THE EFFECT OF SEMANTIC INTERFERENCE

ON SPEECH PERCEPTION

IN NOISE ABILITY

by

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Abstract

The goal of this study was to determine the effect of semantically meaningful masker content on speech perception. The maskers included four-talker babble and conversational maskers presented forward and in reverse. Speech perception in noise ability was determined using the AzBio sentences. Semantic interference was identified when speech perception for the reverse masker condition was better than the forward masker condition. Poorer speech perception was found for the forward masker conditions than for the same masker conditions in reverse. Greater semantic interference was found for the four-talker babble conditions as opposed to the conversational masker conditions.

Introduction

The History of the Measurement of Hearing Ability

David Edwards Hughes was a pioneer in the field of audiology. He not only invented the first audiometer in 1879 but also observed many phenomena that are still commonly seen today in the field of audiology. Hughes's audiometer led to the development and commonality of hearing evaluations, including pure-tone threshold testing (Stephens, 1979). Within the field of audiology, pure-tone threshold testing has long been considered the gold standard for evaluating the function of the auditory system (Carhart et al., 1969). Pure-tone threshold test results tell the audiologist what the lowest level of sound, measured in dB HL, patients can hear across a range of test frequencies (Carhart & Jerger, 1959). However, the ability to perceive tones in quiet is generally not predictive of the ability to perceive speech in noisy environments (Dickson et al., 1946).

Defining Speech Perception

Pure-tone thresholds have been used to infer speech perception in quiet and in noisy environments (WHO, 2021). While pure-tone threshold testing evaluates how sensitive the auditory system is at detecting specific frequencies, it does not evaluate the ability to recognize speech in noise at suprathreshold levels (Vermiglio et al., 2017). Speech perception is the ability to recognize speech. Speech perception ability is often affected by the environment in which the speech is being heard. There are many different environmental situations in which speech can be presented. Speech can be heard in a quiet environment with minimal background noise or in a noisy environment (Holt & Lotto, 2010). The noisy environment could include speech, which contains semantic content, or other background noises that do not include language. Cherry (1953) described the "cocktail party" problem where the listener experiences difficulty understanding speech in the presence of multiple talkers.

The Need for Speech Perception in Noise Testing

Humans communicate in noisy environments such as restaurants, the workplace, and public transportation. The ability to differentiate speech from background noise is vital to participation in these social environments, as well as others. Determining speech perception abilities is important within the field of audiology because poor speech perception can limit communication and interaction with others. The presence of normal pure-tone thresholds is not a sufficient condition for normal speech recognition in noise ability. Self-reported difficulties with speech perception in background noise has been used as a "gold standard" test for speech perception in noise ability (Middelweerd et al., 1990; Vermiglio et al., 2012). Speech in noise ability must be measured directly and not inferred from pure-tone thresholds.

Several tests have been developed to supplement pure-tone threshold testing when speech perception in noise ability is affected. These tests include the Words-in-Noise test (WIN; Wilson et al., 2012) and the Hearing in Noise Test (HINT; Nilsson et al, 1994; Vermiglio, 2008). Table 1 shows a review of the literature on masker conditions and SRN performance. While there are multiple speech recognition in noise tests it is important to determine the diagnostic efficacy of these tests (Taylor, 2003). The AzBio test is one that has been used to measure speech recognition in noise abilities.

AzBio Test

The AzBio test was developed by Spahr et al. (2012) as a way to assess speech recognition in noise abilities for cochlear implant patients and candidates. There are 1000 sentences in the AzBio sentence corpus spoken by 2 male and 2 female talkers. The test was developed with the intention of creating sentence lists of an equivalent level of difficulty in order to best evaluate performance over a period of time. The validation procedure yielded 15 sentence lists that have been successfully used to evaluate the speech understanding of adults in the clinical and laboratory setting (Spahr et al., 2012). The diagnostic accuracy of the AzBio test was reported by Vermiglio et al. (2021) who concluded that the AzBio test was a significant predictor of self-reported speech recognition in noise loss in babble.

