	7.95	4.51	3.34	1.32
	SD	15.5	7.65	2.61	2.04	0.48	2.00
	Range	5–73.75	5–40	1–10	2–11.5	2.63–4.17	-0.5–7.65
Elderly	*M*	25.06	26.81	8	5.20	4.19	1.97
	SD	14.47	12.20	1.89	1.22	1.42	3.29
	Range	50–70	7.5–50	4–10	3.18–7.74	2.74–9.83	-2.93–15.39

Note. TEA = Test of Everyday Attention. Subtest 4: Elevator Counting and Subtest 7: Dual Task Telephone Search measured sustained attention. Subtest 6: Telephone search measured visual selective attention/speed (Robertson et al., 1994).

[a] Data were omitted for one participant in the older group due to technical problems, and one participant in the elderly group due to invalid responses.

Table 5

Descriptive Statistics of Neurologically Healthy Adults

Condition	DV	Younger			Older			Elderly		
		M	*SD*	Range	*M*	*SD*	Range	*M*	*SD*	Range
Silent	WPM	152.04	25.7	112.42–221.47	131.45	22.34	84.71–175.73	138.06	21.02	106.89–204.60
	% IUs	61.28	9.2	40.67–78.68	53.89	11.77	24.07–72.07	47.08	10.73	22.79–66.67
	MATTR	0.65	0.06	0.53–0.74	0.66	0.04	0.60–0.74	0.66	0.05	0.56–0.74
	% LP Errors	5.76	3.76	0.60–12.33	6.55	4.35	1.74–15.43	4.09	3.12	0.01–11.89
	% DFs	1.53	1.92	0.00–8.37	2.44	2.01	0.00–6.29	1.56	1.4	0.00–4.42
Cocktail party	WPM	148.93	22.49	119.55–210.07	133.16	19.85	96.25–178.60	133.78	22.75	82.69–188.19
	% IUs	58.28	8.8	43.87–81.99	57.73	10.86	36.94–73.89	50.96	11.24	20.63–72.33
	MATTR	0.67	0.05	0.56–0.75	0.67	0.04	0.59–0.72	0.69	0.05	0.62–0.77
	% LP Errors	5.5	4.18	0.00–14.81	5.55	3.74	0.95–15.57	5.36	3.59	0.75–14.77
	% DFs	1.67	2.16	0.00–7.18	2.21	2.08	0.00–8.44	2.61	2.4	0.00–8.90
Convo.	WPM	143.63	23.48	98.04–193.60	139.55	24.73	99.49–198.82	138.12	26.19	87.00–193.07
	% IUs	57.66	10.58	31.61–76.58	56.15	10	43.40–84.68	46.72	13.29	9.32–75.63
	MATTR	0.66	0.05	0.58–0.77	0.66	0.05	0.57–0.75	0.675	0.058	0.531–0.762
	% LP Errors	5.11	3.73	0.48–11.74	6.22	3.69	0.81–14.00	4.9	3.39	0.59–11.56
	% DFs	1.6	1.63	0.00–5.16	2.32	1.97	0.00–5.97	2.36	2.19	0.00–7.64
Phone call	WPM	142.93	18.93	115.29–182.82	130.13	24.49	96.78–177.59	139.19	23.95	86.61–186.41
	% IUs	59.86	7.23	47.77–77.99	53.41	8.82	40.65–75.78	47.78	9.96	28.66–64.86
	MATTR	0.64	0.04	0.58–0.71	0.63	0.05	0.52–0.73	0.66	0.05	0.53–0.75
	% LP Errors	7.4	5.15	1.44–22.36	6.61	4.08	2.23–15.96	6.13	2.81	2.84–14.02

Condition	DV	Younger			Older			Elderly		
		M	*SD*	Range	*M*	*SD*	Range	*M*	*SD*	Range
Dual-Task	% DFs	2.6	2.53	0.38–9.70	2.99	2.28	0.00–6.21	2.88	1.9	0.70–7.87
	WPM	145.27	19.62	110.36–180.52	134.75	19.92	102.94–167.23	132.29	25.59	85.44–168.24
	% IUs	56.4	10.81	44.52–84.68	50.11	12.93	25.81–71.33	42.53	10.41	22.58–61.26
	MATTR	0.67	0.04	0.61–0.74	0.63	0.04	0.56–0.71	0.68	0.04	0.62–0.75
	% LP Errors	5.55	3.9	0.00–12.67	7.94	4.94	2.17–17.91	6.1	3.36	1.05–11.58
	% DFs	1.38	1.73	0.00–7.30	3.23	2.41	0.00–7.69	3	2.12	0.00–7.08

Note. DV = Dependent Variable. WPM = Words Per Minute (excluding fillers, partial words, repetitions of words, or word revisions). % IUs = Percent Information Units; percentage of accurate, intelligible, and relevant words produced (McNeil et al., 2001). MATTR = Moving Average Type-Token Ratio; measure of lexical diversity that accounts for variability in text length (Fergadiotis et al., 2013). % LP Errors = Percent Lexical Phonological Errors; proportion of lexical and phonological errors (false starts, phonological paraphasias, neologisms, semantic paraphasias, passe-partout words [e.g., vague words or general referents], simple repetitions, and fillers) produced per verbalization. % DFs = Percent Disfluent Verbalizations; percentage of false starts and simple repetitions (repeated sounds, syllables, and words) produced per word. Silent = sustained attention. Cocktail party = selective attention. Conversation = selective attention. Phone call = selective attention. Dual-Task = divided attention.

Table 6

Z-Scores for Dependent Variables Comparing PWA to NHA

Ppt.	Group	Condition	WPM	% IUs	MATTR	% Lex-Phon Errors [a]	% Disfluencies [a]
PWA01	Older	Silent	-1.327	-1.290	-1.407	-1101.406	-1194.095
		Cocktail Party	-1.280	-0.855	-0.795	-1791.441	-1778.166
		Convo.	-1.769	-1.678	-1.770	-1514.427	-1724.460
		Phone call	-1.153	-2.012	-0.521	-1985.815	-1883.393
		Dual-Task	-1.406	-0.392	-1.807	-1252.779	-1411.536
PWA02	Younger	Silent	-2.497	-4.849	-0.120	-423.524	-155.709
		Cocktail Party	-2.545	-3.532	-1.027	-549.044	-554.958
		Convo.	-2.195	-2.384	-0.589	-480.896	-243.896
		Phone call	-2.542	-4.579	-0.543	-794.048	-632.199
		Dual-Task	-3.614	-3.249	-0.383	-869.854	-636.739
PWA03	Younger	Silent	-2.067	-4.722	1.043	-370.392	-207.878
		Cocktail Party	-0.387	-2.693	2.311	-46.542	-45.536
		Convo.	-2.224	-2.732	-0.254	-52.216	-60.239
		Phone call	-3.572	-4.591	0.774	-192.585	-78.126
		Dual-Task	-0.598	-1.828	2.091	-177.957	-115.117
PWA04	Older	Silent	-1.260	-0.520	-1.078	-733.769	-397.221
		Cocktail Party	-2.148	-0.309	-1.529	-854.838	-575.985
		Convo.	-2.689	-1.277	-0.006	-269.051	-100.331
		Phone call	-1.719	-0.704	-0.004	-1004.365	-436.993
		Dual-Task	-2.552	-0.473	-0.504	-645.818	-538.876

Note. Ppt. = Participant. WPM = Words Per minute (excluding fillers, partial words, repetitions of words, or word revisions). % IUs = Percent Information Units; percentage of accurate, intelligible, and relevant words produced (McNeil et al., 2001). MATTR = Moving Average Type-Token Ratio; measure of lexical diversity that accounts for variability in text length (Fergadiotis et al., 2013). % Lex-Phon Errors = Percent Lexical Phonological Errors; proportion of lexical and phonological errors (false starts, phonological paraphasias, neologisms, semantic paraphasias, passe-partout words [e.g., vague words or general referents], simple repetitions, and fillers) produced per verbalization. % Disfluencies = Percent Disfluent Verbalizations; percentage of false starts and simple repetitions (repeated sounds, syllables, and words) produced per word. Silent = sustained attention. Cocktail Party = selective attention. Convo = Conversation, selective attention. Phone call = selective attention. Dual-Task = divided attention. Orange = Greater than 3 SD below the group mean. Yellow = Between 2 and 3 SD below the group mean. Blue = Between 1 and 2 SD below the group mean.

[a] Multiplied by -1 so all negative numbers express costs and positive numbers express benefits.

Table 7

Tone Discrimination Data for Neurologically Healthy Adults

Group	Condition	Accuracy (%)			Response Time (ms)		
		M	*SD*	Range	*M*	*SD*	Range
Younger	Baseline	99.584	1.863	91.67–100.00	872.98	187.46	563.3–1236.5
Younger	Dual-Task	98.139	3.356	90.48–100.00	1,060.42	225.34	691.5–1670.6
Older	Baseline	98.235	5.286	80.00–100.00	987.53	198.84	631.5–1370.8
Older	Dual-Task	95.327	8.552	66.67–100.00	1,227.27	224.53	872.3–1755.6
Elderly	Baseline	97.425	6.186	75.00–100.00	1,027.55	217.86	563.3–1236.5
Elderly	Dual-Task	90.676	13.043	58.82–100.00	1,244.81	210.79	691.5–1670.6

Note: Baseline = sustained attention. Dual-Task = divided attention.

Table 8

Z-Scores for Tone Discrimination Performance Comparing PWA to NHA

Ppt.	Group	Condition	Accuracy (%)	Response Time (ms)	Accuracy *z*-scores	Response Time *z*-scores
PWA01	Older	Baseline	100.00	1353.8	0.334	1.842 [a]
		Dual-Task	100.00	1344.5	0.546	0.522
PWA02	Younger	Baseline	100.00	915.0	0.224	0.224
		Dual-Task	100.00	1100.0	0.555	0.176
PWA03	Younger	Baseline	100.00	794.3	0.224	-0.420
		Dual-Task	100.00	1393.1	0.555	1.476 [a]
PWA04	Older	Baseline	100.00	1067.7	0.334	0.403
		Dual-Task	96.46	1385.7	0.443	0.668

Note. Ppt. = Participant. Baseline = sustained attention. Dual-Task = divided attention. [a] Greater than 1 SD above the group mean.

Table 9

Z-Scores for Questionnaire Responses Comparing PWA to NHA

Ppt.	Group	Condition	Effort	Overall Stress
PWA01	Older	Silent	-0.346	0.259
		Cocktail Party	-0.229	-0.685
		Conversation	0.386	0.943
		Phone call	-0.682	-0.762
		Dual-Task	0.317	0.513
PWA02	Younger	Silent [a]	NA	NA
		Cocktail Party	0.584	0.751
		Conversation	1.642 [b]	1.726 [b]
		Phone call	-0.239	1.511 [b]
		Dual-Task	1.380 [b]	0.889
PWA03	Younger	Silent	2.130 [b]	1.342 [b]
		Cocktail Party	1.606 [b]	1.109 [b]
		Conversation	1.642 [b]	0.781
		Phone call	1.770 [b]	2.134 [c]
		Dual-Task	1.380 [b]	1.545 [b]
PWA04	Older	Silent	0.832	-0.541
		Cocktail Party	0.860	-0.360
		Conversation	0.386	-0.629
		Phone call	0.315	0
		Dual-Task	1.214 [b]	0.804

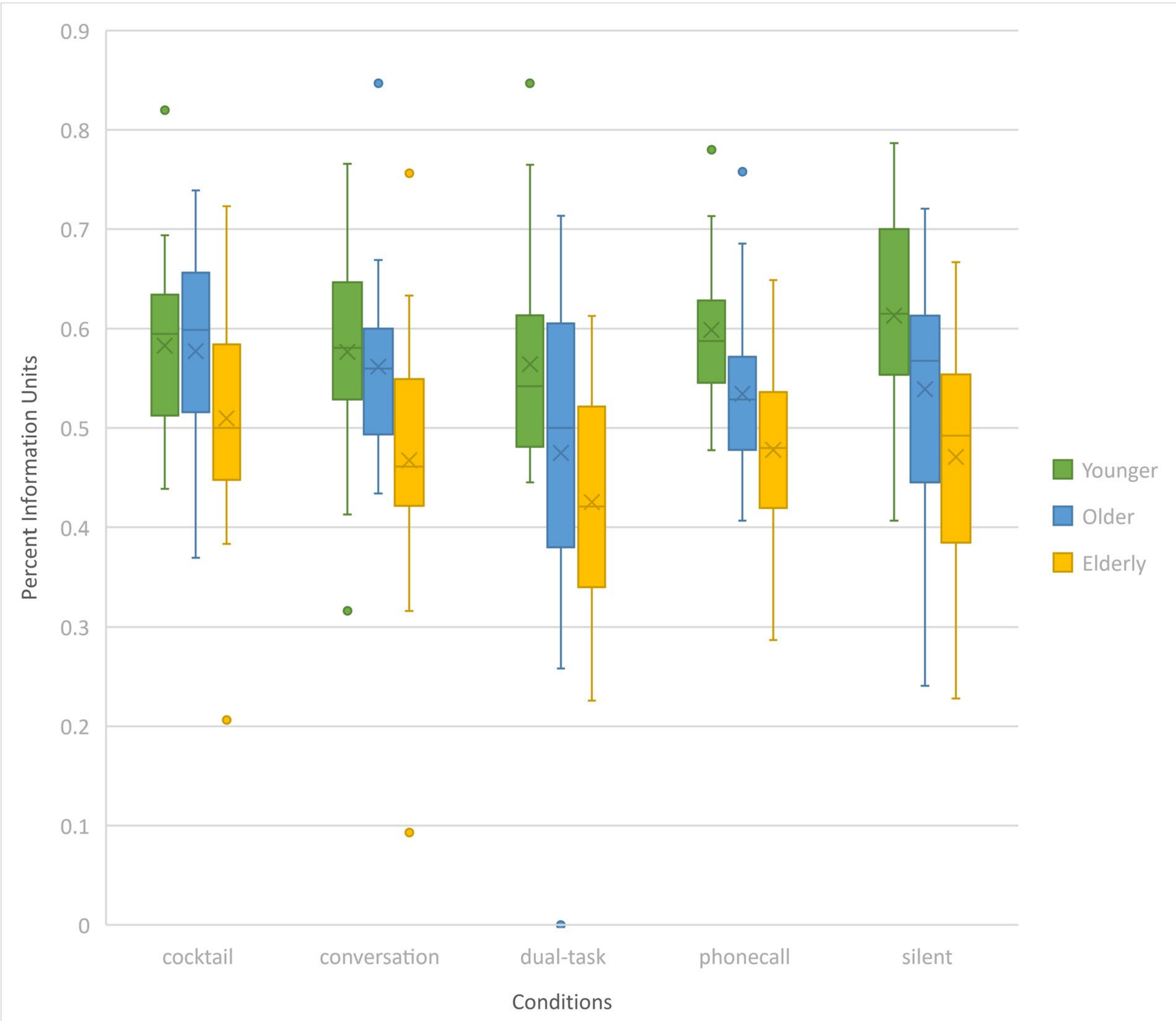
Note: Ppt. = Participant. Silent = sustained attention. Cocktail Party = selective attention. Conversation = selective attention. Phone call = selective attention. Dual-Task = divided attention. Higher numbers indicate higher levels of effort and stress.

[a] Questionnaire responses for PWA02 in the silent condition were not obtained due to technical error. [b] Greater than 1 SD above the group mean. [c] Greater than 2 SDs above the group mean.

