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The Effects of Complex Listening Environments on Semantic Processing in Young and Middle-Aged Adults

Emily Ferguson B.S.
Illinois State University, emferg1@ilstu.edu

Nicholas Stanley Ph.D. Au.D.
Illinois State University

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By

Emily Ferguson, B.S.

Illinois State University

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Approved By

Nicholas Stanley, Au.D., Ph.D., Advisor

ABSTRACT

The purpose of this research study is to determine how young adults and middle-aged adults process speech in different complex listening environments. Young adult and middle-aged adult volunteers will complete a cognitive screening and audiological evaluation to establish inclusionary status for experimental speech understanding in noise testing. If they meet the requirements of the study and wish to participate further, they will continue with a semantic judgement task, in which they will be asked to listen and respond to words presented in different background noises. Within the task, participants will be asked to identify word pairs into either a "match" or "no-match" category, matches being words that fall into the same broad category (foods, animals, clothing, etc.), and no-matches being words that do not fall into the same category. This task will be completed in several different listening conditions: quiet, single-talker competition, two-talker competition, speech-shaped noise competition, and reversed speech competition. Accuracy and reaction time data will be collected during the experimental task.

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LITERATURE REVIEW

Introduction

Many studies have evaluated the various effects of different maskers on speech repetition and recognition tasks. However, very few of these studies have required the listener to do more than simply repeat what they have heard. A few studies (Brungart et al., 2013; Kidd et al., 2016; Rennies et al., 2019) have investigated the influence of energetic and informational maskers on speech understanding and the subjective effort required for these tasks. In these studies, the listeners were asked to repeat what they heard. By adding an additional level of semantic processing to speech understanding tasks, like having a listener make judgments about what they hear, it may be possible to identify more cognitive and linguistic effects of informational and energetic maskers. Speech understanding tasks which require the listener to do something with the information they hear are more representative of the type of speech understanding that is necessary for effective communication especially in complex listening environments.

Repetition Recognition vs. Semantic Tasks

When considering the auditory systems role in verbal communication, it is obvious that individuals must have the ability to hear speech to communicate; however, if the system is unable to utilize cognitive resources appropriately to address the perceived signal, a communication breakdown will likely follow. In order to reproduce a more realistic conversation, semantic judgment tasks require listeners to evaluate the words they hear and make decisions about their categorization,. This task requires individuals to processing auditory information at a higher linguistic and cognitive level than is required for recognition and repetition tasks by selecting “yes” when two words are in the same semantic category and “no” when two words are not in the same semantic category.

Jerger, Wilson, and Margolis (2014) propose that the word recognition scores, speech reception thresholds, and speech discrimination tasks often utilized in audiometry are not “genuine” measures of an individual's ability to understand speech. With that, they posited that a true measure of understanding must require the listener to do something with the information they have heard, such as following a direction they have heard. Schneider and Pichora-Fuller (2000) concur, stating that perception and cognition should “be considered parts of an integrated system” in order to fully evaluate understanding. Tun, Williams, Small, and Hafter (2012) agreed that evaluations of speech understanding must go beyond simple word recognition to evaluate comprehension, as repetition alone does not effectively evaluate the cognitive element of speech processing. They also recommended that future research focus on speech comprehension in complex listening conditions. Carlile and Keidser (2020) echoed this sentiment and argued that, in order to assess higher-level speech processing, measures beyond repetition must be pursued. Stanley (2019) argued that tasks of repetition “intentionally limit” the use of the higher-order cognitive structures which are likely highly involved in understanding speech. Overall, there is a multitude of support suggesting that tasks of recognition and repetition are not sufficient to gauge the impact of different conditions on everyday speech understanding and communication.

Decision-based semantic judgment tasks have been utilized with success in both behavioral and electrophysiologic studies to evaluate speech understanding in various conditions (Stanley, Davis, & Estes, 2017; Stanley, 2019; Davis, Jerger, & Martin, 2013; Romei et al., 2011). Stanley, Davis, and Estis (2017) used a semantic judgment paradigm to target aging effects of both bottom-up and top-down linguistic and cognitive processing in which participants were required to sort pairs of words into match and no match semantic categories in the presence of varying levels of competition. These researchers utilized +3, 0, -3, and -6 dB SNR with a two talker speech competition. They discovered that both young and older adults' accuracies and reaction times were adversely affected by a decrease in SNR, with the only significant age effect being present at -6 dB SNR, where older adults had significantly lower accuracy scores. Stanley (2019) utilized both behavioral and electrophysiologic measures to assess processing in young and middle-aged adults under linguistic and non-linguistic maskers using the same semantic judgment task in two-talker, reverse two-talker, and quiet conditions, with the competitions being presented at 0 dB SNR. Behavioral results for this task revealed no significant age effects on timing or accuracy of responses. Electrophysiological data, however, revealed processing of no-match word pairs to be reduced in middle-aged adults in comparison to young adults via the N400 amplitude. It was noted, however, that middle-aged adults showed a delayed late positive component (LPC) when competition was present that was not evident in the young adult group. Davis, Jerger, and Martin (2013) also utilized this task with electrophysiological measurements to determine if evidence could support the existence, or lack thereof, of interaural asymmetry amongst young and middle-aged adults. They found no significant interaural asymmetry in either age group for the reference word but reported that middle-aged females showed a deeper N400 wave when the competition was presented from the right side than from the left side during the second word of the pair. Davis, Jerger, and Martin (2013) also suggest the use of middle-aged adults over older adults as research participants to reduce the risk of age-related high-frequency hearing loss confounding results. Romei et al. (2011) use a similar semantic judgement task in their study in which they examined the N400 through electrophysiological measures to identify the effects of multitalker babble on word processing. Romei and colleagues suggested that using a semantic judgement paradigm is a more accurate reflection of daily listening, as individuals must process single words in order to comprehend a larger idea without regurgitating every individual word. By using words over sentences, they also note that context is reduced to allow for a more accurate word-level analysis of semantic processing.