Determination of Semantic Interference

Semantic interference occurs when speech perception is poorer in masker conditions with greater semantic content (Carhart, 1959). In other words, the competing speech and its semantic information interferes with the listeners' ability to hear and understand the target speech. Sperry et al. (1997) evaluated word recognition performances for two listening conditions, a meaningful multitalker competing message and the same message in reverse to eliminate semantic content.

They found 15% better speech recognition performance with the backwards masker than with the forward masker. Sperry and colleagues concluded that the presence of semantic content in the forward masker had a more detrimental effect on speech recognition compared to the masker condition without semantic content. Wilson et al. (2012) used forward and backward multitalker babble to evaluate speech perception abilities using the Words-in-Noise (WIN) test. They found a 0.3 dB difference between the forward and backward multitalker babble scores, with the forward babble score being the highest. Calandruccio et al. (2018) used semantically meaningful and semantically anomalous maskers to evaluate speech perception in noise abilities. They reported a 0.5 dB difference between the scores of the semantically meaningful and semantically anomalous maskers. This was a small difference and they concluded that the presence or absence of sentence-level semantic content did not affect speech perception abilities.

The present study is an investigation of semantic interference using AzBio sentences in forward and backwards speech maskers. It was hypothesized that speech perception would be poorer for the forward masker conditions than the backwards masker conditions. The forward condition would produce greater semantic interference due to the presence of semantic content because of the listener's ability to understand the speech within the masker. Semantic content is eliminated when the maskers are played in reverse because the listener can no longer understand the linguistic content of the masker. This was hypothesized because the auditory cortex, which processes and interprets sounds including speech, has to simultaneously process the semantic content from both the target speech and the masker in the forward masker conditions (Purves et al., 2001).

Study	SRN Test	Noise Conditions	Performance of Forward Masker Result	Performance of Backwards Masker	Backwards masker minus forward masker scores	Level of Background Noise	Target Speech	Level of Target Speech	Adaptive or Fixed SNR	*p*-value
Sperry (1997)	Northwestern University Auditory Test No. 6 (NU-6)	Forward Mulitalker Competing Message and Backward Multitalker Competing Message	40.3% correct	56.1% correct	15.8 percentage points difference	Presentation level 40 dB SL re; PTA for 1.0, 2.0, 4.0 kHz	Female-talker version of NU-6 50-item word lists	Presentation level 40 dB SL re; PTA for 1.0, 2.0, 4.0 kHz	Fixed	$p < .01$
Wilson et al. (2012)	Words-in-Noise test (WIN)	Multitalker Babble Played Forward and Backwards and Quiet	4.2 dB S/N	3.9 dB S/N	≤4%; 0.3 dB difference	80 dB SPL	List 1 and List 2 of the WIN	104 to 80 dB SPL in 4 dB increments	Fixed	$p = 0.45$
Calandruccio et al. (2018)	Basic English Lexicon (BEL) with modified AzBio maskers	Semantically Anomalous and Semantically Meaningful	-3.8 dB SNR	-3.3 dB SNR	0.5 dB difference	58.5, 59.8, and 61.2 dB (-1, -3, and -5 dB SNR)	List 6-13 and 16-20 of the BEL	55 dB SPL	Fixed	$p = 0.78$
Present Study	AzBio with standard and alternative maskers	Speech Maskers Forward and Backwards				65 dBA	AzBio Sentences	65 dBA		

Table 1. A Review of the Literature on Masker Conditions and SRN Performance.

Methods

Participants

Fifty-two native English speakers participated in this study. Participants were students recruited from East Carolina University. The participants were offered extra credit points if they volunteered to take part in the study. All participants had normal pure-tone thresholds (≤ 25 dB HL, 0.25 – 8.0 kHz) with the exception of two participants who had thresholds of 30 dB at 8.0 kHz in the right ear. The mean age was 21.33 years (SD = 1.96). All but two participants were female.

Pure-tone Testing

The pure-tone thresholds for the participants were measured at the following audiometric frequencies: 250, 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz. A modified Hughson-Westlake protocol was used to obtain pure-tone thresholds (Carhart & Jerger, 1959). Using the inclusion criteria from Vermiglio et al. (2012), participants with normal pure-tone thresholds (≤25 dB HL, 250-6000 Hz) were included in this study.