Figures

Figure 1

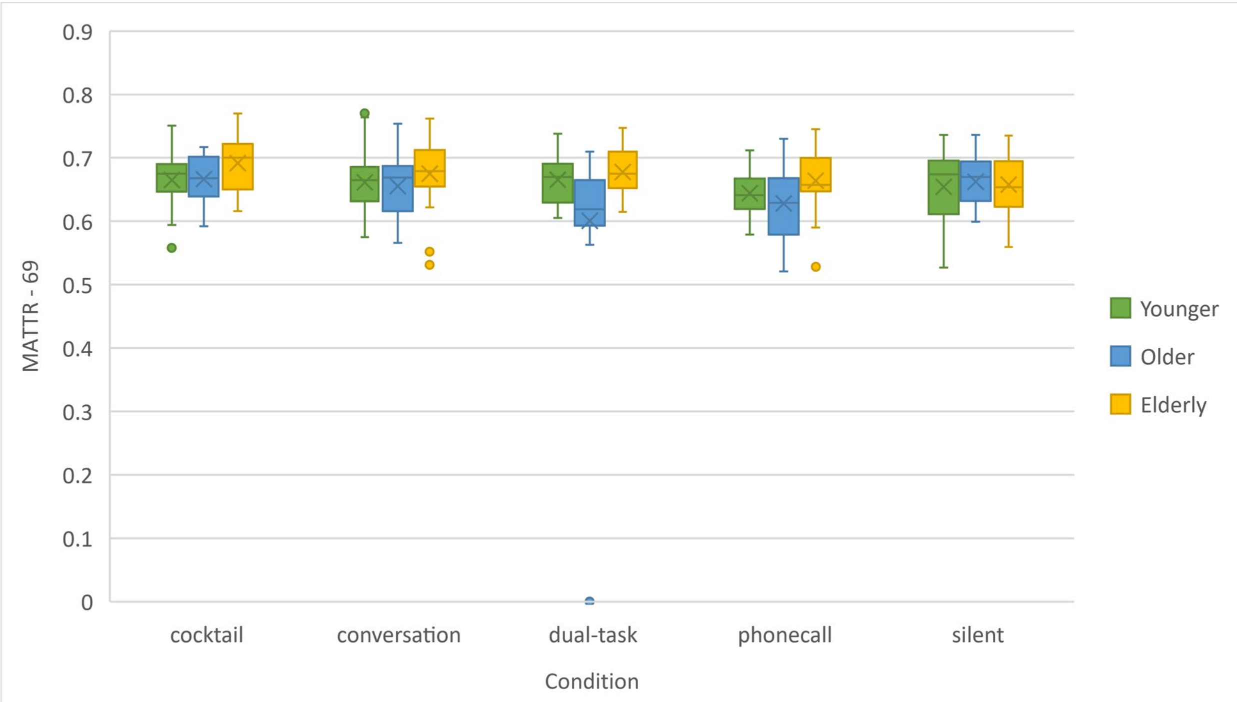
Language Efficiency (Percent Information Units)



Note. The elderly group was significantly less efficient than the younger ($p < .001$, $t = 4.772$) and older ($p = .015$, $t = 2.897$) adult groups, and the older group was significantly less efficient than the younger group ($p = .01$, $t = 3.01$). Across groups, language efficiency was significantly lower in the dual-task condition compared to the cocktail party condition ($p < .001$, $t = 4.116$).

Figure 2

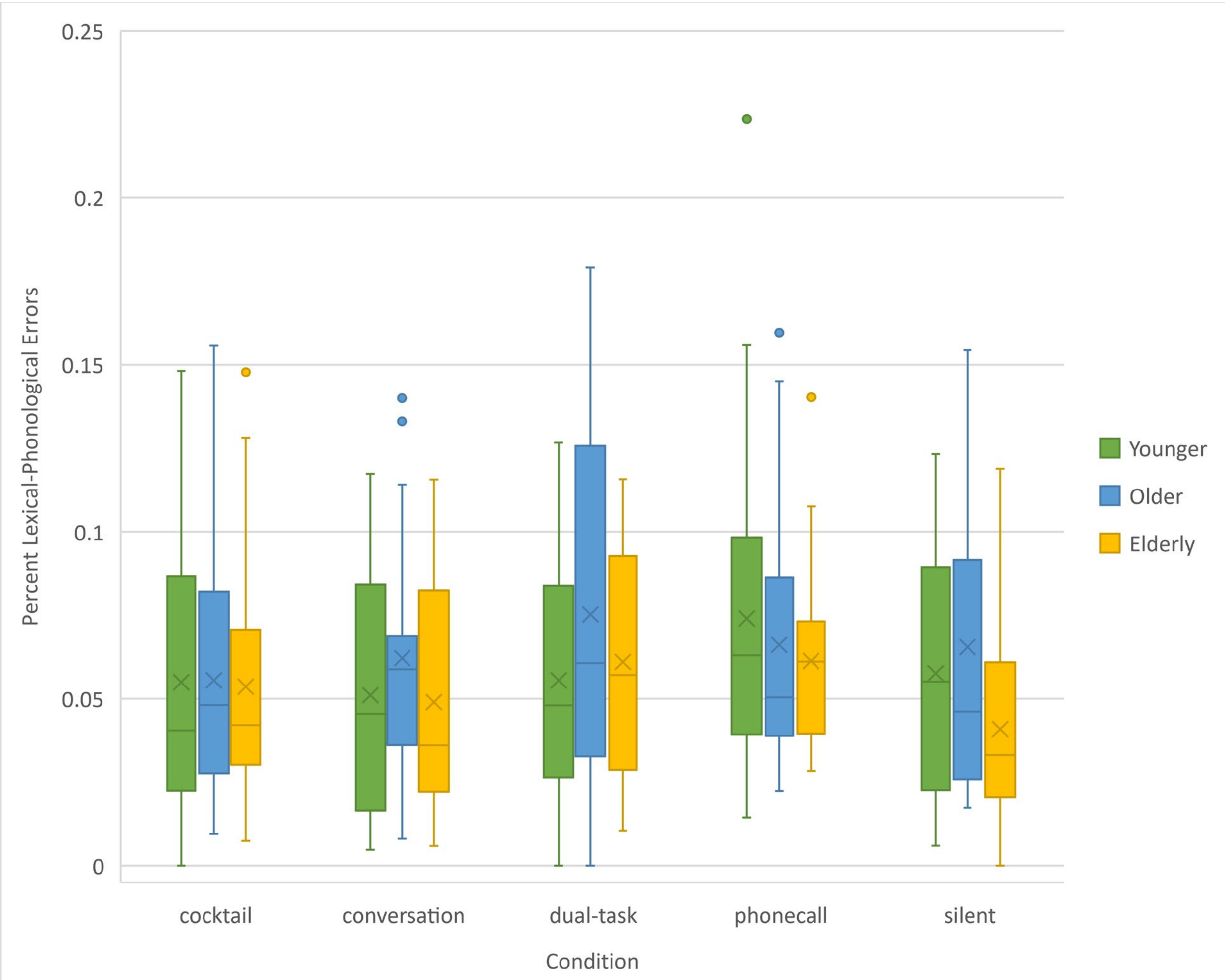
Lexical Diversity (MATTR)



Note. Across groups, lexical diversity significantly decreased in the phone call condition compared to the cocktail party condition (p =.003, t = 3.631).

Figure 3

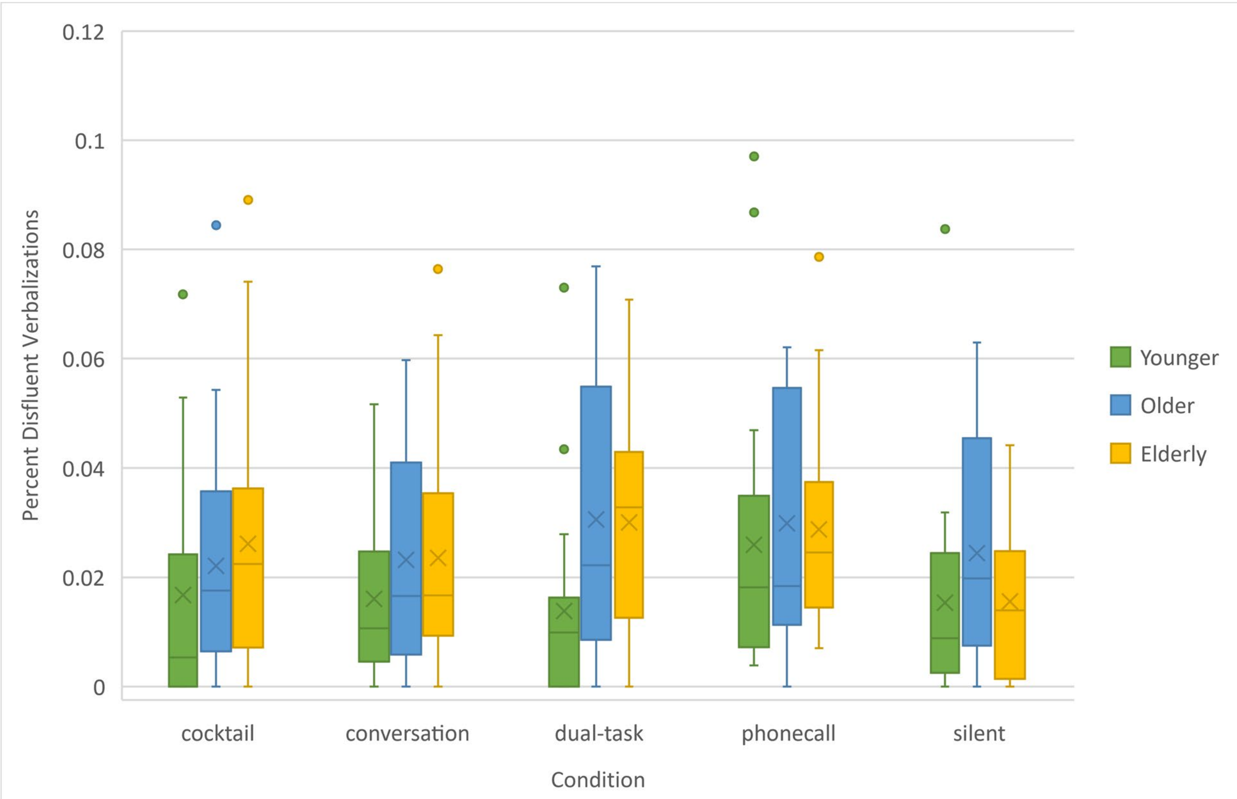
Percent Lexical-Phonological Errors



Note. Across groups, significantly more lexical-phonological errors were produced in the phone call condition than both the silent ($p < .001$) and conversation ($p = .006$) conditions, as well as in the dual-task condition compared to the conversation condition ($p = .037$).

Figure 4

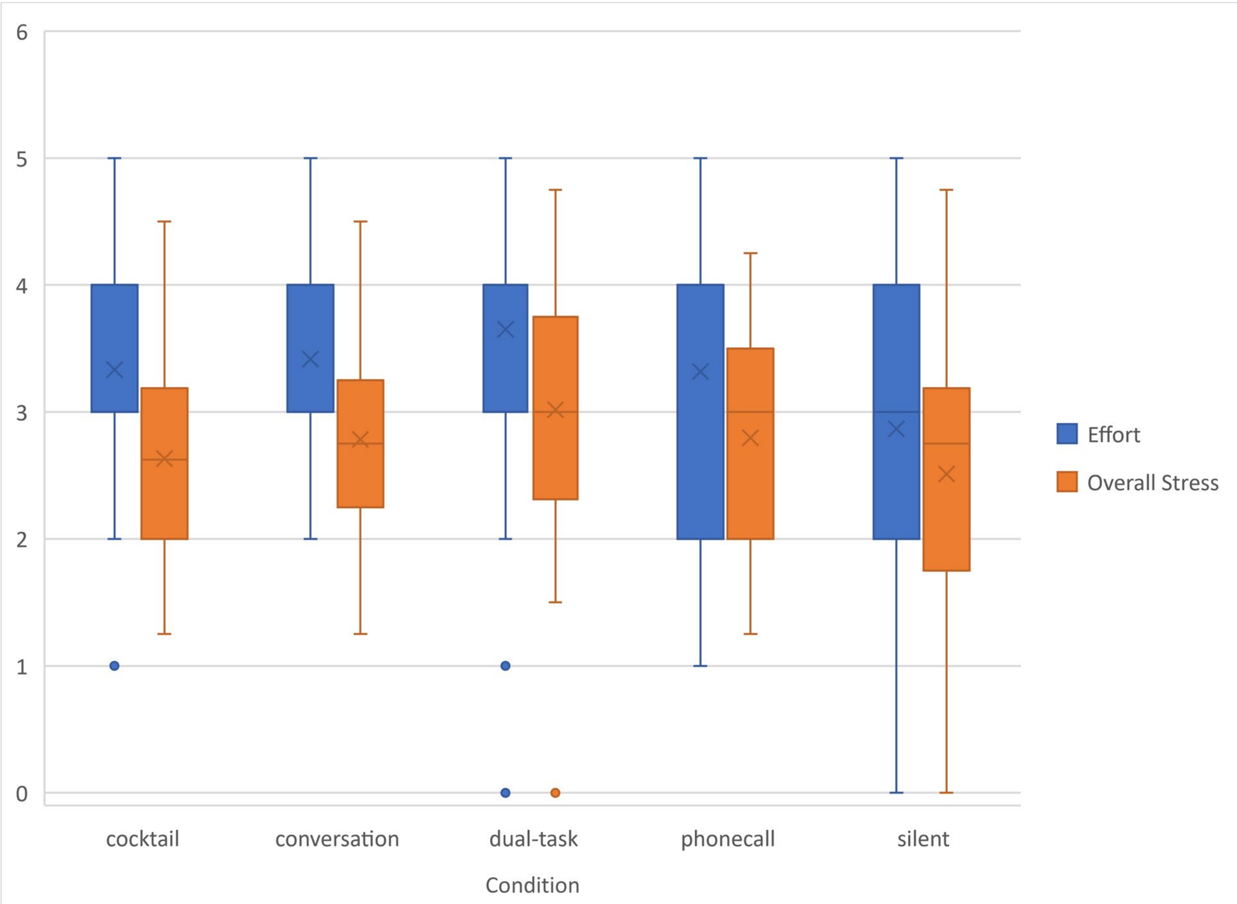
Percent Disfluent Verbalizations



Note. The older ($p = .002$) and elderly ($p = .002$) groups produced significantly more disfluent verbalizations than the younger group across all conditions. Across groups, more disfluent verbalizations were produced in the phone call condition than the silent condition ($p = .002$). The elderly group also produced significantly more disfluent verbalizations in the dual-task condition compared to the silent condition ($p = .006$).