Speech-in-Noise Tasks

Listening to speech in noisy environments may pose a challenge for listeners, as it degrades the speech signal and creates a need for greater focus from the listener. Currently, most audiometric test batteries utilize speech testing in quiet, which may not be an accurate representation of the real-world environment that most individuals are required to listen in during daily life. Gosselin and Gagné (2011) reported that listening to speech while in noise requires more listening effort, especially for older adults, even when hearing loss is not a factor. Portnuff and Bell (2019) postulate that speech-in-noise testing may provide a more well-rounded estimate of the auditory status of a patient, as it requires the use of higher-order processing structures than speech-in-quiet testing.

By evaluating the effects of differing maskers on performance, valuable insight may be provided as to what conditions require more cognitive and linguistic processing. This may allow for better identification of the challenging environments that may require more communication support.

Masking Competitions

The content of a masking competition can vary greatly, so it is vital to explore studies utilizing competition to form a strong basis of knowledge about the characteristics of maskers and how they can be controlled. Maskers can be categorized by their varying informational and energetic content, also known as linguistic and non-linguistic content. Pollack (1975) is credited with the creation of the term “informational masking” which he defines as the increase in threshold due to similarities between the target stimuli and competition. In contrast, energetic masking occurs when the target and stimuli contain energy in the same critical frequency bands (Brungart, 2001). Spyridakou and Bamiou (2015) explained energetic masking in that the differing spectral and temporal properties of varying background noises may interact with the target signal at the level of the cochlea, which may provide more or less masking depending on the interaction. This influences the degree of activation of both auditory and cognitive resources used when listening in varying types of noise. As research teams seek to better understand the interactions between energetic and informational masking and the auditory and cognitive systems, many valuable studies have surfaced comparing masker effectiveness.

One-talker, forward speech competitions are often utilized as a primary informational masker with which to compare other competitions (Summers & Molis, 2004; Rhebergen, Versfeld, & Dreschler, 2005; Cook, Lecumberri, & Barker, 2008; Brungart, 2001; Simpson & Cooke, 2005). In order to provide the most direct energetic masking comparison to the forward speech competition, some researchers have utilized competitions that contain similar qualities to speech, such as the frequency makeup and temporal fluctuations, but without the informational content (Summers & Mollis, 2004; Rhebergen, Versfeld, & Dreschler, 2005; Van Engen & Barlow, 2007; Cook, Lecumberri, & Barker, 2008; Chen et al., 2012; Brungart, 2001; Wilson, Carnell, & Cleghorn, 2007; Simpson & Cooke, 2005). Some utilize reversed speech or a foreign language to maintain the speech signal qualities, but to reduce the informational masking that occurs (Rhebergen, Versfeld, & Dreschler, 2005; Van Engen & Barlow, 2007; Cook, Lecumberri, & Barker, 2008).

Summers and Molis (2004) note that listeners are often able to take advantage of the temporal fluctuations of speech, which allows them to better recognize the target signal. When the informational content of the speech is reduced during reversal, the speech becomes unintelligible and the masking properties of the competition are less effective than that of forward speech. Rhebergen, Versfeld, and Dreschler (2005) conducted a study to evaluate this idea. Native Dutch speakers were presented with 39 lists of 13 target sentences spoken by a male speaker, with both forward and reverse Swedish and Dutch female speech as competitions. These lists were used to find the speech reception threshold (SRT) under each condition. They found that when the native speech, Dutch, was reversed, it provided a release from masking of an average 4.3 dB. However, when an unfamiliar language, Swedish, was used, performance worsened with reversal (SRTs were higher). These results provide support for the use of forward and reversed speech to better understand the effects of informational and energetic masking in the semantic judgement task.

Van Engen and Barlow (2007) worked to identify differences in native to non-native speech masking to determine if informational masking is occurring, or if speech has acoustic characteristics that are providing masking (i.e. energetic masking). Their experiment required native English listeners to listen to and write down target English sentences in varying conditions, including competing English and Chinese-Mandarin utterances with 2 and 6 talkers for each language competition at –5, 0, and 5 dB SNR. Their results revealed that English competition at the most adverse SNR (-5 dB) was the most difficult, likely because this competition produced both the highest noise level and the highest degree of linguistic similarity to the target signal. The less adverse SNR levels (0 and 5 dB SNR) did not show significant differences between the English and Mandarin competitions. For both English and Mandarin competitions, performance was better for the 2-talker competition than for the 6-talker competition, indicating that speech understanding is easier when competing with a lower number of talkers.