AzBio

The AzBio test was used to evaluate binaural speech perception in four-talker babble forward, four-talker babble backwards, conversational masker forward, and conversational masker backwards. The lists used in this study included lists 2, 4, 9, 10, 11, 13, and 15 due to being found to be equivalent in difficulty (Schafer et al., 2012). The AzBio sentences and maskers were presented at 65 dBA (0 dB SNR). The AzBio was administered binaurally under supra-aural headphones in a sound-treated booth. All test conditions and sentence lists were randomized.

Masker Types

Semantically meaningful and semantically anomalous maskers were used as masking conditions. The semantically meaningful maskers included four-talker babble forward and conversational forward. Semantically anomalous maskers included four-talker babble backwards and conversational backwards. The four-talker forward condition was taken from the same Auditec source file used for the Quick Speech-in-Noise Test (Killion et al., 2004). The conversational forward masker was found on youtube.com from Everyday Cinematic Sounds and was calibrated to the same RMS levels as the other maskers. These maskers were chosen to provide linguistic distraction from the target speech. The semantically anomalous maskers are identical to the semantically meaningful maskers except they are time-reversed. Reserving the masker strips it of linguistic content which could distract from the target speech and lead to semantic interference.

Results

The descriptive statistics including the mean score, standard deviation, maximum percentage, minimum percentage, and the range of scores are presented in Table 2. The maximum and minimum scores for the four-talker forward condition were 75.36% and 15.07%, respectively. This was the largest range of scores (60.29 percentage points) out of all of the masker conditions. Additionally, the minimum score was the lowest score out of all of the masker conditions. The mean score for the four-talker backwards condition was 66.92%. This was the highest mean score of all the masker conditions. The maximum and minimum scores for the conversational backwards condition were 89.86% and 45.19% respectively. The maximum score of 89.86% was the highest score of all of the results.

Semantic interference was calculated by subtracting the backwards masker score minus the forward's masker score. The differences between scores were found for the four-talker babble masker conditions and the conversational masker conditions. The negative minimum scores for semantic interference in the conversational and four-talker babble maskers indicate that those maskers provided a semantic advantage.

Masker Type	Mean (%)	SD	Max (%)	Min (%)	Range
Four-talker Forward	44.79	13.56	75.36	15.07	60.29
Four-talker Backwards	66.92	10.30	85.51	45.65	39.86
Conversational Forward	64.35	11.42	84.89	39.86	45.04
Conversational Backwards	65.62	9.80	89.86	45.19	44.67
Four-talker Babble Semantic Interference	22.12	12.64	58.31	-0.15	58.46
Conversational Masker Semantic Interference	1.27	11.08	29.71	-24.17	53.88

Table 2. Descriptive Statistics for all AzBio Scores.

A repeated-measures ANOVA was conducted to investigate the main effect of masker condition on AzBio scores. This analysis revealed that the main effect was statistically significant ($F = 52.84$ for masker condition, $p < 0.0001$). A post-hoc analysis was conducted using one-sample t-tests. Poorer performance was found for the four-talker forward masker than the four-talker backwards masker (22.13 percentage points, $p < .0001$). This indicates that speech-in-noise performance was better when the masker was backwards and that the semantic content of the four-talker forward masker had a negative effect on speech perception (semantic interference).

Figures 1 through 5 represent scatterplots of the data. For scores that are above the diagonal line, the y-axis scores are better than the x-axis scores. Scores that are below the diagonal line indicate the x-axis scores are better than the y-axis scores. Poorer performance was found for the conversational forward masker than the conversational backwards masker as seen in Figure 1; however, this difference was not statistically significant (only 1.27 percentage points, $p = 0.41$). Comparisons of the scores of the forward and backwards condition of the four-talker masker condition are shown in Figure 2. Ninety-eight percent of subjects demonstrated an advantage in their recognition of speech in background noise in the four-talker backwards condition compared to 2% in the four-talker forward condition. Figure 3 shows the scores of the two forward conditions, four-talker forward and conversational forward. Ninety-four percent of subjects demonstrated an advantage in their recognition of speech in background noise in the conversational forward conduction compared to 6% of subjects in the four-talker forward condition. The scores of the two backwards conditions, four-talker backwards and conversational backwards are compared in Figure 4. Sixty-four percent of subjects demonstrated an advantage in the conversational backwards condition compared to 36% of subjects in the four-talker backwards condition. Figure 5 provides a comparison of the four-talker masker condition semantic interference score and the conversational masker condition semantic interference score. Semantic interference for the four-talker babble masker conditions was demonstrated by 100% of subjects. Semantic interference for the conversational masker conditions was demonstrated by 56% of subjects while 44% of subjects demonstrated a semantic advantage for these test conditions.