Figure 5

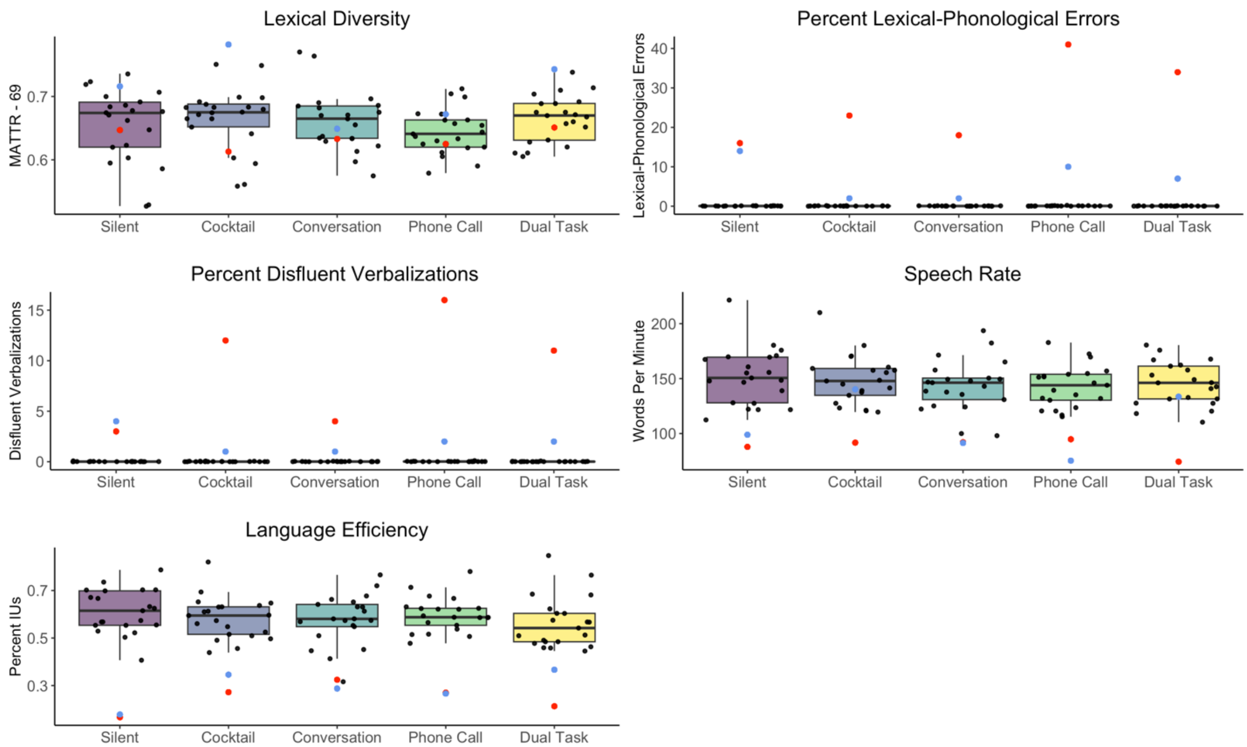
Questionnaire Responses from Neurologically Healthy Adults



Note. Questionnaire responses are on a 5-point Likert scale, with higher numbers indicating greater levels of effort/stress. The younger group showed significantly lower levels of overall stress than both the older ($p = .006$, $t = 3.18$) and elderly ($p < .001$, $t = 4.84$) groups. Across groups, significantly higher levels of overall stress were perceived in the dual-task condition compared to the silent ($p < .001$) and cocktail party ($p < .001$) conditions. Across groups, significantly higher levels of effort were perceived in the dual-task condition compared to the silent condition ($p = .002$).

Figure 6

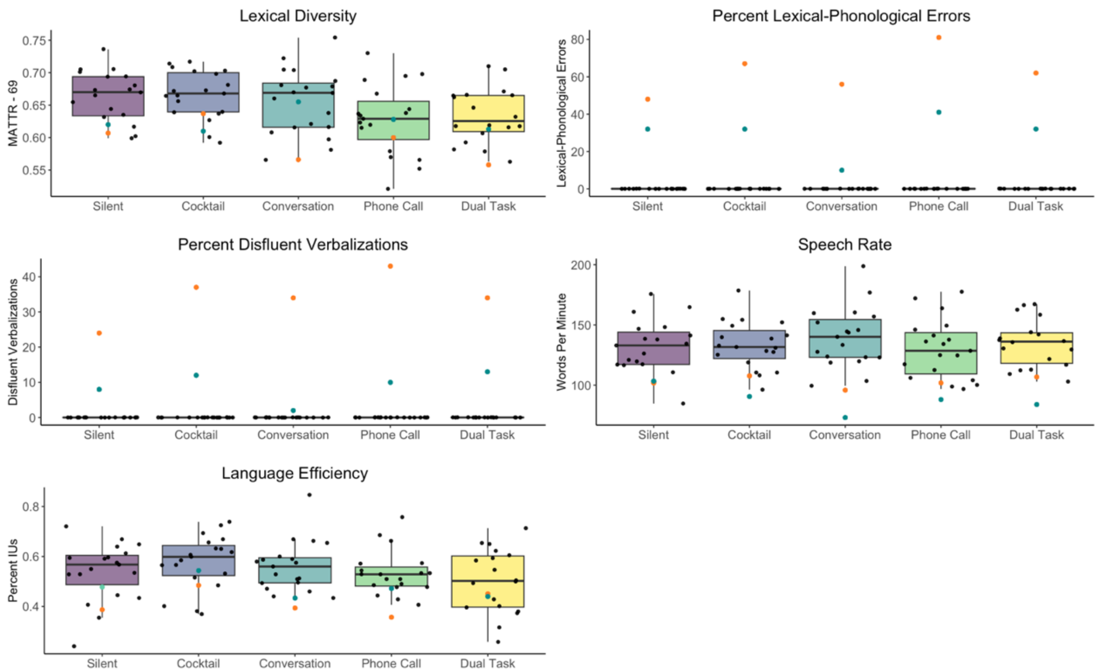
Two Participants with Aphasia Compared to Younger Adult Group



Note. Red dots = PWA02, Blue dots = PWA03, Black dots = younger NHA. The language efficiency (i.e., Percent IUs) of both PWA02 and PWA03 was greater than 1 SD below the younger adult group mean across conditions. The lexical diversity (i.e., MATTR-69) of PWA02 was greater than 1 SD below the younger adult group mean in the cocktail party condition, and the lexical diversity of PWA03 was greater than 1 SD above the group mean in the silent, cocktail party, and dual-task conditions. Both PWA02 and PWA03 produced greater than 3 SDs more lexical-phonological errors and disfluent verbalizations than the younger adult group. The speech rate of PWA02 and PWA03 was greater than 1 SD below the younger adult group with the following exceptions: PWA03 in the cocktail party and dual-task conditions.

Figure 7

Two Participants with Aphasia Compared to Older Adult Group



Note. Orange dots = PWA01, Green dots = PWA04, Black dots = older NHA. The language efficiency (i.e., Percent IUs) of PWA01 was greater than 1 SD below the older adult group mean in the silent and conversation conditions and greater than 2 SD below the older adult group mean in the phone call condition. The language efficiency of PWA04 was greater than 1 SD below the older adult group mean in the phone call condition. The lexical diversity (i.e., MATTR-69) of PWA01 was greater than 1 SD below the older adult group mean in the silent, conversation, and dual-task conditions, and the lexical diversity of PWA04 was greater than 1 SD below the group mean in the silent and cocktail party conditions. Both PWA01 and PWA04 produced significantly (i.e., greater than 3 SDs) more lexical-phonological errors and disfluent verbalizations than the older adult group. The speech rate of PWA01 and PWA04 was greater than 1 SD below the older adult group in all conditions.

APPENDIX A

Annotated Bibliography

Bailey, D. J., & Dromey, C. (2015). Bidirectional interference between speech and nonspeech tasks in younger, middle-aged, and older adults. *Journal of Speech, Language, and Hearing Research*, *58*(6), 1637–1653. https://doi.org/10.1044/2015_JSLHR-S-14-0083

Objective: This study investigated the extent that divided attention between nonspeech tasks and speech motor tasks caused bidirectional interference on the speech motor performance of individuals across a large age range (20s-60s).

Methods: 60 participants, with 10 men and 10 women in each age group: younger adults (20-28); middle-aged adults (40-50); and older adults (58-70), participated in a speech task, a linguistic task, a cognitive task, and a manual motor task in both single- and dual-task conditions. Speech kinematic and intensity data were analyzed for each of the tasks in both the single- and dual-task conditions. Nonspeech tasks were also scored and analyzed to measure bidirectional interference.

Results: The secondary tasks had significant effects on all speech measures except lower-lip velocity. However, interference between speech and the linguistic, cognitive, and manual were all specific to the task. For example, divided attention between speech and the linguistic task led to significant interference for the linguistic task as compared to when it was completed in isolation, as well as interference on the speech kinematic measures. The cognitive task showed similar interference on speech, but not the same interference on the secondary task. Utterance duration increased in both the linguistic and cognitive dual-tasks compared to speech only. Additionally, utterance duration increased with age. Younger adults showed a significant difference in total response count and number of correct responses for both semantic-decision and quantity-comparison compared to middle-aged adults, while the semantic-decision task accuracy declined between the middle-aged and older adult groups. Older adults decreased their accuracy even more when they divided attention between speech and the cognitive task.

Conclusions: The wide age range of this study provides clarity about how task type plays a role in the interaction between divided attention performance and age. Additionally, these results demonstrate interference between speech and nonspeech tasks.

Relevance to present work: This study investigated divided attention intervention on speech measures across a large age group, similar to the large age group we are using to investigate divided attention interference on language measures. Specifically, the change utterance duration between conditions and across age groups could be compared to the dependent variable of rate in the present study. The greater level of interference between the linguistic task and speech compared to the cognitive or manual-motor task and speech can also be used to support the theory we have that phone call seems to be a more difficult condition for language production than the tone discrimination task because it has a linguistic base.

Other notes*:* Navon & Gopher (lit review) regarding how differences in DT interference come from four dimensions (processing, codes of processing, perceptual modalities, and visual channels). The more that tasks overlap in each of these dimensions, the more DT interference there will be.

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), 119–126.

https://link.gale.com/apps/doc/A165578856/AONE?u=byuprovo&sid=bookmark-AONE&xid=05049853

Objective: This study investigated the extent that both continuous and sparse MRI scanning noise affected language processing for both healthy controls and PWA.

Methods: Participants completed a picture-word matching and a lexical decision task under three conditions: the silent background, sparse MRI noise background, and continuous MRI noise background. There were 8 participants with diagnosed aphasia and 8 age, gender, and education level matched control participants.

Results: For the picture-word matching task and the lexical decision task, PWA performed with a longer reaction time and lower accuracy in comparison to the control group. There were no noise condition effects for reaction time or accuracy for either condition, nor group-condition interactions for reaction time or accuracy.

Conclusions: Generally, MRI scanner noise only has a small effect on performance. However, PWA that have more severe auditory comprehension deficits may display longer reaction times in continuous MRI scanner noise, but not in sparse MRI scanner noise.

Relevance to present work: It seems that energetic noise, such as MRI scanner noise, does not have as great of an impact on linguistic tasks as other types of noise or other attentional demands. The findings regarding the difference between continuous versus sparse scanner noise could be interesting to consider in our comparisons between the intermittent background noise and dual-task with continuous background noise in the present study.

Erickson, R. J., Goldinger, S. D., & Lapointe, L. L. (1996). Auditory vigilance in aphasic individuals: Detecting nonlinguistic stimuli with full or divided attention. *Brain and Cognition, 30*(2), 244–253. https://doi.org/10.1006/brcg.1996.0016

Objective: This study investigated the nature of auditory vigilance in aphasia through assessment of the ability people with aphasia have to detect nonlinguistic auditory stimuli during focused and divided attention tasks, as opposed to linguistic stimuli that has been used in previous studies. These nonlinguistic stimuli were used to to determine if the divided attention interference found previous studies was specific to linguistic stimuli or a more specific disruption to resource allocation.

Methods: 10 participants with aphasia and 10 control participants completed a sustained auditory attention task to identify a target complex harmonic intermixed with a series of pure tones in both single- and dual-task conditions. The single-task consisted of just identifying the harmonic, while the dual-task required identifying the harmonic while also simultaneously sorting cards.

Results: Control participants had the same tone identification accuracy in the single- and dual-task conditions (mean: 60 for both conditions), while the accuracy of participants with aphasia declined significantly (single-task mean: 58.6 vs dual-task mean of 23.5). In the dual-task, control participants had a mean number of cards sorted of 124, while participants with aphasia had a mean number of cards sorted of 88.3. The performance of individual participants with aphasia was compared between the two tasks, and the changes could not be fully predicted by either aphasia quotient or months post onset.

Conclusions: These results suggest that there is an attention allocation deficit beyond the linguistic deficits experienced in aphasia.

Relevance to present work: The present study is based upon the understanding that people with aphasia have deficits in resource allocation. Through a story-retell procedure, the present study aims to investigate how these resource allocation deficits may interfere with various measures of linguistic production in the context of a story retell task.

Fernandes, M. A., & Moscovitch, M. (2003). Interference effects from divided attention during retrieval in younger and older adults. *Psychology and Aging*, *18*(2), 219–230. https://doi.org/10.1037/0882-7974.18.2.219

Objective: This study investigates how different divided attention conditions (linguistic and nonlinguistic) impact memory retrieval for younger and older adults. This study also examined how an increased number of study trials impacted retrieval for older adults.

Methods: 24 younger adults and 40 older adults participated in a free-recall of words task in three different conditions: single task, linguistic dual-task (animacy decisions about words), and nonlinguistic dual-task (odd-digit decisions about two-digit numbers). The older adult group was divided into two, with the first group hearing the word lists twice prior to recall, with the second group hearing the word lists only once. The younger adults always only heard the word list once. Participants also completed an auditory continuous reaction time task where they listened for high, medium, and low tones and identified them through pressing a key using their index, middle, and ring fingers in the same three conditions.

Results:

Memory Task Older adults recalled fewer words overall than young adults. Additionally, older adults recalled fewer words when the word list was heard once compared to when the word list was heard twice for each condition. However, the encoding changes did not change the interference patterns of the divided attention conditions. All adults also had a main effect of attentional manipulation, with no interaction between attentional manipulation and age group. There was a significant difference in the number of words recalled between the single task condition and the linguistic dual-task, but not the non-linguistic dual-task. All participants also had poorer accuracy and reaction time for the distracting tasks in divided attention with the free-recall task compared to in isolation, with there being greater interference for the linguistic task than the nonlinguistic task. There does not seem to be a correlation between accuracy rate and memory interference for each condition, meaning that there are seemingly not tradeoffs between memory and distracting tasks that can be explained by performance.

Auditory CRT Task Older adults showed lower accuracy rates than younger adults on the distracting tasks with the CRT task. Older adults also showed lower performance on the CRT task than younger adults, as well as lower reaction times. Additionally, more tones were correctly identified in the CRT task in isolation as compared with both divided attention conditions, with the linguistic task interfering more with CRT accuracy than the nonlinguistic task.

Conclusions: Though older adults had poorer recall performance than younger adults, the divided attention conditions impacted the memory of older and younger adults in a similar way. Of the two divided attention conditions, the linguistic distracting task caused a higher interference on free recall than the nonlinguistic task, which is in line with the component-process model. The results of this study suggest that free recall is relatively immune to disruption unless the memory task and the distracting task share the same representational system (e.g., both tasks are linguistic).

Relevance to present work: This article found that though general memory performance was influenced by age, divided attention interference on memory was not, meaning that young and old adults showed similar levels of interference in divided attention conditions.

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). https://doi.org/10.1044/2019_JSLHR-L-18-0399

Objective: Investigating how attentional demands impact spoken language (study 1) and the overall communication experience (study 2) for PWA.

Methods: Study 1: Groups of mild aphasia (n= 11), moderate aphasia (n=10), no aphasia (n=12) completed a story retell in a single- and dual-task condition. *Dependent variables:* self-rated perceived effort and quantitative story retell performance (measured through utterance, word, CIU, and disfluency counts), tone discrimination accuracy, and tone discrimination response times.

Study 2: Following the completion of the tasks for study 1, participants completed a semi-structured interview. Qualitative descriptive research design was used to describe and summarize the experiences of the participants. All interviews were orthographically transcribed and coded to consensus between two coders. The codes were then organized into themes (e.g., negative reactions to a dual-task, proactive management of a dual-task).