Cook, Lecumberri, and Barker (2008) attempt to isolate the informational and energetic components of masking by requiring English and Spanish speakers to perform a word identification task in quiet and in the presence of background noises, including English speech and stationary noise. The researchers originally hypothesized that English speakers will be more affected by the English utterance competition than Spanish speakers, as it would provide more informational masking to the English speakers due to the familiarity of the language making it more of a distraction. The results, however, indicated that Spanish speakers were more adversely affected by the presence of competing English utterances than the English speakers. This information conflicts with results found by Rhebergen, Versfeld, and Dreschler (2005) and Van Engen and Barlow (2007).

These different complex informational and energetic masking situations may affect the processing required to complete the semantic judgement task, thereby changing the timing and accuracy of responses. By analyzing these responses and identifying correlations between different complex situations, it may be possible to identify the diverse ways in which the unique characteristics of each competition influences cognition. To do so effectively, it is pertinent to evaluate other investigations of masker effectiveness.

Chen et al. (2012) investigated the informational and energetic masking effectiveness for several competitions on nonsense sentence understanding. This study was split into three experiments which utilized speech-shaped noise (SSN) that was based on the same harmonics as the target stimuli with sinusoidal modulations and fundamental frequency variations, SSN with fluctuating fundamental frequency contours during voiced speech, and flat SSN with noise-like bursts occurring at various times for experiments 1, 2, and 3, respectively, all contrasted by flat SSN. Competition was presented at a –8 dB signal-to-noise ratio (SNR) for the first experiment, and SNR was varied for experiments 2 and 3. It was revealed that similarities in fundamental frequency between the target and the masker and increased irregularity of the masker provided more effective masking and produced higher thresholds.

Brungart (2001) utilized speech, Gaussian noise, and SSN as maskers for a nonsense sentence recognition task. The speech competition was made up of the same pool of words/speakers as the target stimuli, but without the priming phrasing and in a differing order. Additionally, the target stimulus level was modulated to produce a –12 to 15 dB SNR with the masking competition in different blocks of target speech. SNR levels were chosen randomly with replacement for each trial. The speech competition condition was aimed to focus on the ability of the participant to attend to the target stimuli. Gaussian noise, meaning noise that is shaped to have the probability density function of a normal distribution curve that was spectrally shaped with a finite impulse response to match the long-term target speech spectrum, was also utilized. In the condition using Gaussian noise, the target stimulus was varied to create a –18 to 15 dB SNR in different trials. The final noise masker, SSN, was modulated to the same envelope as random target phrases, and was used with the target stimulus level being changed to create a –21 to 0 dB SNR in different trials, with this level also being chosen randomly with replacement. Results of this study provided evidence that similar voice characteristics (same sex of speaker for target and competition) provide more effective masking than when the target and competition speakers were not of the same sex. Additionally, the SNR produces a smaller difference in performance for speech maskers than for noise maskers, indicating that performance with energetic maskers are more adversely affected by poorer SNRs than when informational maskers were used.

Wilson, Carnell, and Cleghorn (2007) compared performance in two groups of listeners, one with normal hearing and one with hearing loss, on the Words-in-Noise (WIN) test using multitalker babble and SSN as competitions. In this assessment, four 35-word lists were presented to assess the different competitions at levels varying from 0 dB to 24 dB SNR with the competition being set at a consistent 70 dB HL. They determined that, while the two competitions had identical RMS and similar spectra, the differences in amplitude modulation allowed for an advantage when listening under multitalker babble. This was supported by the 2.1 to 2.3 dB improvement when listening under the multitalker babble condition in comparison to the SSN condition for normal-hearing listeners. This is due to the “dips” of improved SNR present in the multitalker babble condition, which were not present in the SSN condition, that allowed normal-hearing listeners to achieve a release from masking during these times, as suggested by Summers and Molis (2004).

The number of speakers utilized as competition may also have an effect on the masking provided. Simpson and Cooke (2005) preface their study examining human ability to identify consonants in N-talker babble by specifying that most speech is not heard in an ideal, quiet environment. With that being said, they evaluate the human ability to understand speech sounds under speech masking based upon the number of conflicting speakers (1, 2, 3, 4, 6, 8, 16, 32, 64, 32, 64, 128, 512, ∞), as well as, under SSN and babble-modulated noise. For the speaker competition, performance worsened as the number of talkers increased through the 8-talker competition and remained fairly stable until the 128-talker competition, at which point performance recovered to a similar level as was found for speech-shaped noise at the 512-talker competition. The babble-modulated noise was found to be a less effective masker when compared to competitions with more than two talkers. Although the babble-modulated noise does cause a very gradual decrease in performance as the number of speakers increase, the effect is much less than in the speech babble condition.