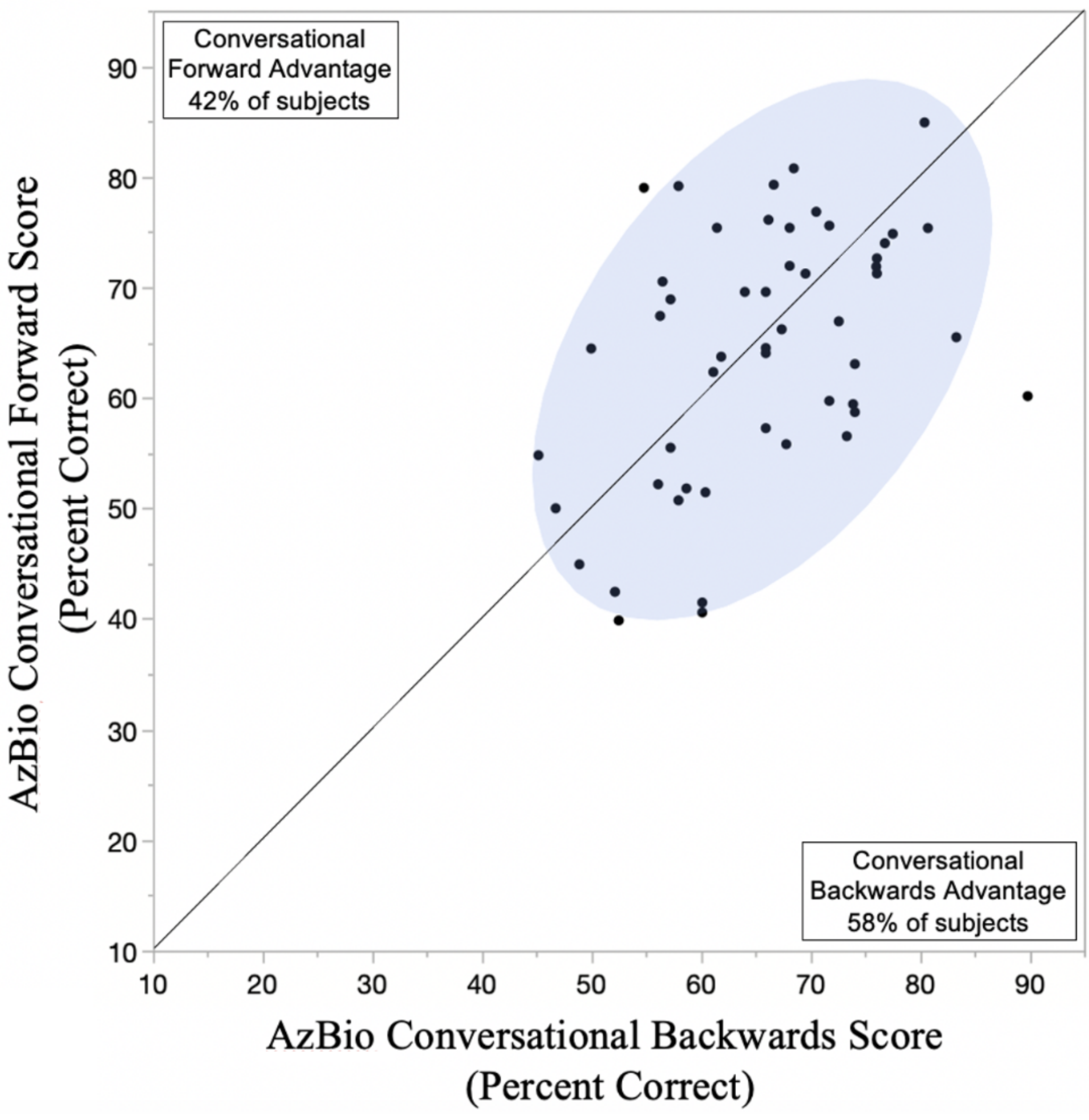

Figure 1. Scatterplot of Conversational Forward vs. Backwards Scores.