Results: Study 1: *Story retell effects* – Story retell accuracy, efficiency, and speed, as well as tone discrimination accuracy and response time, differed between groups, with the moderate aphasia group performing the lowest in all variables and the no aphasia group performing the highest. *Perceived effort* – overall, there was greater perceived effort during the DT condition. Mild aphasia participants reported significantly greater effort than the control group, but there was not a significant difference between the moderate aphasia and control groups. The moderate aphasia group had much more variability in their ratings of perceived effort, which is likely what led to the non-significant difference.

Study 2: PWA had a primarily negative comments about retelling a story with a dual-task, while control participants generally had more positive comments. The mild aphasia group was the only group that explicitly mentioned strategies that they used during the DT condition.

Conclusions*:* Communicating with competing tasks is difficult for PWA, with their performance being impacted by the severity of their language impairments. Increased effort occurred across all groups, with this increased effort correlating with negative emotional responses from the PWA. Aphasia severity seems to influence the types of errors that occur in spoken language, as well as the strategies implemented, during the DT condition.

Relevance to present work: The present work is building upon the findings presented in this study. A similar dual-task condition is employed in the present study, with the purpose of collecting data that will allow for use of such conditions in assessment and treatment of people with mild aphasia. The emotional responses from PWA are significant in the underlying purpose of the present study, as PWA experience more attentionally demanding conditions they also experience emotional reactions of greater intensity, which can impact their spoken language performance as well. Further

investigation of linguistic response in these attentionally demanding conditions that led to high emotional responses may facilitate instruction of strategies to utilize in the attentionally demanding conditions.

Hegewald, R. R. (2022). The impact of background noise on the communicative experience of people with mild to moderate aphasia: A qualitative study. https://scholarsarchive.byu.edu/etd/9584/

Objective: This study examined how communicating in noise subjectively impacted the communicative experience for people with aphasia.

Methods: 22 participants (11 with aphasia, 11 control participants) participated in a semi-structured interview following the experimental arm of this study, which is reported in the Nelson (2022) article. In the semi-structured interview participants with aphasia were asked about their experiences with speech therapy. All participants were asked their impressions regarding the experiment, including what was easy and difficult for them, what strategies they used throughout the experiment, and what day-to-day experiences the experimental conditions reminded them of. All interviews were transcribed verbatim and then coded qualitatively using codebook thematic analysis.

Results: *Cognitive Reactions* – Participants mentioned how background noise, especially informational noise, led to difficulty attending to and remembering details for the story retell task. However, PWA identified background noise as being much more interfering with their daily lives as compared to control participants. PWA additionally indicated fatigue associated with communicating in the background noise, either in the experiment or their everyday communication. Strategies used by both control participants and PWA to cope with the cognitive demands of the background noise included focusing, using

internal memory aids, and reducing sensory input (e.g., closing one's eyes, turning down or off the TV when communicating, etc.) both in the experimental condition and daily communication. Strategies mentioned only by PWA included taking breaks and slowing down, as well as some negative strategies, such as avoiding or withdrawing from communicative encounters to eliminate possible communication breakdowns. PWA also indicated that strategies for communicating in background noise were not expressly taught to them when in speech therapy.

Emotional Reactions – Both control participants and PWA expressed stress, while PWA only also expressed fear, frustration, and overwhelm. All participant groups identified emotional strategies of positive affirmations and emotional regulation, with only PWA identifying gratitude as well.

Social Reactions – PWA shared comments regarding unsupportive relationships and social withdrawal because of background noise. Control participants did not report any social challenges, though both PWA and controls described the strategy of self-modifications to better be understood by their communication partner. PWA also mentioned the strategy of relying on supportive communication partners.

Conclusions: This study found that people with aphasia perceive greater cognitive effort when speaking in noise than control participants. Additionally, PWA expressed greater difficulty with background noise conditions that included linguistic content in comparison with energetic types of noise.

Relevance to present work: The present study uses similar experimental protocol as this study, and the experiences of PWA are important to consider in conjunction with language analysis. The difference in perception between PWA and control participants is important to consider when identifying how utilizing background noise may help them in therapy; in this study PWA specifically identified that strategies to communicate in background noise had never been addressed for them, and that having it be addressed in therapy could be helpful. By collecting more data regarding the interference of selective and divided attention for control participants and PWA, we can help provide evidence for the inclusion of these types of strategies in speech therapy.

Heuer, S., & Hallowell, B. (2015). A novel eye-tracking method to assess attention allocation in individuals with and without aphasia using a dual-task paradigm. *Journal of Communication Disorders*, *55*, 15–30. https://doi.org/10.1016/j.jcomdis.2015.01.005

Objective: The aim of this study was to assess the construct validity an eye tracking method for assessing attention allocation during auditory linguistic processing in comparison to more traditional methods for assessing attention allocation.

Methods: Participants with aphasia and control participants completed an auditory sentence comprehension and visual search tasks completed in both single- and dual-task conditions. Eye-tracking measures were used to measure differences in attention allocation during the tasks.

Results: For visual search single- and dual-task performance there were significant group differences for PWA and the control group. For comprehension single- and dual-task, there were significant main effects for group and complexity, as well as a significant interaction between group and complexity. Finally, the WAB-R Aphasia Quotient & Auditory Verbal Comprehension Score were observed to be significantly correlated with the eye-tracking attention allocation measures for the simple sentences in the single comprehension task and all complexity conditions in the dual comprehension task, but not for the visual search conditions.

Conclusions: This eye-tracking method captured the increase in attentional demands for the single vs dual visual search task. People with aphasia had more difficulty allocating attention efficiently to the target image than people without aphasia in both single- and dual-tasks. Both groups decreased their PFDT in dual-task conditions, leading the difference between groups in single- and dual-tasks to be similar. This is different from the comprehension task, which showed interactions between group and complexity of condition as well as significant main effects for group and condition. These significant group differences indicate differences in comprehension abilities between PWA and the control group.

Relevance to present work: This study showed that the differences between groups in single- and dual-task remained similar in the visual search task, but does not relate to all dual-task studies done. This supports the question of the present study to investigate if linguistic tasks in selective attention or a dual-task are better at identifying PWA than a single linguistic task. However, the comprehension task is likely more comparable to the present study than the visual search task was. It is when there is a linguistic component added to the attentional demands that group differences appear.

Notes: *Limited capacity account:* there is a limited amount of attention to be allocated to varying task demands. In this model, when task demands are greater than attention capacity resources performance decreases. *Central bottleneck model:* central processing limits lead to dual-task decrements.

Hula, W., McNeil, M., Doyle, P., Rubinsky, H., & Fossett, T. (2003). The inter-rater reliability of the story retell procedure. *Aphasiology*, *17*(5), 523–528. https://doi.org/10.1080/02687030344000139

Objective: To measure the reliability of the SRP when scored by minimally trained judges without transcription.

Methods: Four untrained judges used the SRP to score audio-recorded language samples from four subjects with aphasia and eleven healthy control subjects to calculate percent information units per minute. Separate inter-rater reliability coefficients were calculated for participants with aphasia and the control participants using %total, %direct, and %alternate IU/minute scores from all four judges. Then, absolute-agreement intraclass correlation coefficients (ICCs) were calculated to allow for generalization to judges beyond the four presented in the study. To calculate point-to-point reliability was calculated for all four aphasia participants and four of the control participants between all six pairings of judges using the following formula: (agreements / disagreements + agreements) x 100.

Results: Point-to-point reliability averaged 91% for both subject groups.

ICCs for aphasic participants (n=4): 0.995 (total %IUs/min), 0.986 (direct %IUs/min), 0.944 (alternate %IUs/min); ICCs for neurotypical participants (n=11): 0.993 (total %IUs/min), 0.979 (direct %IUs/min), 0.885 (alternate %IUs/min).

Conclusions: The high inter-rater reliability of the %IUs/min metric indicate that it can be scored directly from audio recordings by newly and minimally trained judges.

Relevance to present work: The story retell procedure was used to calculate percent information units for analysis of the data in this study. It may be important to calculate reliability for both direct and alternate IUs as well as the total IUs.

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: This study aimed to assess whether concurrent task demands have differential effects on the speech of young and older adults.

Methods: Young (18-28 years old) and older (70-80 years old) adults completed language samples in response to questions in isolation and while walking, finger tapping (simple and complex), and ignoring speech and cafeteria noise. The language samples were then scored on fluency, complexity, and content.

Results: Dual-task costs were found to be significantly greater than 0 for young adults for the following measures: mean length of utterance, developmental level, mean clauses per utterance, and propositional density for all 5 dual-task conditions. Older adults had significant dual-task costs for speech rate (WPM), developmental level, and propositional density for all 5 dual-task conditions. There was also a significant multivariate age x task interaction for fluency and language complexity, meaning that the changes in fluency and language complexity were impacted by the age of the participants as well as the task demands. Additionally, tapping rates increased while participants were talking but walking rate decreased while participants were talking. Finally, the amount of time on task was measured and a significant multivariate interaction between age x task was found for older adults in complex tapping.

Conclusions: The type of task as well as the age of the participant impacts the dual-task costs present, especially when measuring fluency and grammatical complexity. Though all participants experienced dual-task costs, they presented themselves differently based on the age of the participant.

Relevance to present work: The present study is investigating language changes in a variety of conditions (background noise and dual-task) across a broad age range of participants. The results of this study that are most applicable are those of ignoring concurrent speech or noise, though the simple tapping results may also be a similar construct to the dual-task presented in this study. This study indicated that there were certain measures that were impacted by dual-task more than others, but these measures differed between the age groups (MLU and MCU for young adults, and WPM for older adults – developmental level & propositional density for both).

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: The aim of this study was to identify if the fluency, complexity, and content of healthy older adults speech had a true buffer against dual-task costs, or if it will begin to resemble the speech of stroke survivors when dual-task demands increase.

Methods: Young (18-28 years old) and older (70-80 years old) adults produced language samples in response to elicitation questions in three conditions: walking while talking, walking and talking while carrying a 10 lb bag of groceries, and walking and talking and climbing steps. Baseline talking alone and walking alone tasks were also completed. The language samples were scored on fluency (% utterances without fillers, % grammatical sentences, MLU, and WPM), grammatical complexity (MCU and developmental level), and content (propositional density and TTR). Additionally, performance measure of walking rate and time-on-task were coded from video of the participants walking.

Results: In baseline, older adults were less fluent in MLU and WPM and produced less complex speech. Walking rates in baseline were the same for young and older adults. In general, the dual-task costs for carrying groceries and climbing steps were comparable, though they impacted the speech of young and older adults differently. Young adults showed significant dual-task costs in all conditions for number of fillers, developmental level, and MCU. They additionally showed significant dual-task costs to propositional density in the climbing and walking and carrying groceries and walking conditions. Older adults showed significant dual-task costs in all conditions for MLU, WPM, walking rate, and time on task. They additionally showed significant dual-task costs for number of fillers in the climbing and walking and carrying groceries and walking conditions.

Conclusions: Both young and older adults experience dual-task costs, but they adopt different strategies to cope with dual-task demands. In dual-task conditions, young adults adopted a restricted speech register (shorter, less complex sentences) that resembled that of older adults in the baseline condition. The more complex the dual-task became, the more restricted the speech register for young adults became. Contrastingly, older adults decreased their speech and walking rate while walking and talking. In the more complex dual-tasks, older adults additionally became more disfluent. Older adults also alternated speaking and walking when they faced obstacles such as short flights of steps. These results, along with the Kemper et al. 2003 study, suggest that there is a "function floor" for developmental level and propositional density that is age-related, meaning that cognitively sound older adults will not decrease the complexity and content of their speech below the floor scores.

Relevance to present work: Dual-task costs can be expected for all adults, though they will likely differ across ages. Therefore, understanding the specific dual-task costs that are significant for each age group is an important step in our ability to compare PWA to adults in their specific age group. It is also important to understand the differing baseline performance of adults in different age groups. For example, older adults can begin with a restricted speech register in comparison to younger adults, so when faced with dual-task demands they are able to preserve the complexity and content of their speech but sacrifice their fluency and time on task. Young adults, on the other hand, restrict their speech register when faced with dual-task demands to be similar to that of older adults in the baseline condition. These differing changes are interesting to note and compare to those for PWA.

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, and Cognition*, *18*(3), 257–279. https://doi.org/10.1080/13825585.2010.527317

Objective: This study sought to identify the costs of speech planning, speech production, and speech output monitoring during a digital pursuit rotor task for both young (18-34 yo) and older (65-85 yo) adults.

Methods: Participants completed a digital pursuit rotor task, tracking a bull's-eye target around a track and a language sample both individually and simultaneously. Transcripts of the speech samples were analyzed for number of words, number of propositions, and grammatical complexity. Pauses between utterances were automatically determined by the computer program ROSS.

Results: Costs of speech planning: When the next utterance was propositionally dense, tracking error (TE) increases and time on target (TOT) decreases were found. These costs were similar for all participants, regardless of age or measured cognitive ability. However, young adults showed more variability in their TE and TOT than older adults. Speakers with greater working memory capacity showed less errors than those with lower working memory capacity, and speakers with larger vocabularies saw more errors than speakers with more limited vocabulary.

Costs of speech production: There were significant main effects for content, propositional density, and sentence complexity for TOT and TE for all participants. TOT and TE variability also increased with the increase of utterance content, propositional density, utterance duration, and speech rate. This indicates increased costs of speech production to the secondary task.

Costs of speech output: Prior utterances did not influence TE during the following pause. However, tracking TOT declined and became more variable after words that had more words, propositions, length, or greater speech rate.

Conclusions: The examination of utterance-by-utterance variation with time-locked continuous measure of the pursuit rotor tracking indicated that speech planning, production, and output are all costly, though slightly less so for older adults than younger adults. This is likely because the simpler speech register used by older adults may provide protection against dual task costs for speech planning and speech production. Greater working memory capacity and faster processing abilities may protect against dual task costs before and during utterances as well.

Relevance to present work: The examination of utterance-by-utterance variation in dual task performance indicate that there are multiple levels of dual task costs for both young and older adults while talking and completing a secondary task simultaneously. These multiple levels may be important to consider when attempting to create normative data. Understanding the capacities of different age groups and cognitive levels, and the impacts of the dual task at different levels of speech production can provide further evidence for use of dual task use during therapy for people with aphasia.

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 study sought to measure the dual task costs of digitally tracking a moving target to language production for young and older adults.

Methods: Young (18-34 yo) and older (65-85 yo) adults completed a digital pursuit rotor tracking task alone, a language production task alone, and the two tasks concurrently. Processing speed, working memory, verbal ability, and Stroop interference were also assessed to identify how these factors impacted performance to each task in both conditions. Fluency, grammatical complexity, and linguistic content of the baseline and dual task language samples were analyzed.

Results: Tracking Performance: It was found that the dual task costs of language production on tracking performance were similar for young and older adults, with both groups experiencing an decrease in time on target and an increase in tracking error during the concurrent language and tracking tasks. Processing speed, working memory, and vocabulary were not correlated with either dual task cost. However, Stroop interference was significantly correlated with dual task costs of time on target and increased tracking errors for both young and older adults.

Baseline language sample comparisons: Young adults used longer, more complex sentences and a faster speech rate than older adults in the baseline language sample. They also used more fillers than older adults, leading to lower TTRs and propositional density.

Language Production: Both groups spoke more slowly during the dual task than during the baseline language sample. Young adults additionally used fewer fillers and less complex sentences. Overall, young adults experienced more dual task costs than older adults, though older adults experienced greater dual task costs for speech rate.

Conclusions: Young and older adults experience similar dual task costs to the secondary task with different costs to their language. During the dual task, the speech register of young adults was more similar to that used by older adults in the baseline condition. The reduced speech register used by older adults seems to be related to age-related changes in working memory and processing speed. This creates a functional floor to the language produced by older adults, allowing them to experience less extensive dual task costs to their language than young adults.