Rationale and Purpose

After a careful analysis of the available research on the effects of age, semantic judgment tasks, and different listening conditions, it was discovered that there is still work to be completed to better understand how individuals process speech in different listening conditions. The purpose of this study is to determine if aging has an effect on semantic processing in different informational and energetic masking conditions. It is hypothesized, based on the current published literature, that conditions with more linguistic, informational content will produce poorer accuracies and longer reaction times across age groups. Middle-aged adults, however, may differently impacted by the informational masking provided by the conditions with more fluctuation (reversed speech, 1-talker speech, 2-talker speech), as they have more experience listening to speech than their young-adult counterparts. Gaining more knowledge on the impact of aging on semantic processing in differing listening conditions may have widespread consequences in producing more favorable listening conditions for individuals across the lifespan.

METHODS

Participants

Participants for this study will be young adults, aged 19 to 30 years, and middle-aged adults, aged 40 to 60 years, with normal hearing sensitivity. All participants are to be speakers of American English, right-handed, and had no known history of brain injury, stroke, diabetes, neurologic, psychiatric, reading, speech, or language disorder. Participants will be compensated with a $10 Amazon gift card for approximately 1.25 hours of participation. Informed consent will be obtained in accordance with the guidelines provided by the Internal Review Board (IRB) at Illinois State University.

Inclusionary Tasks

Consent and Questionnaires. Prior to completing any measurements, consent will be obtained. After consent, a show case history will be completed to determine if the participant is eligible to complete the study. Case history elements that will be collected include participant age, gender, education, language, relevant medical diagnosis, and hearing health history. The form can be found in Figure 1.

If case history does not reveal any exclusionary characteristics, the participant will complete a handedness questionnaire. The Hand Preference Questionnaire, developed by Annett (1970), requires the participant to determine which hand they use most often when completing a variety of activities. This questionnaire also collects information about family members' hand preferences. This questionnaire can be found in Figure 2.

Cognitive Assessment. Prior to testing, participants will be screened for mild cognitive impairment utilizing the Montreal Cognitive Assessment (MoCA). This assessment utilizes short-term memory recall, visuospatial, executive function, phonemic fluency, verbal abstraction, attention, concentration, working memory, orientation, and language tasks to determine if cognitive impairment is present. To pass this screening assessment, participants must score better than 25 out of 30 points. This cutoff has a 90% sensitivity rate and an 87% specificity rate to identifying mild cognitive impairment (Nasreddine et al., 2005). Those who score below 26 points will be excluded based on the high probability that they have a mild, or greater, cognitive impairment that may influence their performance on the task.

Auditory Assessments. Otoscopy and tympanometry will be performed to identify potential outer and middle ear pathologies. Pure-tone air conduction testing will be completed across octave frequencies from 250 to 8000 Hz, with bone conduction testing being completed at 500, 1000, 2000, and 4000 Hz. Participants will be excluded from participating in the experimental task if their thresholds are greater than 25 dB HL, indicating a hearing loss.

Additional Auditory Assessments

Additionally, recognition scores (WRS) will be obtained separately in each ear using the Northwestern University Auditory Test No. 6 (NU-6) list of 25 words presented at 40 dB above the participant's three frequency pure-tone average (PTA). Each participant's PTA will be averaged from their pure tone thresholds at 500, 1000, and 2000 Hz. Performance on WRS is not an exclusionary criteria, therefore poor word recognition performance will not eliminate an individual from participating in the task.

The Quick Speech-in-Noise test (QuickSIN) will be completed following the word recognition task. This test will be presented binaurally at 70 dB HL. The QuickSIN establishes a signal-to-noise ratio (SNR) loss which can assist in determining a participant's ability to understand speech in noise. The QuickSIN takes approximately 10 minutes to complete and consists of six sentences presented with a background of four-talker competition at SNR levels ranging from 25 dB to 0 dB, decreasing by 5 dB for each sentence. This is completed twice with two different word lists. The assessment is scored by subtracting the total number of correct words for each block from 25.5, and then averaging the two scores. Results may range from 0 to over 15 dB SNR loss. Results ranging from 0-3 dB SNR loss indicate normal/near normal performance, which correlates with the ability to hear better than normal when in noise. Scores from 3-7 dB SNR loss indicate a mild SNR loss. Those in the mild loss range are noted in the

QuickSIN manual may have the ability to "hear almost as well as normal in noise" (Etymotic Research Incorporated, 2006). Scores ranging from 7-15 dB SNR loss indicate a moderate SNR loss consistent with the need for some directional qualities in hearing technology, and scores of greater than 15 dB SNR loss are consistent with a severe SNR loss that requires maximum SNR improvement to successfully communicate, which may necessitate a remote microphone system. Information from the word recognition in quiet and speech-in-noise tasks will be utilized to better understand the audiologic profile of each participant individually, as well as identify any correlation between these scores and that identified in the primary task. It should be noted that individuals will not be excluded from testing based on their QuickSIN performance.