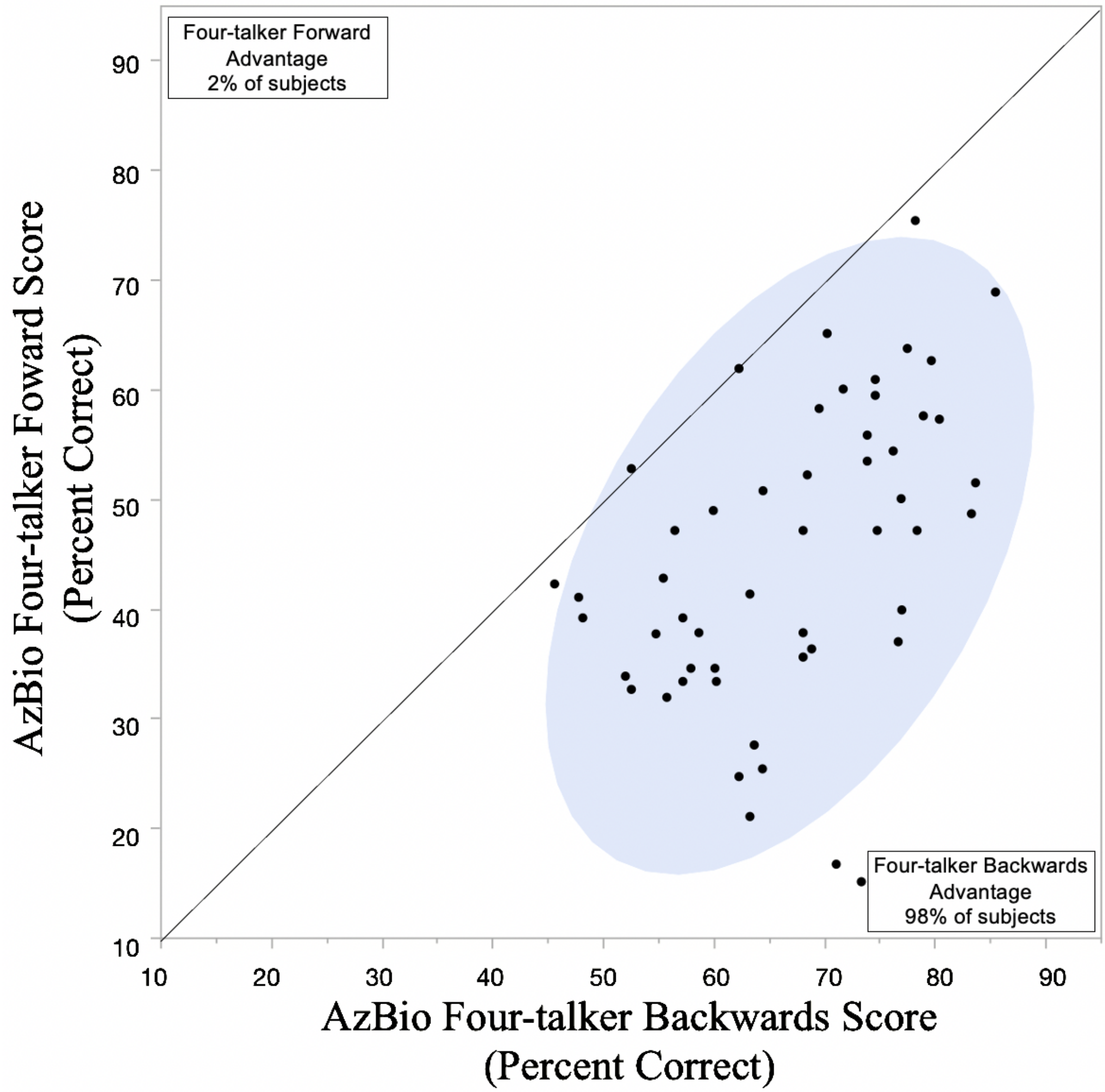

Figure 2. Scatterplot of Four-talker Forward vs. Backwards Scores.