Relevance to present work: Differences in language production performance between young and older adults both in baseline and dual task conditions are important to consider when evaluating the changes from when brain injury or stroke occurs. Because there are age-related differences, creating a normative database for different age groups in these various conditions can be helpful in evaluating and tracking progress of the language of individuals with aphasia or other injury related language disorders. Further investigation of how language is impacted by age and dual task demands can provide insight on dual task trade-offs, which can inform language treatment for people with aphasia.

Kemper, S., Schmalzried, R. L., Hoffman, L., & Herman, R. (2010). Aging and the vulnerability of speech to dual task demands. *Psychology and Aging*, *25*(4), 949–962. https://doi.org/10.1037/a0020000

Objective: This study expanded upon the study of Kemper et al. (2008) to examine the limits of older adults' vulnerability to dual task demands by manipulating dual task difficulty and making both group comparisons and analyzing individual differences in dual task performance.

Methods: Young (18-28 yo) and older (65-85 yo) adults completed baseline pursuit rotor tracking and language production tasks, and then two dual task conditions: (1) talking while tracking a pursuit rotor movement at the same speed as baseline, and (2) increased difficulty by talking while tracking a pursuit rotor movement at 150% the baseline speed. Language production was assessed by verbal fluency, grammatical complexity, and linguistic content. Tracking performance was assessed by average time on target (TOT) and average tracking error (TE). Prior to completing the experimental condition, cognitive measures were given to assess differences in vocabulary, working memory, processing speed, and inhibition.

Results: Tracking Performance: As dual task demands increased, TOT decreased and TE increased for both age groups. TE was lower for individuals with better measured processing speed and inhibitory control. The tracking advantage of processing speed was similar for both age groups, but the inhibition advantage was attenuated for older adults in comparison to the young adult group.

Language Performance: As dual task demands increased, there were significant costs for verbal fluency, grammatical complexity, and linguistic content. Young adults had speech that became less fluent, less complex, and less informative in dual task demands, with the costs increasing progressively as the dual task demands increased. In contrast, older adults fluency, grammatical complexity, and linguistic content only declined in the more demanding dual task condition.

Cognitive Performance and Language Interactions: Individuals with greater vocabulary produced longer sentences and more grammatical sentences, with this advantage being greater for older adults than younger adults. Individuals with greater processing speed spoke significantly faster and had more propositionally dense speech. Processing speed also affected level of coherence, with this affect being attenuated for older adults in the dual task conditions but for younger adults it was attenuated in the baseline condition. Working memory predicted grammatical complexity, and those with better working memory were less vulnerable to dual task demands.

Conclusions: Young and older adults use different strategies to cope with dual task demands during a language elicitation task. In the most demanding dual task condition, young and older adults used a speech style with many ungrammatical fragments and short, simple, incoherent sentences. The speech of young adults changed more in the dual task conditions than the older adults, likely due to their faster speech in the baseline condition that slowed significantly in the dual task conditions. Additionally, the cognitive measures of vocabulary, processing speed, working memory, and inhibition were predictive of baseline speech style for both young and older adults. Older adults typically are more resistant to moderate dual task demands, but produce similar language to young adults in more demanding dual task conditions. Therefore, though older adults may be able to maintain their speech register in mild or moderate dual task demands, they will not be resistant to all dual task demands.

Relevance to present work: Cognitive levels and age are both predictive factors of language sample content and complexity in baseline and dual task conditions. This understanding indicates that these types of cognitive measures may be useful when identifying resource limitations for dual-task demands. Therefore, cognitive testing (such as the test of everyday attention) may be informative to how dual tasks will impact the spoken language of adults. Because the different modalities of cognitive ability were found to impact dual task costs differently, these may be important when seeking to understand how dual tasks will impact the spoken language of individuals with aphasia in comparison to healthy adults.

Kuptsova, S. V., Dragoy, O. V., & Ivanova, M. V. (2021). Switching attention deficits in post-stroke individuals with different aphasia types. *Aphasiology, 37*(2), 260–287. https://doi.org/10.1080/02687038.2021.2002804

Objective: This study investigated the characteristics of switching attention within one type of task for participants with different types of aphasia.

Methods: 40 participants with aphasia post-stroke (20 with frontal lobe damage leading to non-fluent aphasia and 20 with temporal lobe damage leading to fluent aphasia) and 20 healthy age- and education-matched, neurologically healthy control participants completed the experimental task. For PWA, the type of aphasia (fluent or non-fluent) was classified by both an SLP and a neuropsychologist using Luria's classification of aphasia, including confirmation through neuroimaging. Aphasia severity ranged from mild to severe, as defined by the Assessment of Speech in Aphasia. The experimental task for attention switching task was completed by listening to and counting high-pitched (2000 Hz) and low-pitched (500 Hz) tones separately and then saying how many high- and low-pitched tones they heard at the end of the sequence. They were then scored on accuracy and reaction times.

Results: For all participants, when the stimuli changed, reaction times were higher than when the stimuli stayed the same. Participants with non-fluent aphasia had significantly more errors and slower reaction times when compared with control participants. Additionally, participants with non-fluent aphasia made more errors than participants with fluent aphasia. Participants with fluent aphasia, on the other hand, had a significantly higher number of errors than control participants, but their reaction times were similar.

Conclusions: This study indicates that the type of aphasia impacts an individuals ability to switch attention, with each type having distinct impairments. However, aphasia severity did not greatly impact attention switching ability. This indicates that attention deficits are likely independent of language deficits for PWA. These results are important for addressing the language deficits of individuals with aphasia in distinct ways to provide targeted rehabilitation programs that address the distinct mechanisms necessary. For example, the slower reaction times of participants with non-fluent aphasia may be associated with the frontoparietal attention network that is thought to be associated with attention switching ability (Petersen & Posner, 2012). The site of lesion for participants with non-fluent aphasia indicate that they would have more difficulty with switching between tasks than individuals with a lesion at a different site. The errors made by participants with fluent aphasia can similarly be tracked to the site of lesion. These errors indicate a possible deficit in auditory memory and attending to auditory information, which would correspond with temporal lobe damage. These errors would be caused by an impairment in modality-specific auditory attention, rather than impaired attentional switching ability as was found with participants with non-fluent aphasia.

Relevance to present work: Though this study used only non-linguistic stimuli, it provides evidence that aphasia does impact attention switching ability. This study showed that PWA have great difficulty with attention switching tasks in comparison to control participants. It is therefore likely that these attention switching deficits will be even more pronounced for PWA when one of the tasks is linguistic. This study further suggests that site of lesion changes the type of attention deficits, with frontal lobe damage leading to deficits in switching attention and temporal lobe damage leading to working memory and/or modality-specific attention deficits. The Petersen and Posner model of attention may also be important to understand when identifying how a lesion and subsequent aphasia may impact attentional abilities.

Notes: This article defines the different types of attention in the intro. Participants were native Russian speakers (the study was performed in Russia).

LaCroix, A. N., Tully, M., & Rogalsky, C. (2020). Assessment of alerting, orienting, and executive control in persons with aphasia using the Attention Network Test. *Aphasiology, 35(*10), 1318–1333. https://doi.org/10.1080/02687038.2020.1795077

Objective: This study sought to use the Attention Network Test (ANT) to quantify and compare the attention subtypes of alerting, orienting, and executive control in PWA and controls.

Methods: 22 PWA and 20 age, gender, and education-matched controls completed the ANT. Alerting, orienting, and executive control were then analyzed for accuracy and reaction time. Alerting was calculated by No Cue minus Double Cue, meaning that a larger score would equal better alerting. Orienting was calculated by center cue minus spatial cue, meaning that larger scores would be better orienting. Executive control was measured by incongruent minus congruent trials, with smaller scores meaning better executive control.

Results: The reaction time of the control group showed significant effects of alerting, orienting, and executive control. The aphasia group showed significant orienting and executive control effects, but no significant alerting effects. For accuracy, the control group showed significant effects for orienting and executive control and the aphasia group showed significant executive control costs. The control group overall had faster reaction times tan the aphasia group, but there was not a significant difference in accuracy. There were no group differences for alerting, orienting, or executive control for reaction time. The control group did show a greater orienting cue benefit than the aphasia group for accuracy. For accuracy of the control group, there was a positive correlation between executive control abilities with alerting and orienting (better alerting & orienting correlated with poorer executive control). For both the accuracy and reaction times of the aphasia group, there was a negative correlation between orienting and executive control (better orienting attention was associated with better executive control performance).

Conclusions: This study found that the ANT is an effective assessment for attention in aphasia when assessing the subtypes of alerting, orienting, and executive control separately. The separation of the subtypes is supported by a correlation found between the usually independent attention networks of orienting and executive control in PWA for both accuracy and reaction time. This may indicate that when a lesion impacts the adjacent areas of the frontoparietal networks that there will be a negative impact on both orienting and executive control.

Relevance to present work: The multiple subtypes of attention investigated in this study can be useful when understanding the ways that attention deficits may be correlated with language deficits in aphasia. As stated by these authors, there is a possibility that alerting and orienting may have an impact on language performance in addition to the more well-studied impact of executive control. These relationships between subtypes of attention are important to consider when defining the relationships between attention and language in aphasia.

LeCheminant, E. (2022). Effects of background noise on the spoken language of young and older adults during narrative discourse. https://scholarsarchive.byu.edu/etd/9541/

Objective: This study investigated how different background noise conditions impacted the spoken language production of young (18-25) and older (60-85) adults during a story retell task.

Methods: 20 young and 20 older adult participants retold stories in a silent baseline and five background noise conditions (conversation, monologue, phone call, cocktail, and pink noise). Speech fluency and language production measures were compared between groups and across conditions.

Results: The older adult group showed an increase of speech rate in background noise conditions compared to the young adult group. There was a main effect found for disfluent words between the phone call and conversation condition and the pink noise and phone call conditions. The older adult group showed background noise benefits to their speech fluency in the conversation and phone call conditions and lexical production in the conversation condition, while the young adult group showed background noise costs for speech rate in the phone call condition.

Conclusions: In this study, young adults experienced language costs in background noise while older adults experienced language production benefits. This suggests that there are differences in the processing of background noise for young and older adults.

Relevance to present work: The present study is a follow-up to this study, and uses similar methods. The results of this study, in conjunction with Nelson, 2022, informed the background noise conditions chosen for the present study – specifically the phone-call, conversation and cocktail noise conditions were chosen for the present study because they provided the most interesting data in this and the Nelson study. Additionally, similar language analysis procedures will be utilized in the present study. The present study sought to use an expansive age-range in part due to

Lee, J. B., Kocherginsky, M., & Cherney, L. R. (2020). Attention in individuals with aphasia: Performance on the Conners' Continuous Performance Test–2nd edition.

Neuropsychological Rehabilitation, *30*(2), 249–265.

https://doi.org/10.1080/09602011.2018.1460852

Objective: This study sought to examine whether people with aphasia (PWA) exhibit attentional impairments by using a larger sample size and a standardized attention assessment with established psychometric properties. They additionally sought to identify what relationship there was between attention and language performance.

Methods: The attention of 114 PWA with varying types and severities of aphasia, as measured by the WAB-R, was examined using the standardized, norm-referenced attention assessment, *the Connors' Continuous Performance Test-II (CPT-II).* Their performance was analyzed by measuring omissions (failure to respond to target letters), commissions (responses given in response to non-targets), reaction time of correct responses, detectability (difference between signal & noise distributions), and confidence index (degree to which results suggest a clinical or non-clinical profile).

Results: There were significant differences between the more and less severe groups of PWA for omissions, commissions, detectability, and the confidence index (CI), indicating that the more severe aphasia group had higher levels of attentional impairment. However, omissions was the only area that both groups were in the impaired range (the less severe groups performed in the average range for commissions, detectability, and the CI). There were not significant differences between non-fluent and fluent PWA for CPT-II performance, though there were significant differences in WAB-R AQ, age, and time post onset. It was also found that as aphasia improved, attention improved.

Conclusions: The CPT-II is a measure that can be used feasibly to assess attention in PWA. This could be useful in further investigating the links between attention and language impairments in PWA.

Relevance to present work: Understanding the correlation between attention impairment and aphasia severity can be useful when investigating how attention impairment may impact spoken language production in PWA. Therefore, the correlations between attention and language impairment in PWA that was found in this study can be useful, and indicate that the usage of standardized testing in conjunction with the experimental protocols would be beneficial in defining attentional impairments. Though the CCPT-II was not used in the present study, another standardized test (the TEA) was. It is possible that there will be similar correlations between attentional performance and language profile on the TEA.

McNeil, M. R., Doyle, P. J., Fossett, T. R. D., Park, G. H., & Goda, A. J. (2001). Reliability and concurrent validity of the information unit scoring metric for the story retelling procedure. *Aphasiology*, *15*(10–11), 991–1006. https://doi.org/10.1080/02687040143000348

Objective: The purpose of this study was to establish the reliability and concurrent validity of the Information Unit (IU) as a part of the Story Retelling Procedure (SRP).

Methods: 15 participants with aphasia and 31 neurotypical participants completed the SRP. Reliability was established through agreement by ¾ judges on model transcripts for both neurotypical and aphasia transcripts. Validation was obtained through comparing calculated %CIUs and %IUs for both neurotypical and aphasia groups.

Results: *Reliability:* The scoring reliability of four raters averaged 96% for both normal and aphasic retells.

Validity: The correlation coefficient for %CIUs and %IUs averaged .87 for all 4 forms for the aphasia group, which is high and significant. For the neurotypical group he correlation coefficients were only significant for %IUs on form A with %CIUs on forms A, B, and D, averaging 4.1.

Comparison of PWA with Control Group: On average across forms, slightly less than one quarter of PWA scored within two standard deviations of the normal group's performance. The %IUs of PWAs was less than half of that produced by the control group. Additionally, PWA showed significantly more variability in their %IUs than did the control group.

Conclusions: The percentage of PWA who performed significantly lower than the normal group indicates that %IUs may be useful in identifying PWA in comparison to a normative group. Additionally, the high correlations between the measures %IUs and %CIUs indicate that %IUs can be an informative and useful measure in describing language efficiency for PWA. However, the lack of significant correlations for control subjects indicates that the %IU measure may be less useful alone in describing language efficiency than it is for individuals without aphasia.

Relevance to present work: The present work uses the SRP during data collection from all participants. The dependent variable of language efficiency is measured using % IUs obtained using the procedure outlined in this article with the following exceptions: scoring of the participants IUs is done using orthographic transcripts rather than listening to recordings of the story retells, and additional alternate IUs are accepted in accordance with a decision made a priori by the author and committee chair (see Methods). The measure of %IUs was chosen because it is more efficient than other measures, such as CIUs, and is more closely related to the successful performance of the story retell task than CIUs may be (for example, what is said could be considered a correct information unit, but not be relevant to the story). Though this article found that %IUs were less useful in describing the language of control participants in this initial stage, it was found to be a useful procedure for the present study because it has been revised since and also is being used in conjunction with other validated language analysis measures.

McNeil, M. R., Doyle, P. J., Park, G. H., Fossett, T. R. D., & Brodsky, M. B. (2002). Increasing the sensitivity of the story retell procedure for the discrimination of normal elderly subjects from persons with aphasia. *Aphasiology*, *16*(8), 815–822. https://doi.org/10.1080/02687030244000284

Objective: This study aimed to refine the Percent Information Unit (%IU;) metric of the Story Retelling Procedure (SRP) to be more sensitive as a tool to discriminate between people with aphasia (PWA) and neurotypical adults.