Stimuli

Stimuli for the experimental semantic processing task will include monosyllabic word pairs recorded in a sound-treated room by a male monolingual English speaker. The words have also been used in various other studies (Martin et al., 2007; Davis et al., 2012; Davis et al., 2013; Davis & Jerger, 2014; Davis et al., 2015; Davis et al., 2017; Stanley et al., 2017; Stanley et al., 2019). Word pairs will be organized into blocks of 25 word pairs and will be presented as "Match (M)" and "No Match (NM)" pairs. M word pairs are semantically related, and NM word pairs are semantically unrelated. For example, a M word pair may include "cat" and "dog," as both fall under the semantic category of animals. Conversely, "skunk" and "cheese" would be a NM word pair because they fall under different semantic categories, animals and food. All M word pairs fit into category prototypes as defined by Van Overschelde et al. (2004) and include categories such as food, transportation, clothing, animals, and more. All word pairs will be examined to ensure that no combination of words could be mistaken to be a compound or disyllabic word.

Stimuli have been rate sampled at 22,050 Hz with 16-bit amplitude resolution. Stimuli used includes two-hundred and eight words chosen based upon concreteness, familiarity, and imagery rating identified by the MRC Psycholinguistic Database with ratings ranging from 100 to 700, higher ratings indicating a higher quality, and therefore being more desired. Mean concreteness rating was 594.27 (SD = 29.53), mean familiarity rating was 562.27 (SD = 40.66), and mean imagery rating was 592.11 (SD = 29.93) (Coltheart, 1981; Wilson, 1988). These mean ratings are greater than the mean ratings identified in the MRC Psycholinguistic Database, with ratings for 17 of the 208 words being unavailable.

The word stimuli were also analyzed by duration, fundamental frequency, and adjusted root mean square (rms). This revealed a mean duration of 550 msec (SC = 13.67, range = 478-600 msec), mean fundamental frequency of 121.17 Hz (SD = 10.9), and mean rms amplitude of –22.99 dB Full Scale (dB FS) (SD = -0.54). The mean rms amplitude was adjusted to approximate –23 dB FS using Adobe Audition 1.5 software, with dB FS values indicating intensity of the signal in comparison to the full scale of the software (Adobe Audition).

Participants will listen and respond to one of four list options (A, B, C, or D). Each list contains 10 blocks of word pairs, with 2 blocks containing each competition, as detailed below, and 2 blocks of word pairs presented in quiet. Each block will include 25 word pairs, totaling 250 word pair presentations for the list, not including practice items used to familiarize participants with the task. Between the two blocks, each condition contained a total of 25 M and 25 NM word pairs. Lists A and C and lists B and D have the same competition order (Table 1), and lists A and B and lists C and D have the same target stimuli order, making each list unique. Each list is balanced to contain an equal number of match/no-match word pairs. It should be noted that word pairs in quiet were presented in flipped order. For example, the word pair "dog, shoe" would be changed to "shoe, dog" in the second block of quiet.

Competition

Competition for this experimental task will consist of five listening conditions, four different types of speech competitions and in quiet. The four speech competitions utilized will be 1-talker speech, 2-talker speech, reversed 2-talker speech, and speech-shaped noise (SSN). A reading of The Wizard of Oz with an identified fundamental frequency of 118.94 Hz and rms amplitude of -21.24 dB FS will be used for the 1-talker speech condition. A combination of The Wizard of Oz and The Arizona Travelogue (fundamental frequency of 140.87 Hz and rms amplitude of -23.14 dB FS) recordings make up the 2-talker speech competition. Because the Arizona Travelogue has a duration of 6 minutes and 45 seconds, it was repeated to create an appropriate length for the experimental task. The reversed 2-talker speech competition was generated by reversing the 2-talker speech competition using Adobe Audition. The SSN competition was created by calculating the long-term average speech spectrum of The Wizard of Oz recording (Figure 3) in the Praat software (Winn, n.d.). The SSN was then edited in Adobe Audition to create a file of the appropriate length.

Room Layout

Audiometric and experimental task testing will be completed in a sound-treated room. Participants will sit in the middle of the room facing a computer monitor and an ear level loudspeaker located at 0° azimuth Additionally, ear level loudspeakers will be located at 90° and 270° azimuth. The participant will be seated equidistant from each of these loudspeakers by 1 meter. A response pad will be located to the immediate right of the participant's chair. An image of this layout can be found in Figure 4.

PROCEDURES

Experimental Tasks

Median Plane Localization Task. Prior to completing the experimental task, a median plane localization task (Jerger et al., 2000; Davis & Jerger, 2014; Stanley et al., 2017; Stanley et al., 2019) will be performed to ensure that the perceived loudness of the competition is the balanced between the right (90º azimuth) and left (270º azimuth) loudspeakers. The 2-Talker speech competition will be played simultaneously through the right and left loudspeaker for approximately 3 seconds at various intensity differences. Participants will then use an 11-point scale (Figure 5) to rate the perceived location of the sound. The intensity level of the right speaker will be set at 68dBA, and the left speaker level will be adjusted until midline is identified. The specific order of adjustment can be found in Figure 5.