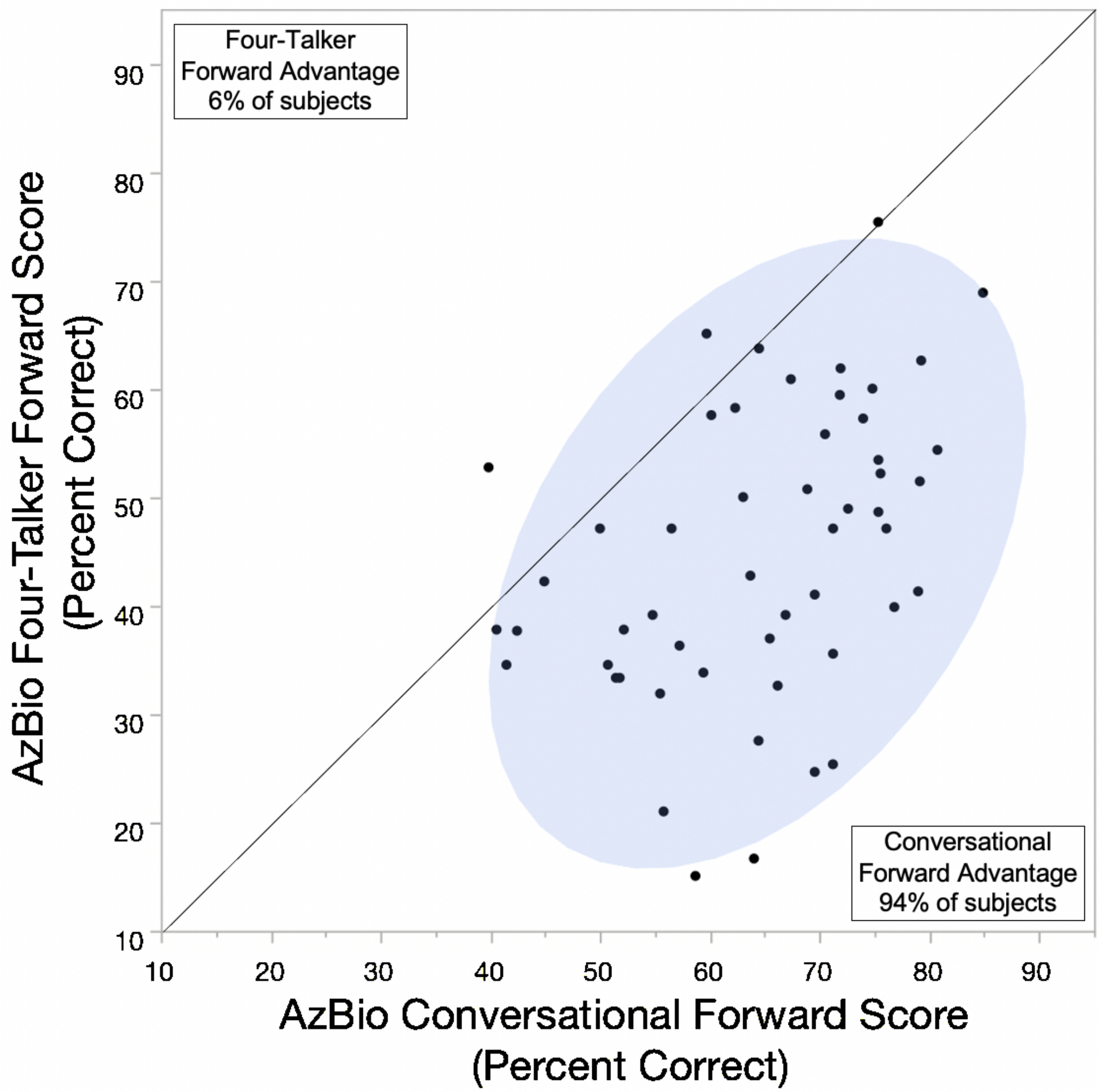

Figure 3. Scatterplot of Four-talker Forward vs. Conversational Forward Scores.