Methods: 15 PWA and 31 neurotypical control participants completed story retells of 12 stories from the SRP. The retells were then scored for %IUs and %IUs/minute using procedures outlined by McNeil et al. (2001). Comparisons were made between PWA and control groups, age groups, SRP forms, and scoring methods.

Results: *Groups:* PWA produced significantly less %IUs/Min than the entire control group. The young and old control groups did not significantly.

Forms: There were no significant differences between forms for the aphasia group. However, there were significant SRP form effects for the control group (both combined and separated by age). Specifically, the %IUs/Min in form B were significantly greater than form A, and form D was significantly greater than all other SRP forms.

Group Classification: Upper (aphasic) and lower (control) cutoff scores were calculated for each subject group to classify aphasic and control participants based on %IUs/Min. Misclassification was identified as 13-27% for PWA and 13-26% for control (6-13% young control, 20-47% old control).

Conclusions: The four SRP forms showed high correlation, meaning that they can be used equivalently in language assessment in aphasia. Only SRP forms A and C can be used equivalently to classify language for control subjects. Additionally, %IUs/Min is more sensitive than %IUs alone in differentiating individuals with aphasia from control participants.

Relevance to present work: The SRP is used in the present work, as is the %IUs procedure described. In this description, this article states that %IUs are "an identified word, phrase, or acceptable alternative from the story stimulus that is intelligible and informative and that conveys accurate and relevant information about the story." Therefore, it was decided a priori to accept additional alternative IUs in the calculation of %IUs for the purposes of this study. Further detail on this process is outlined in the methods of the study. This article concludes that %IUs/Min is a more sensitive metric in differentiating individuals with aphasia, and should therefore be considered as a useful dependent variable to be included in the present study.

McNeil, M., Matthews, C., Hula, W., Doyle, P., Rubinsky, H., & Fossett, T. (2005). A dual-task tool for quantifying normal comprehension of aphasic connected speech production: A constructive replication. *Aphasiology*, *19*(3-5), 473–484. https://doi.org/10.1080/02687030444000895

Objective: This study aimed to identify whether increased demands in the visual-manual tracking task used previously (McNeil et al., 2004) would elicit a cost on concurrent story comprehension.

Methods: 24 neurotypical adults (40-70 years old) performed a visual-manual tracking task in isolation and concurrently with a story comprehension task (the SRP). The difficulty level of both the listening (stories produced by individuals with mild and moderate aphasia equated mild and moderate difficulty) and the tracking (easy and hard) tasks was manipulated. These manipulations were paired in multiple ways for a total of 12 dual-task trials for each participant.

Results: *Tracking Performance:* Significant main effects were found for both tracking difficulty level, along with significant interaction effects. All participants showed increased tracking error in the dual-task for the easy tracking task paired with the moderate story condition as compared to the dual-task with the mild story condition. There were not statistical differences for the hard tracking task across story retell conditions.

Story Performance: Participants produced significantly more %IUs/Min for the mild story difficulty compared to the moderate story difficulty condition. However, there were no statistically significant differences in story retell performance in the dual-task conditions for either the easy or hard tracking task.

Conclusions: This study found that there was no significant effect of tracking difficulty on story retell performance, though there were costs to tracking performance for the easy tracking task in concurrent story retell tasks. This unidirectional dual-task cost could be explained by a variety of theories, including a partial overlap of processing resources, where the resources used for language processing can be shared with the visual-manual tracking pool but the resources allocated to visual-manual tracking cannot be shared with language processing even when task demands increase. The lack of dual-task costs to the hard tracking performance could represent a floor effect to tracking performance.

Relevance to present work: This study, as well as the McNeil et al. (2004) study, found that in a dual-task condition there were only costs to the participants tracking performance, not their story retell performance. This lack of bidirectional performance costs highlights the importance of investigating performance in both the primary (story retell) task as well as the secondary concurrent task to see the full scope of dual-task costs. For this reason, both language analysis and concurrent task performance analysis will be completed in the present study. By analyzing both language performance and the concurrent task performance, insights may be found regarding the interactions of attentional capacity and language production for both healthy and aphasic adults. It is possible that this could be attributed to individual priorities of communication over other tasks when they are being completed concurrently.

Murray, L. L. (2012). Attention and other cognitive deficits in aphasia: Presence and relation to language and communication measures. *American Journal of Speech-Language Pathology*, *21*(2). https://doi.org/10.1044/1058-0360(2012/11-0067)

Objective: This study examined how attention relates to aphasia through the evaluation of attention, short-term and working memory, executive functioning, and communication abilities.

Methods: 78 adult participants (39 with aphasia post-stroke, 39 healthy control participants) completed a cognitive test battery, including attention measures (the TEA [all subtests except lottery], BIT, and RSAB), memory measures (forward and backward Visual Memory Span subtest of Wechsler Memory Scale, Tompkins working memory protocol), and executive functioning measures (the RUFF). Language measures were also taken, including the ADP and the ASHA FACS.

Results: *PWA vs Control:* PWA showed significantly poorer scores than the control group on all subtests of the TEA, the BIT, the memory measures, and the RUFF. On the RSAB, PWA displayed attention deficits more frequently than control participant. Individually, more than 50% of PWA performed within the impaired range on five of the eight TEA subtests. Some control participants scored within the impaired range on 1-2 subtests of the TEA, but none more than 2. Additionally, 5 PWA received scores on the BIT indicative of visual neglect.

PWA Communication vs Attention: Comparisons were made between PWA's performance on the attention measures. These comparisons found that there was a significant correlation between the ADP Aphasia Severity score and every TEA subtest and the RSAB ratings, with a moderate correlation with the BIT. There was also a significant relationship between the ADP Auditory Comprehension and Lexical Retrieval scores and the attention measures. The ASHA FACS Overall Communication Independence score also showed significant correlation with each attention measures except for the TEA TS subtest.

Conclusions: This study found that PWA performed significantly worse than the control group on all attention measures, as well as on memory and executive functioning measures. This indicates that attention, memory, and executive functioning deficits may all co-occur with aphasia. The variation of attentional abilities found between PWA is also important to note, meaning that attention may not be the sole contributor to deficits associated with aphasia. These results are more in support of the cognitive or resource models of aphasia that indicate that cognitive impairments can exacerbate aphasic symptoms, but are not the sole cause of these symptoms as the attentional model of aphasia contends.

Relevance to present work: The present study is investigating the relationship between attention and language through selective and divided attention tasks where language production is a one of key task. The use of the TEA in conjunction with the language analysis may be useful in identifying how attention deficits may compound aphasic symptoms as argued in this article. It is also important to note that the article found some PWA (all anomic) who did not test in the impaired range on the TEA but do still present with symptoms of aphasia. Investigating the relationship between attention and aphasia through both modalities can be useful to further understand these relationships and how the attentional measures may be used reliably in aphasia treatment.

Murray, L. L., Holland, A. L., & Beeson. (1998). Spoken language of individuals with mild fluent aphasia under focused and divided-attention conditions. *Journal of Speech, Language, and Hearing Research, 41*(1), 213–227. https://doi.org/10.1044/jslhr.4101.213

Objective: This study investigated how varying attentional demands effected spoken language of individuals with aphasia compared to control participants.

Methods: Participants with mild aphasia (14) and age-matched controls (8) competed picture-description and tone discrimination tasks in isolation, focused attention, and divided attention conditions. They completed divided attention tasks twice, one instructed to prioritize the picture description and then again prioritizing the tone discrimination. Morphosyntactic completeness and complexity, lexical performance, and pragmatic performance were analyzed from the picture descriptions.

Results: *Morphosyntax:* PWA produced significantly less syntactically complete utterances than the control group in the divided attention condition, with no significant differences in the isolated or focused attention conditions. PWA showed a significant decrease in the proportion of syntactically complete utterances during the divided attention condition where priority was placed on the tone discrimination task compared to isolation and focused-attention conditions. In the divided attention conditions PWA also produced more simple sentences than the control group.

Lexical & Pragmatics: PWA produced significantly less words and more word finding errors than the control group across conditions. PWA also showed significant decreases in word production in the divided-attention conditions compared to the isolation and focused attention conditions, with the difference between divided attention focused on language production to the focus on the tone discrimination task approaching significance. PWA produced significantly less %CIUs than the control group, with great variability across conditions.

Tone Discrimination Accuracy: The control group had significantly more accuracy than PWA except during isolation. PWA had significantly more accuracy in the isolation and focused attention conditions compared to the divided attention conditions.

Tone Discrimination Reaction Time: The control group had a significantly faster reaction time than PWA in the isolation and focused attention conditions. Both groups significantly decreased their reaction times in the divided attention conditions.

Conclusions: The results of this study suggests that increased attentional demands have a negative impact on spoken language production for PWA. The differences in verbal output between PWA and the control group were greater in the divided attention conditions compared to isolation and focused attention, indicating that an increased attentional demands impact spoken language significantly more for PWA than for the control participants. The communication of PWA was also classified as less efficient and effective. The control's significant decrease in reaction time paired with unchanging linguistic output indicates that the control group used a speed/accuracy trade-off.

Relevance to present work: The differences in linguistic production and secondary task performance between PWA and the control group in this study contribute to the hypotheses of the present study. In this study, participants were instructed to prioritize certain tasks during the divided attention condition. This priority showed differences in performance across the two tasks. Contrastingly, in the present study the participants are instructed to give both tasks equal importance. I hypothesize that when participants are instructed to prioritize two tasks equally at the same time that they will subconsciously prioritize the task that has more significance to them, which will likely be their language production because communication typically has a more significant impact than secondary tasks.

Nelson, B. S., Harmon, T. G., Dromey, C., & Clawson, K. D. (2023). Telling stories in noise: The impact of background noises on spoken language for people with aphasia. *American*

Journal of Speech-Language Pathology, 32(5s), 1–17.

https://doi.org/10.1044/2023_AJSLP-22-00299

Objective: Determine how different background noise conditions impact the spoken language of people with aphasia during a story retell task.

Methods: 11 adults with mild to moderate aphasia and 11 age- and gender- matched controls participated in a story retell task under six different conditions (silent baseline, conversation, monologue, phone call, cocktail, and pink noise). Dependent variables of speech acoustics (e.g., mean intensity, fundamental frequency), speech fluency (e.g., speech rate, disfluent words), and language production (e.g., correct information units, lexical errors, lexical diversity, and cohesive utterances) were analyzed and compared across groups and conditions.

Results: *Language production:* Participants with aphasia (PWA) experienced significantly more interference than the control group on communication efficiency (e.g., percent correct information units) in all background noise conditions, as well as decreased lexical diversity in the phone call condition. There were no significant background noise costs for the control group, though they did increase their lexical diversity in the cocktail noise condition. More interference occurred for both groups when noise was informational (e.g., conversation, monologue, phone call) as compared to continuous noise (e.g., cocktail, pink).

Speech acoustics: PWA only increased their mean intensity and fundamental frequency in some conditions, while control participants increased it in all background noise conditions. There was greater interference across groups on speech acoustic measures in continuous noise than informational noise.

Conclusions: This study found that PWA experience more interference to their language production in background noise than neurologically healthy adults. This indicates that therapy addressing communicating in noise may benefit PWA.

Relevance to present work: This study is foundational to the purpose of the present study; the methods of data collection and language analysis are similar to those of the present study.

Rogalski, Y., Altmann, L. J. P., Plummer-D'Amato, P., Behrman, A. L., & Marsiske, M. (2010). Discourse coherence and cognition after stroke: A dual task study. *Journal of Communication Disorders*, *43*(3), 212–224. https://doi.org/10.1016/j.jcomdis.2010.02.001

Objective: This study examines the relationship between coherence (both global and local) and cognitive variables of mobility-impaired stroke survivors through single and dual task conditions. It was predicted that global coherence would be impacted more severely by the dual task for gait-impaired individuals than local coherence due to the increased attention requirements to maintain a topic over an extended period of discourse.

Methods: 13 gait-impaired stroke survivors without aphasia complete a single (talking while seated) and dual (talking and walking) task conditions. A cognitive battery, including executive function (Stroop test), working memory (digit spans), and vocabulary measures, was also collected. Discourse samples were coded using SALT for local and global coherence (5 = completely related to topic, 3 = some relation to topic, 1 = no relation to topic). The sum of coherence scores of each type for each T-unit was divided by the number of T-units.

Results: Global coherence scores were significantly lower than local coherence scores in both conditions, with no interaction between condition and coherence type. There were no correlations between local or global coherence for age or MMSE scores, nor did local and global coherence correlate with each other. Executive function, working memory, and vocabulary measures did not correlate with local coherence. However, there were strong positive correlations between global coherence scores and Digit Symbol Substitution (higher global coherence associated with greater number of symbols transcribed), as well as moderate negative correlations between global coherence scores and Digit Symbol Copy (higher global coherence associated with faster times to copy all symbols). There were no significant correlations between global coherence and other cognitive or vocabulary measures, nor was there correlation with microstructural language variables.

Conclusions: Overall, global coherence was poorer than local coherence across conditions, and global coherence was correlated significantly with executive function measures of attention and processing speed while local coherence was not. These findings are consistent with similar literature on coherence in other populations. This difference between global and local coherence could be due to (1) a dissociation between global and local coherence because they are on different ends of the macrolinguistic spectrum or (2) global coherence maintenance is generally more cognitively demanding than local coherence maintenance, and therefore global coherence breaks down before local coherence when cognitive demands increase. It is likely that effects of age and cognition impact global coherence in addition to other cognitive demands. These findings suggest the use of top-down treatments that target areas such as attention and memory in conjunction with discourse tasks for PWA.

Relevance to present work: The correlations found between the Digit Symbol test, which assesses attention, concentration, and processing speed, and global coherence suggest that attentional demands impact discourse in individuals post-stroke at a macrolinguistic level, even when aphasia is not present. These macrolinguistic costs may be compounded in as attentionally demanding conditions increase, as well as when aphasia is present. Therefore, a macrolinguistic measure of global coherence may be interesting to include in the present study to identify at what point global coherence declines when attentional processing is taxed for both healthy adults (are there differences in ages?) and PWA.

Sohlberg, M. K. M., & Mateer, C. A. (2001). *Cognitive rehabilitation: An integrative neuropsychological approach*. The Guilford Press.

Summary: Problems with attention and concentration are some of the most commonly reported problems from people with brain damage. There are three clinical circuits that attention can be divided into: spatial orientation, target selection and conflict resolution, and alerting and sustained attention and working memory processes. Each of these circuits rely on different brain structures to execute. There are five components of attention (listed least to most complex) that create a clinical model: focused attention, sustained attention, selective attention, alternating attention, and divided attention.

Focused attention is a direct response to stimuli, which is the most basic type of attention. Sustained attention is divided into two categories: vigilance (how long can an individual attend to a specific stimulus) and working memory (how effectively can an individual hold and manipulate information). Selective attention is focusing on a specific stimulus in the midst of distraction, whether internal or external. Alternating attention requires a mental flexibility to switch between tasks that have differing cognitive requirements (e.g., listening to a lecture and taking notes). Divided attention is the most complex form attention, requiring behavioral responses to two or more different tasks or task demands simultaneously.

How to measure these different components of attention are outlined in the text as well. These measures include digit span tasks, used to measure the immediate span of attention; rejection or cancellation tasks that measure focused attention; auditory or visual continuous-performance tests, which measure sustained attention; divided attention tasks such as The Brief Test of Attention or the Letter-Numbering Sequencing subtest of the WAIS-III; and simple & complex reaction time tests that measure the speed of information processing. The Test of Everyday Attention is another measure that was developed in an attempt to create a more ecologically relevant assessment through approximation to common day-to-day activities. Attentional abilities can also be measured through self- and/or caregiver-report scales.