Experimental Semantic Judgment in Noise Task. Participants will begin the experimental semantic judgment in noise task with a practice session, during which they will be observed by the researcher in the same room to evaluate for task understanding. Participants will be shown a visual detailing the buttons on the response pad (Figure 6) prior to the practice session and will be instructed to press “yes” for pairs where the two words fall into the same category to indicate a M and “no” for pairs where the two words do not fall in the same category to indicate a NM word pair. This session will begin with a brief description of semantic categories, which will then be demonstrated with 2 M and 2 NM pairs. After the participant understands the task, they will complete short blocks of 3 word pairs that will contain both M and NM word pairs for each listening condition in the following order: quiet, 1-talker speech, 2-talker speech, reversed speech, and SSN.

After the practice session, the participant will be administered the experimental task using one of the four task lists. Once the participant is ready to begin, they will be informed of the listening condition in which the block will be completed. Once they hear the competition, or lack thereof (in quiet), they are instructed to begin the block of word pairs. A 200 ms alert tone will be played to ready the participant for the reference word, which will occur 1700 ms after the alert tone. The probe word will follow the reference word by 2100 ms, after which a response will trigger the next trial, which will begin with the alert tone. After 25 word pairs have been administered, the program will provide an optional break for the participant. This cycle will continue until all 10 blocks of the experimental task is complete, or the participant chooses to withdraw themselves from the study (Figure 7). If the participant withdraws from the study, any completed participation will be omitted from the database.

Post-Experimental Task Interview. After the task is complete, the participant will undergo an informal interview. Questions asked in the interview may be found in Figure 8. Additionally, participants will be asked to provide a subjective order of difficulty for the listening conditions.

TABLES AND FIGURES

Table 1: A breakdown of the competitions used for each block of the experimental task for each list. It should be noted that Lists A and C and Lists B and D have the same competition orders, but the target blocks of word pairs are reversed.

	List A	List B	List C	List D
Block 1	1-Talker	SSN	1-Talker	SSN
Block 2	Reverse	1-Talker	Reverse	1-Talker
Block 3	Quiet	2-Talker	Quiet	2-Talker
Block 4	SSN	Quiet	SSN	Quiet
Block 5	2-Talker	Reverse	2-Talker	Reverse
Block 6	Reverse	2-Talker	Reverse	2-Talker
Block 7	Quiet	SSN	Quiet	SSN
Block 8	2-Talker	Quiet	2-Talker	Quiet
Block 9	1-Talker	Reverse	1-Talker	Reverse
Block 10	SSN	1-Talker	SSN	1-Talker

Figure 1: The Case History Form to verify that participants do not exhibit any of the exclusionary criteria noted in the consent form.

Participant Code: ________
Date: ________

Illinois State University

Participant Case History Form

Date of Birth: ____________ Age in Years ______ Gender: ________

Native Language: ______________________ Second Language: ____________
Primary language spoken at home: __________ Handedness: Right Left Both
Occupation: __________________________ Years of education: __________

Have you been diagnosed with any of the following? (Circle all that apply)

Anxiety
Attention Deficit Disorder
Autism
Concussion
Dementia
Depression
Diabetes
Dizziness/Balance Disorder
Dyslexia
Ear Disease/Disorder
Eye or Vision Problems
Head Injury
Hearing Loss
Language Disorder
Learning Disability
Neurological Disorder
Psychiatric Disorder
Reading Disability
Schizophrenia
Sleep Disorder
Speech Disorder
Stroke
Tinnitus
Other: __________

Current Medication:

____
____
____

Have you had a hearing test before: **Yes** **No**
Results: ______________________________________

Do you have trouble hearing in noisy environments? **Yes** **No** (Circle all that apply)

Group Setting
Movie/Play
Restaurant
Telephone
Television
Someone speaking from another room

Are sounds equally loud in both ears or is one ear better than the other? Explain.

____

Do you ever have ringing or buzzing (tinnitus) in your **RIGHT** or **LEFT** ear or **BOTH** ears?

____

Is it **CONSTANT** or **INTERMITTENT**? ____________

Do you have a history of ear infections or ear drainage? ______________________

Have you ever been exposed to loud noises in any of the following environments? (Circle all that apply)

Loud concerts/play in a band
Workshop Tools
Target Shooting/Hunting
Firecrackers
Yard Equipment
Farm Machinery
Military
Stereo, Headsets, or MP3
Aircraft
Motorcycles
Racing Engines
Explosions
Employment
Sporting Events
Other: ________________

Does anyone in your family have a hearing problem? ______________________
Describe: ______________________________________

Phone Number: ________________
Email Address: ________________

Figure 2: The Hand Preference Questionnaire given to participants to verify handedness.