Relevance to present work: The described components of attention provide important background knowledge to the different attentional systems in the brain. This is important to the present work, as it allows for classification of our various experimental conditions into the categories of focused attention, selective attention, and divided attention. The definitions for these various components of attention can help us recognize where attentional breakdowns may occur, which has guided the hypotheses of the present study.

Taconnat, L., & Isingrini, M. (2004). Cognitive operations in the generation effect on a recall test: Role of aging and divided attention. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *30*(4), 827–837. https://doi.org/10.1037/0278-7393.30.4.827

Objective: This study sought to understand why the generation effect appears in elderly subjects under certain conditions, specifically when based on semantic processing. They used different production tasks and full and divided attention conditions to define the mechanisms involved in the generation effect.

Methods: *Experiment 1:* Young (20-35 years), elderly (60-75 years), and very old (76-90 years) subjects completed a free-recall test of word pairs that were either related through rhyming or strong semantic associations. Half of the word pairs were learned in a reading condition while the other half were learned in a generation condition with the rule (rhyme or associate) written on the card. Participants were instructed to memorize the words in the second column (either read or generated).

Experiment 2: Young (20-35 years), elderly (60-75 years), and very old (76-90 years) subjects completed a generation task with words that were either semantically associated fragments or anagrams.

Experiment 3: Young (20-35 years), elderly (60-75 years), and very old (76-90 years) subjects completed a recall task with words that were always associated through rhyming, with some learned through generation while others were learned through reading.

Experiment 4: Young (20-35 years) subjects completed a concurrent task while generating and reading words associated through rhyming to be memorized. The secondary task was detection of signals through a continuous background noise.

Experiment 5: Young (20-32 years), elderly (60-74), and very old (76-89) participants completed a recall task identical to Experiment 1 while dividing their attention with the same secondary task as in Experiment 4.

Results: For all experiments, young adults recalled more words than older adults and generated words were recalled better than read words.

Experiment 1: Words with semantic associations were recalled better than rhyming words for all participants. Only young adults had any generation effect benefits for rhyming words.

Experiment 2: Words learned through associations were recalled better than words learned with anagrams. There was a significant interaction between Age x Learning Condition x Generation Rule, indicating that there are differences in the generation effect based on age and type of cue. The generation effect was greater when the cues were semantic associates at all age levels, with the generation effect of anagrams being only significant for young adults.

Experiment 3: When all words were learned through rhyming, rhyme cues were more effective than associate cues. Young subjects recalled words better when reading for rhyming cues than semantic cues, while in generation both types of cue were effective. There was only a significant age interaction when words were generated; with elderly subjects having less benefit from rhyme cues compared to associated cues but similar effectiveness for young adults.

Experiment 4: Generated words were recalled better than read words, and words with phonological cues were more effective for recall than semantic cues for young subjects.

Experiment 5: Young subjects recalled more words than elderly subjects, generated words were recalled better than read words, and semantically associated words were recalled better than rhyming associated words. The generation effect was more significant when the cue words were semantic in nature. The generation effect of rhymes was not significant for young subjects in the divided attention condition, contrasting with the results of Experiment 1.

Conclusions: The generation effect of semantic associates provides great benefit for elderly and very old subjects, being similar to the generation effect benefits young subjects experienced, even in divided attention conditions. The environmental-support hypothesis indicates that self-initiated processes are highly effortful while task-driven processes are less effortful.

Experiment 1: The rhyme-generation effect was only present for young adults, and seemed to decline quickly with age. Contrastingly, adults of all ages benefited from the generation effect of semantic associates.

Experiment 2: Results indicate that young adults benefit from the generation effect for words learned through anagrams while older adults do not. For older adults there is only benefit when the words are learned through semantic associations, as was established in the first experiment.

Experiment 3: The results indicate that both semantic and phonological processing are used for generating rhymes for young adults. The non-significance in the reading situation indicate that young and elderly adults use the same type of processing, which is not the case for generated words. This suggests that in generation young adults use more processes than older adults.

Experiment 4: When young subjects divided their attention their reliance on semantic generation seemed to no longer be used. This may indicate that when processes are self-initiated instead of driven by the task they more dependent upon processing resources.

Experiment 5: The generation effect of semantic associates was resistant to divided attention losses for subjects in all age groups. This indicates that the interference in the generation effect for rhymes for young adults in the divided attention condition supports the theory that rhyming associations are less robust than that of semantic associations, as was posited by the lack of benefit for older adults in the rhyming condition in Experiment 1.

Relevance to present work: The age differences discussed in this study are useful, especially because the older adult group is divided. The benefits that older adults had from the generation effect were conditional upon the type of relationship, with semantic associations causing benefits that anagrams or rhymes did not for older adults. These age differences indicate that there may be certain cognitive processes that differ with age, while others may maintain with aging. For the purposes of the present study, this may be important to consider because there may be certain measures that differ across age groups while other measures do not. Additionally, the divided attention results (Experiments 4 & 5) are interesting for the present study in considering the language processes used for semantic associations and how that may relate to other forms of language production in divided attention. The semantic benefits that older adults experienced indicate that semantic memory is less impacted by aging than other forms of cognition (such as working memory which would be required for anagrams, for example). Because it was found that semantic associations were robust against aging and divided attention costs, these types of associations may be beneficial to use in treatment for adults with aphasia.

Notes: The generation effect is an advantage in memory for material that is self-generated compared to material that is read. There are three hypotheses to explain this effect (1) *semantic hypothesis:* an increase of conceptual/semantic processing carried out on target words; (2) *effort hypothesis:* generation involves an improvement in allocation of processing resources; or (3) *transfer-appropriate processing hypothesis:* principle that there is compatibility between processes used at encoding & retrieval levels.

Tun, P. A., & Wingfield, A. (1994). Speech recall under heavy load conditions: Age, predictability, and limits on dual-task interference. *Aging, Neuropsychology, and Cognition*, *1*(1), 29–44. https://doi.org/10.1080/09289919408251448

Objective: This study investigated the age differences in recall performance when cognitive load was increased via a divided attention condition.

Methods: Young and elderly adults listened to and recalled spoken passages that ranged from high predictability to low predictability in both single and dual task conditions. In the dual task condition, participants concurrently completed a speeded matching task.

Results: In the single task, it was found that there were age differences in memory that varied according to the predictability of the text and the level of importance of information. Elderly adults generally recalled less than young adults. All adults showed similar patterns in their recall for major ideas, though the differences in details recalled between the two subject groups increased as passages became less predictable. Older adults also took more time in their recall than did young adults. There were no significant differences between age groups when attention was divided, though there was an increase in recall time in divided attention, with type of concurrent matching task impacting the recall task response time as well; the recall took longer for the category matching task than the physical matching task.

Conclusions: Speech processing ability shows great levels of resilience to high cognitive load, such as that from divided attention conditions. Age-related differences that are more observable seem to be at lower levels of information, with older adults showing a sharp drop in their ability to recall minute details as the passage difficulty increased. Contrastingly, young adults maintained a pattern of recall, with the major details being recalled best and a gradual slope as details became more minute, regardless of passage difficulty. The increased amount of time required by older adults to complete the recall task indicates that their processing abilities were slower and more effortful than that of young adults.

Relevance to present work: For the present work, the differing levels of recall for minor details is an interesting finding. This would relate to the %IUs measure in the present study. From this finding I would expect the A and B groups to have a higher %IUs than the C and D groups. Additionally, I anticipate that the increased recall time will transfer to the present study as well through the WPM measure in the present study; I would expect the C and D groups to produce fewer WPM than the A and B groups. These types of measures indicate processing abilities, and may be related to working memory capacity. In a divided attention condition, working memory capacity becomes overloaded and the lower level details with more strenuous memory representation will likely be lost. This study also found that the nature of the concurrent task influenced the level of detail

Tun, P. A., & Wingfield, A. (1995). Does dividing attention become harder with age? Findings from the divided attention questionnaire. *Aging, Neuropsychology, and Cognition*, *2*(1), 39–66. https://doi.org/10.1080/13825589508256588

Objective: This study aimed to assess whether there are age-related changes in self-perceptions individuals hold about their own divided attention abilities, and whether those beliefs differ across behavioral domains.

Methods: This study developed the Divided Attention Questionnaire (DAQ) to assess whether adults report increased difficulty for divided attention tasks as they age. This assessment had questions that assessed the level of difficulty for each dual task, how that combination had changed in difficulty in the last ten years, and frequency of performance of each task combination. 83 young (18-27), 114 young-old (60-71 years), 104 old (72-81 years), and 27 old-old (82-91) participants then completed the DAQ, as well as 6 items from the MIA instrument to assess the association between attention and memory self-ratings.

Results: Older adults rated most combinations of activities to be more difficult compared to young adults. There were also significant differences between young-old, old, and old-old subjects perceptions of task difficulty. Additionally, there was a significant difference between the young and older adult groups in the changes of task difficulty over time, with older adults reporting that activities had become more difficult and young adults reporting that most activities had become slightly easier. The frequency of the task and the task domains also impacted the self-perceptions of ability in old age, with activities monitoring novel information being increasingly difficult and routine activities or those involving speech processing showing little change in the older adults.

Conclusions: Self-perceptions of divided attention ability do show systematic changes as adults ages, with older adults consistently rating dual tasks as more difficult than young adults. Additionally, the differences between the young-old, old, and old-old groups indicate that as age increases there is a subjective increase of difficulty in divided attention. The correlation of difficulty and frequency of task performance may impact an individual's willingness to participate in certain tasks, and could have important social consequences for elderly adults.

Relevance to present work: The findings regarding the self-belief of individuals divided attention task performance are important to consider in conjunction with objective measures of their task performance. This study found that there was some correlation between the performance of participants and their self-reports, and that they changed with age. In the present study there was a broad range of ages tested, and it is likely that there will be differences in their self-reports as well. Additionally, finding regarding level of difficulty for tasks more frequently performed has important implications in assessment and treatment for people with aphasia. When PWA have had therapy focusing on certain tasks, they are likely to do better than PWA who have not had therapy, even if that therapy did not exclusively target divided attention. Though this is not directly related to the present study, the implications of learning effects, individual's beliefs of their abilities, and their objectively measured abilities would be important to consider in future research.

Villard, S. (2017). Potential implications of attention deficits for treatment and recovery in aphasia. *Perspectives of the ASHA Special Interest Groups*, *2*(2), 7–14. https://doi.org/10.1044/persp2.sig2.7

Objective*:* This study sought to artic ulate the importance of attention processing as a component in language recovery for people with aphasia.

Summary: Previous research has found that PWA as a group have decreased attention compared to control participants, with these attention impairments being in both linguistic and non-linguistic contexts, indicating that attention deficits in aphasia are domain-general. However, increased language processing demands may compound these domain-general attention deficits. Though PWA as a group show attention deficits, these vary widely from individual to individual. Though there have been found general correlations between attentional abilities and language abilities (Murray, 2012), within individuals there are still complex differences.

When studying attention, it is important to consider the type of attention involved, as well as the modality (e.g., auditory or visual) in which this attention is being tested. All of these factors will impact therapy with PWA. Successful attention during therapy with PWA likely will require both auditory and visual attention, as both types of stimuli will be presented, as well as integration of these different stimuli (which would draw upon simultaneous attention processing).

Language therapy may also take place in a distracting environment, especially in the hospital setting, which will further require selective attention in addition to any other attentional needs in therapy. These attentional needs of therapy combine to increase the attentional processing required for successful performance, which will make therapy difficult for individuals who already have impaired attentional abilities. It is additionally important to consider intra-individual variability, both between-session and within-session.

Conclusions: Attention is a prerequisite for language therapy, and attentional abilities must be considered when working clinically with clients. The complexity of attention requires more research to fully understand all of the variabilities in attention and aphasia. However, being aware that these deficits will likely be present with PWA is an important place to start when approaching therapy with PWA.

Relevance to present work: Understanding how different types of attentional demands, as is being examined in the present study, would provide valuable information to the current literature regarding attention. The present study aims to understand how different attentional demands impact language production, which would allow these attentional demands to be more definitively considered in language therapy with PWA. Villard posits that attention is a prerequisite to therapy abilities, which may indicate that an attention assessment may be an important thing to include in assessment and treatment for PWA. The present study aims to begin preliminary investigation on how that may be possible.

Villard, S., & Kidd, G. (2019). Effects of acquired aphasia on the recognition of speech under energetic and informational masking conditions. *Trends in Hearing*, *23*(January-December). https://doi.org/10.1177/2331216519884480

Objective: This study investigated the consequences of informational and energetic background noise on receptive speech processing for PWA compared to age-matched controls.

Methods: 12 PWA and 12 age-matched healthy controls completed a forced-choice speech identification task in speech masking, noise masking, and glimpsed speech conditions. Participants also completed a hearing threshold test and a battery of linguistic and cognitive tests to classify the cognitive-linguistic profile of PWA. Any hearing loss was compensated for by an individualized frequency-specific gain. The target-to-masker ratio (TMR) was averaged across the five trials for each participant in each condition.

Results: There were significant differences between PWA and control participants for the speech masking condition. For the noise masking condition and the glimpsed speech condition the difference between PWA and controls did not reach significance. These results were compared to the cognitive-linguistic testing, which indicated that the increased susceptibility to the effects of informational masking that PWA was not be attributable to age, hearing status, or comprehension deficits.

Conclusions: These findings indicate that the speech processing of PWA break down more than those of control participants when competing speech levels increase. Because of the control for age, the results of this study found that this increased susceptibility PWA experienced to speech masking is a consequence of the cognitive-linguistic deficits of aphasia. Therefore, aphasia may lead to an increased difficulty with sound segregation which would impact PWA's ability to comprehend conversations in noisy environments.

Relevance to present work: This study investigated the speech processing abilities in different background noise conditions of PWA compared to healthy controls. These processing abilities are important to consider in conjunction with the present studies aim to classify how similar background noise conditions impact language production. In the context of communication, both receptive and expressive abilities in background noise conditions are necessary to understand how these conditions fully impact communication experiences for PWA.

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 investigated the relationships between measures of comprehension and production for stories in wordless picture books and measures of attention and memory for 2 age groups.

Methods: Young (20-29 years) and older (70-89 years) completed cognitive measures, story production of wordless picture books, and answering multiple-choice comprehension questions pertaining to the story.

Results: The two groups did not show significant differences in proportion of propositions conveyed. The younger group did show significantly better comprehension than the older group. The older group had a statistically significant relationship between story measures.

Conclusions: There were differences found in the comprehension but not the production of both age groups. This may be because the story proposition measure was not sensitive to age differences, rather than an actual lack of difference.

The differing relationship between adults' comprehension of stimuli used to elicit narrative production samples depending on their age suggests that discourse processing abilities change in healthy aging along with the changes in cognitive ability that occurs with aging. These findings indicate that there are memory and attention contributions to the story processing performance of older adults.

Relevance to present work: The differences in performance between young and older adults on the discourse and comprehension tasks this study found provides guidance for the measures that may be useful to include when investigating the differences in discourse for adults of different ages. For example, this study included story propositions coded a certain way, but suggests the inclusion of coding the propositions by story elements to understand the full differences between the two groups. Further, investigation of these phenomena on multiple discourse measures and expanded age groups is warranted, which is what the present study aims to do.

Wright, H. H., Koutsoftas, A. D., Capilouto, G. J., & Fergadiotis, G. (2013). 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 examined the how cognitive processes influence discourse global coherence ability across different discourse tasks for adults of different ages.

Methods: Young (20-39 years) and older (70-87 years) adults completed five discourse elicitation tasks (narrative: eventcasts, stories, recounts, and accounts; procedural: how to make a PBJ and how to plant a flower in a garden), after which the language samples were analyzed for maintenance of global coherence. Participants also completed cognitive measures of memory and attention (including Weschler Memory Scale-III, Comprehensive Trial Making Test, and STROOP Color and Word Test).