The University of South Alabama

Hand Preference Questionnaire (Annett, 1970)

ID #: ______________________

Date: ______________________

Please indicate the hand(s) you use *most often* to do each of the following activities by circling: **R** for right **L** for left **B** for both

To write a letter clearly?	R	L	B
To throw a ball to hit a target?	R	L	B
To hold a racket in tennis, squash or badminton?	R	L	B
To hold a match while striking it?	R	L	B
To cut with scissors?	R	L	B
To guide the thread through the eye of a needle?	R	L	B
At the top of the broom while sweeping?	R	L	B
At the top of the shovel when moving sand?	R	L	B
To deal a deck of cards?	R	L	B
To hammer a nail into wood?	R	L	B
To hold a toothbrush while cleaning your teeth?	R	L	B
To unscrew the lid of a jar?	R	L	B

If you use the RIGHT HAND for all these actions, are there any one-handed actions for which you use the left hand? Please list:

If you use the LEFT HAND for all of these actions, are there any one-handed actions for which you use the right hand? Please list:

Do you have a twin? **Yes** **No** If so, what is hand preference of your twin: R L B

Please answer the handedness questions about your family (if applicable):

Hand preference of your mother:	R	L	B				
Hand preference of your father:	R	L	B				
Hand preference of your brother/sister:	R	L	B				
Hand preference of your brother/sister:	R	L	B				
Hand preference of your first child:	R	L	B	Child's other parent:	R	L	B
Hand preference of your second child:	R	L	B	Child's other parent:	R	L	B
Hand preference of your third child:	R	L	B	Child's other parent:	R	L	B

Figure 3: The script utilized to transform a speech passage to speech-shaped noise.

```
pause select all the sounds to analyze for the LTAS
Concatenate
Rename... Sound_for_LTAS

call make_LTAS Sound_for_LTAS 5.0 100 0 LTAS_combined

procedure make_LTAS .name$ .noisedur .freq_specificity
.final_intensity .noise_name$

      select Sound '.name$'
      .samplerate  = Get sampling frequency
      orig_int = Get intensity (dB)
          To Ltas... .freq_specificity

      if .final_intensity = 0
         .new_intensity = orig_int
      else
         .new_intensity = .final_intensity
      endif

      # Create white noise and convert to a spectrum
      Create Sound from formula... noise Mono 0 .noisedur .samplerate
randomGauss(0,0.1)
      To Spectrum... no
      select Sound noise
      Remove

      # Apply LTAS envelope to white noise spectrum and convert back to
sound
      select Spectrum noise
      Formula... self * 10 ^ (Ltas_'.name$'(x)/20)
      To Sound
      Scale intensity... '.new_intensity'
      Rename... '.noise_name$'

      # Cleanup
      select Ltas '.name$'
      plus Spectrum noise
      Remove

endproc
```

Figure 4: A visual of the room layout for the experimental task.

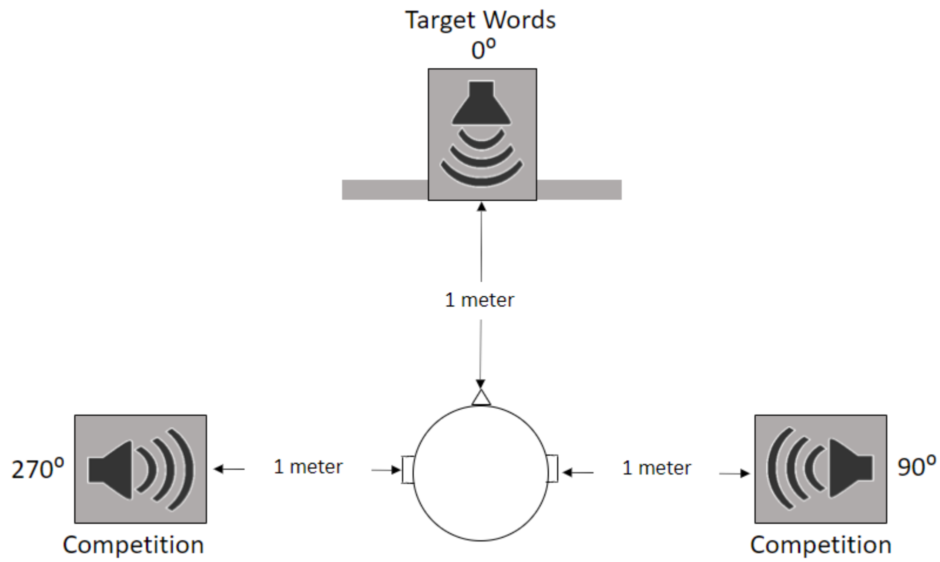

Figure 5: A visual that is shown to participants to allow them to label the perceived direction from which the competitions are coming during the Median Plane Localization Task. The table below is used for the individual administering the task to record participant judgments.

-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5
Extreme Left					Midline					Extreme Right

Median Plane Localization Task

REFERENCE: Right Speaker set at 68 dB HL (68 dBA)

+5 = Extreme Right   0 = Midline   -5 = Extreme Left

	Left Speaker	Ear Difference	Judgment
1	58	+10	
2	76	-8	
3	64	+4	
4	70	-2	
5	62	+6	
6	66	+2	
7	68	0	
8	64	+4	
9	74	-6	
10	70	-2	
11	60	+8	
12	72	-4	
13	68	0	
14	66	+2	
15			
16			
17			
18			

Figure 6: A visual that is shown to participants prior to the “practice” portion of the task to explain which buttons should be used and what each button means.

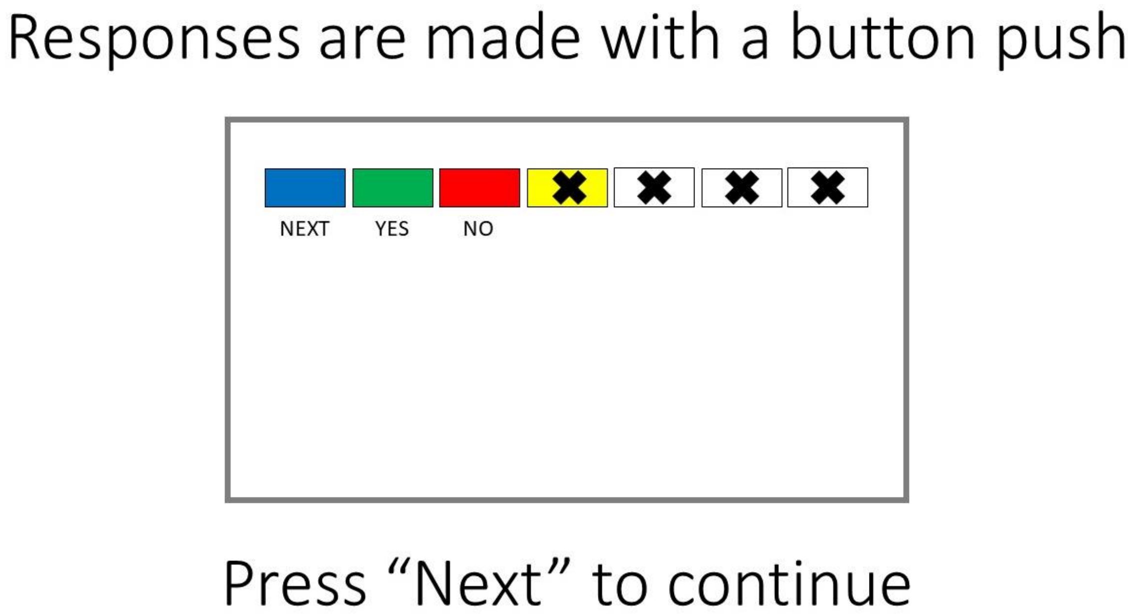

Figure 7: A visual of the presentation order and time spacing of stimuli for each word pair.

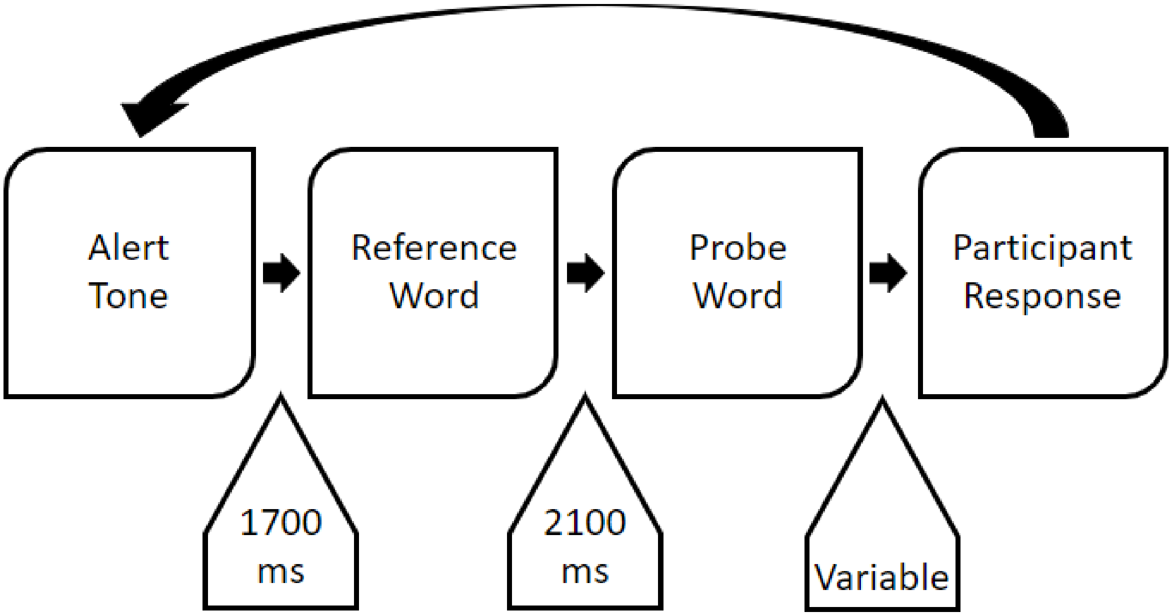

Figure 8: The Informal Post-Experimental Task Questions form. These questions are asked of each participant once the task is fully complete and their responses are documented.

Participant Code: ___________
Date: ___________

Informal Post-Experimental Task Questions

List _______

QUESTIONS

1. Did you hear all the words?

2. Did you miss whole or parts of words?

3. If you did not hear a word or the word pair, how did you make your decision? Did you use a strategy?

4. How often did you guess?

5. If you guessed, do you feel like you selected YES or NO more?

6. At any point was it painful or irritating?

OTHER COMMENTS:

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