Results: *Discourse Effects:* Global coherence group differences were only found for recounts, on which the older group produced significantly lower global coherence scores than the young adult group. Additionally, recounts had the lowest global coherence scores compared to all other discourse elicitation tasks for both groups.

Cognitive Effects: For the older adult group, there were positive correlations between episodic memory and global coherence for stories and the STROOP color and word test and global coherence for stories. There was also a significant negative correlation between working memory index and global coherence for procedures. There were no significant correlations between cognitive and discourse measures for the young adult group.

Conclusions: The influence of cognitive processes on global coherence maintenance differs between young and older adults, with the greatest differences in discourse measures being for recounts. Future directions should investigate how global coherence of discourse tasks differ across different populations (aphasia, dementia, right hemisphere brain damage, etc.). This study used rating scales to measure coherence, which is a validated measure, though they may lack linguistic variable measures.

Relevance to present work: The present study compares multiple measures of language production across multiple age groups, as well as comparing a small pilot group of PWA. The findings of this study posit that global coherence is related to cognitive measures, including attention, but discourse in an attentionally demanding conditions was not studied specifically. By comparing the scores of attention measures with discourse produced both in a baseline as well as in attentionally demanding conditions, this relationship may be more specifically defined.

APPENDIX B

Consent form for Neurologically Healthy Adults

Consent to be a Research Subject

Title of Research Study: Measuring the Effects of Distracting Contexts on Language Production: Normative Data for Use in Aphasia Assessment

Principle Investigator: Dr. Tyson Harmon, Ph.D., CCC-SLP

IRB ID#: IRB2021-289

Introduction

This research study is being conducted by Tyson Harmon, Ph.D., CCC-SLP at Brigham Young University. The purposes of this study are to (1) measure the impact of attentionally demanding conditions on spoken language and (2) create a collection of data from typical speakers to help in the assessment and treatment of language in people with aphasia. 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 to 1.5 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 attentionally demanding conditions. This session will be held on Brigham Young University (BYU) campus (John Taylor Building room 106).

Audio/video Recordings

During the session, **audio and video recordings** will be obtained throughout the research session. Your consent below allows (BYU) to use these recordings for purposes associated with the Study:

I understand that researchers will take audio and video recordings of me as part of this Study. These recordings will include either audio only or both audio and visual information, which may allow me to be identifiable to viewers. I give permission for BYU to use the Media in scientific publications, scientific conferences or meetings, educational presentations, public presentations to non-scientific groups, and other uses related to the Study so long as my name is not used. I agree that all Media will become the property of BYU, and I waive my right to inspect, approve, or be compensated for BYU's use of the Media.

By signing below, **I certify that I have read** this Consent to Use Video Recording **and agree** to its terms.

Name of Participant: ____

(Please Print)

Signature: ____________________________________ Date _______________

<u>Risks/Discomforts</u>

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.

<u>Benefits</u>

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.

<u>Confidentiality</u>

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. As stated previously, if audio or video clips are used for any purpose associated with the study, your name will not be used.

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/video files) will be kept indefinitely on a secured, password protected server. Only those directly involved with the research will have access to these data.

Data Sharing

We will keep the information we collect about you during this research study for analysis and for potential use in future research projects. Your name and other information that can directly identify you will be stored securely and separately from the rest of the research information we collect from you.

De-identified data from this study may be shared with the research community, with journals in which study results are published, and with databases and data repositories used for research. We will remove or code any personal information that could directly identify you before the study data are shared. Despite these measures, we cannot guarantee anonymity of your personal data. The results of this study could be shared in articles and presentations, but will not include any information that identifies you unless you give permission for use of information that identifies you in articles and presentations.

Compensation

You will receive $15.00 cash after completing the session.

<u>Participation</u>

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

<u>Questions about the Research</u>

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 Human Research Protection Program at (801) 422-1461; byu.hrpp@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: ______________

APPENDIX C

Consent Form for People with Aphasia

Consent to be a Research Subject

Title of Research Study: Measuring the Effects of Distracting Contexts on Language Production: Normative Data for Use in Aphasia Assessment

Principle Investigator: Dr. Tyson Harmon, Ph.D., CCC-SLP

IRB ID#: IRB2021-289

Introduction

This research study is being conducted by Tyson Harmon, Ph.D., CCC-SLP at Brigham Young University. The purposes of this study are to (1) measure the impact of attentionally demanding situations on spoken language and (2) determine if data from typical speakers can help in the assessment and treatment of language in people with aphasia. You were invited to participate because you had a stroke or other brain injury that affected your communication.

Procedures

Your participation in this study will involve a **single evaluation session** lasting **1 to 1.5 hours**. During this session, you will be asked to complete several tests and retell stories in background noise conditions.

The tests will involve:

	**Speech, Language, and Attention Tests**	Naming pictures and objects Repeating words and phrases Answering questions Following directions Describing pictures

	**Story Retell Tasks**	Listening to and retelling short stories

Several of these tests will be **audio and/or video recorded** to check scores and complete more detailed analysis after the session. The session will be held on Brigham Young University (BYU) campus (John Taylor Building room 106).

As noted above, **audio and video recordings** will be obtained throughout the research session. Your consent below allows (BYU) to use these recordings for purposes associated with the Study:

I understand that researchers will take audio and video recordings of me as part of this Study. These recordings will include either audio only or both audio and visual information, which may allow me to be identifiable to viewers. I give permission for BYU to use the Media in scientific publications, scientific conferences or meetings, educational presentations, public presentations to non-scientific groups, and other uses related to the Study so long as my name is not used. I agree that all Media will become the property of BYU, and I waive my right to inspect, approve, or be compensated for BYU's use of the Media.

By signing below, **I certify that I have read** this Consent to Use Video Recording **and agree** to its terms.

Name of Participant: ____

(Please Print)

Signature: _____________________________________ Date ________________

Risks/Discomforts

Risks associated with this study are minimal. Because some of the test items 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

Since this is not a treatment study, there is likely no direct benefit to you. However, your participation in this study will provide us with information that might generally improve assessment and treatment of people with communication impairments following stroke or brain injury.

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. As stated previously, if audio or video clips are used for any purpose associated with the study, your name will not be used.

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/video files) will be kept indefinitely on a secured, password protected server. Only those directly involved with the research will have access to these data.

Data Sharing

We will keep the information we collect about you during this research study for analysis and for potential use in future research projects. Your name and other information that can directly identify you will be stored securely and separately from the rest of the research information we collect from you.

De-identified data from this study may be shared with the research community, with journals in which study results are published, and with databases and data repositories used for research. We will remove or code any personal information that could directly identify you before the study data are shared. Despite these measures, we cannot guarantee anonymity of your personal data. The results of this study could be shared in articles and presentations but will not include any information that identifies you unless you give permission for use of information that identifies you in articles and presentations.

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. You do not have to be in this study to receive clinical services through the BYU Speech and Language Clinic. Choosing to not participate will not jeopardize your services at BYU or any other healthcare service you receive.

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.

Questions about Your Rights as Research Participants

If you have questions regarding your rights as a research participant contact Human Research Protection Program at (801) 422-1461; BYU.HRPP@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: ________________ ____________

APPENDIX D

Post-Narrative Questionnaire

Please circle the most appropriate response:

1. Retelling this story was **effortful**

1	2	3	4	5
Not at all	Not very	Neutral	Somewhat	Extremely

2. Retelling this story was **stressful**

1	2	3	4	5
Not at all	Not very	Neutral	Somewhat	Extremely

3. Retelling this story was **pleasant**

1	2	3	4	5
Not at all	Not very	Neutral	Somewhat	Extremely

4. I felt **nervous** when retelling the story

1	2	3	4	5
Not at all	Not very	Neutral	Somewhat	Extremely

5. I was **calm** while retelling the story

1	2	3	4	5
Not at all	Not very	Neutral	Somewhat	Extremely

APPENDIX E

Data Collection Protocol

1. Direct the participant to the audio booth.
2. Ask the client to remove their mask (if wearing one).
3. Instruct participant to ignore the buttons on the table until they are told to use them.
4. Help participant comfortably fit the headphones over their ears.
5. Ensure the microphone is working so that the participant is able to hear you and you are able to hear them.
6. Close the door of the audio booth.
7. Before playing the practice story audio ("AIRPORT"), read the following to the participant:

   You will hear a short story through your headphones. This will be a practice round to make sure all of our equipment is working and to give you the chance to practice the story retell task. Please listen carefully to the story. When the story is finished, I will ask you to retell the story. Are you ready?

8. Once the story audio has finished playing, read the following to the participant:

   Thank you for listening. Please retell that story with as much detail as you remember. Are you ready? [After receiving confirmation] **Begin.**

9. After the participant has finished retelling the "AIRPORT" story, read the following:

Thank you for retelling that story. I will now come back in to the sound booth to do one more equipment calibration.

[Go into the sound booth and complete audio calibration]

10. Calibrate the audio (record this in Audition)
    a. Hold the sound pressure level meter 50 cm away from the participant’s mouth. (The wire, when folded in half, is 50 cm.)
    b. Have the participant sustain an “ah” vowel for 2-3 seconds at a normal, steady volume.
    c. State the average SPL before ending the recording.

11. After calibrating the audio, show the participant the rating forms

After each story, I will ask you to tell me how difficult that story was to retell using this rating form. The papers are labeled with each story, and they are in order as the stories will be told to you.

[Show the participant the rating forms and answer any questions they have before leaving the sound booth.]

12. Use the following prompts for the experiment conditions:

Baseline and Background Noise:

Thank you for listening. Please retell that story with as much detail as you remember. Are you ready? [After receiving confirmation] **Begin.**

[Start audio recording (keyboard shortcut = shift+space) and background noise simultaneously]

After the participant completes the story retell, say:

Thank you for retelling that story. Please fill out the rating form to tell me what you thought about retelling that story.

[After rating form has been completed] **Are you ready to listen to the next story?**

Timed with No Warning (TPW): (time with stopwatch)

Thank you for listening. Please retell that story with as much detail as you remember. Are you ready? [After receiving confirmation] **Begin.**

After 30 seconds have passed, say:

I'm going to stop you there [stop recording].

Thank you for retelling that story. Please fill out the rating form to tell me what you thought about retelling that story.

[After rating form has been completed] **Are you ready to listen to the next story?**

Time Pressure (TPS):

Thank you for listening. You will now have 30 seconds to retell that story with as much detail as you remember. You will hear a bell when there are 15 seconds left, another bell at 10 seconds, and another bell at 5 seconds. When the time is up, stop your retell, no matter where you are in the story. Are you ready? [After receiving confirmation] **Begin.**

[Start audio recording (keyboard shortcut = shift+space) and time pressure audio simultaneously]

After 30 seconds have passed, say:

I'm going to stop you there [stop recording]**.**

Thank you for retelling that story. Please fill out the rating form to tell me what you thought about retelling that story.

[After rating form has been completed complete Dual-Task Practice]

<u>Dual-Task (DT):</u>

Prior to presenting the story before the DT condition, they need to practice the tone discrimination task. Use this script before the tone discrimination practice:

> **Before you listen to the next story, we are going to have you practice a tone discrimination task. You will be listening for high and low tones through the headphones. When you hear this high tone** [play 2k Hz tone] **press the red button, when you hear this low tone** [play 500 Hz tone] **press the blue button. The button light will change to white when you press it. Why don't you practice pressing the buttons a couple of times before we start playing the tones.** [after they practice and know how the buttons work] **Are you ready to start the task?** [After receiving confirmation] **Begin.**
>
> [Press enter to begin the task in MatLab]
>
> To start the DT in MatLab, Open the "Tyson_RT_v1_DT.m" script, press the Start button in the top right hand corner. Then click into the commands box in the bottom, where it asks for the file name. For the practice, name the file "PptID_practice", then press *enter* to begin the task.
>
> > Press start and name the file while the instructions are being given, but do not press *enter* until the PI says "begin"

After the participant has completed a 1-minute tone discrimination practice (time this with a stopwatch), end the DT by pressing *q* on the keyboard. Then say:

Thank you for completing that practice. Are you ready to listen to the next story?

Once the story audio has finished playing, read the following to the participant:

Thank you for listening. Please retell that story with as much detail as you remember, while also listening for high and low tones. When you hear a high tone press the red button, when you hear a low tone press the blue button. Remember that retelling the story and listening for the tones are of equal importance, so please do your best to complete both tasks simultaneously. Are you ready? [After receiving confirmation] **Begin.**

[Start audio recording (keyboard shortcut = shift+space) and MatLab simultaneously]

To start the DT in MatLab, Open the "Tyson_RT_v1_DT.m" script, press the Start button in the top right hand corner. Then click into the commands box in the bottom, where it asks for the file name. Name the file "PptID_DT", then press *enter* to begin the task.

Press start and name the file while the instructions are being given, but do not press *enter* until the PI says "begin"

After the participant has completed the story retell, end the DT by pressing *q* on the keyboard. Then say:

Thank you for retelling that story. Please fill out the rating form to tell me what you thought about retelling that story.

[After rating form has been completed] **Are you ready to listen to the next story?**

<u>Dual-Task with Time Pressure: </u>(time with stopwatch)

Thank you for listening. You will now have 30 seconds to retell that story with as much detail as you remember, while also listening for high and low tones. When you hear a high tone press the red button, when you hear a low tone press the blue button. You will also hear a bell when there are 15 seconds left, another bell at 10 seconds, and another bell at 5 seconds. You do not need to press a button when you hear a bell, only when you hear the high and low tones. Remember that retelling the story and listening for the tones are of equal importance, so please do your best to complete both tasks simultaneously within the time limit. Are you ready? [after receiving confirmation] **Begin.**

[Start audio recording (keyboard shortcut = shift+space) and MatLab simultaneously] To start the DT in MatLab, Open the "Tyson_RT_v1_DTplusTP.m" script, press the Start button in the top right hand corner. Then click into the box in the bottom, where it asks for the file name. Type the PptID, then press *enter* to begin the task.

Press start and name the file while the instructions are being given, but do not press *enter* until the task needs to be started

After 30 seconds have passed, say:

I'm going to stop you there [stop recording and end the DT by pressing *q* on the keyboard]**.**

Thank you for retelling that story. Please fill out the rating form to tell me what you thought about retelling that story.

[After rating form has been completed] **That was our last story. Thank you for participating in this study! I will come help you out of the sound booth.**

13. Help the participant remove the headphones and exit the audio booth.
14. Provide the participant with the cash incentive and have them sign for it before thanking them and ending the session.

APPENDIX F

IRB Letter of Approval to Conduct Research

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: October 29, 2021
IRB#: IRB2021-289
Title: Measuring the Effects of Distracting Contexts on Language Production: Normative Data for Use in Aphasia Assessment

Brigham Young University's IRB has approved the research study referenced in the subject heading as expedited level, Categories 4, 6, and 7. The approval period is from 10/29/2021 to 10/28/2022. Please reference your assigned IRB identification number in any correspondence with the IRB. Continued approval is conditional upon your compliance with the following requirements:

1. A copy of the approved informed consent statement and associated recruiting documents (if applicable) can be accessed in iRIS. No other consent statement should be used. Each research subject must be provided with a copy or a way to access the consent statement.
2. Any modifications to the approved protocol must be submitted, reviewed, and approved by the IRB before modifications are incorporated in the study.
3. All recruiting tools must be submitted and approved by the IRB prior to use.
4. 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.
5. 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.
6. 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.

Instructions to access approved documents, submit modifications, report complaints, and adverse events can be found on the IRB website under iRIS guidance: https://irb.byu.edu/iris-training-resources.