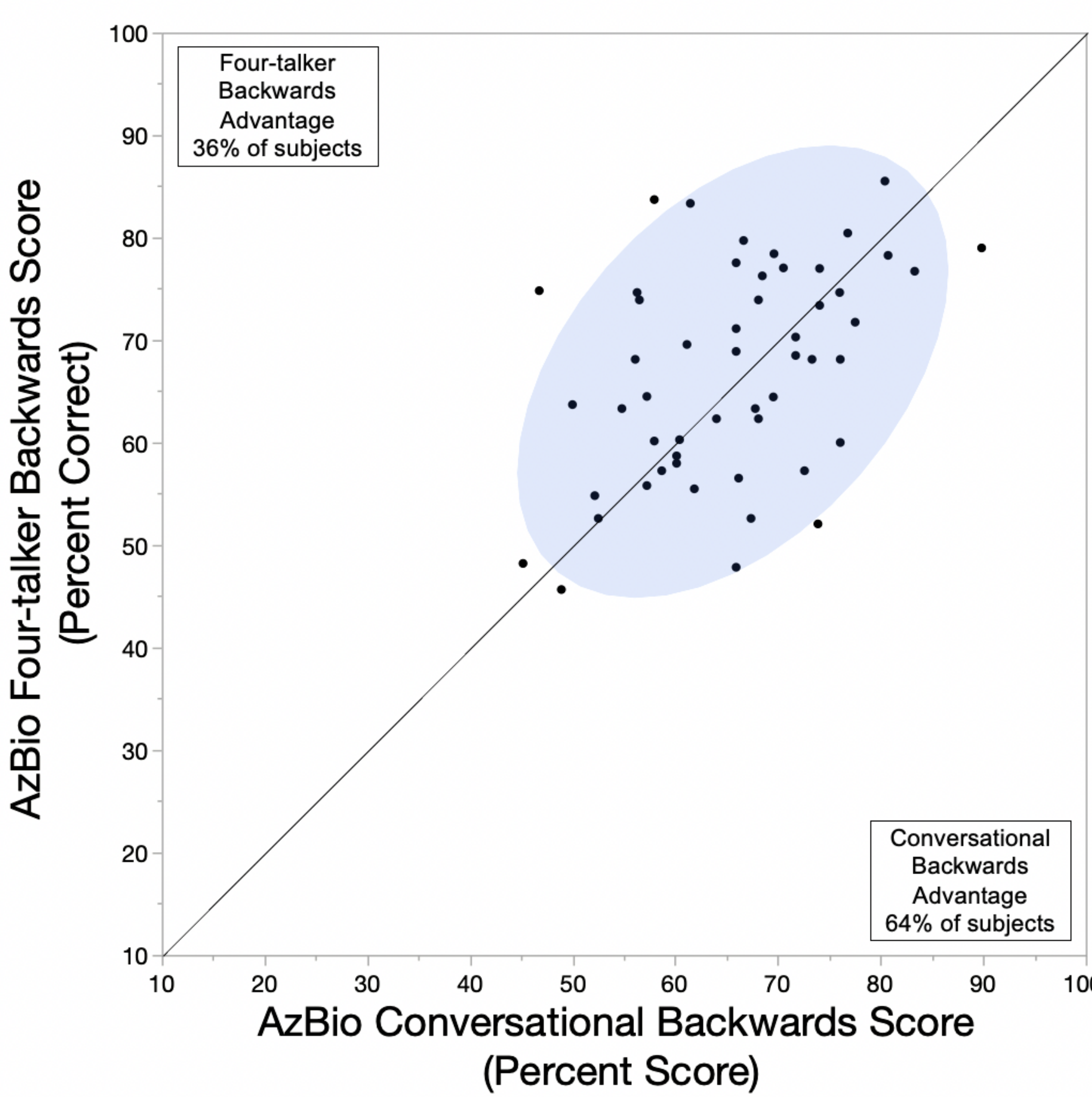

Figure 4. Scatterplot of Four-talker Backwards vs. Conversational Backwards Scores.

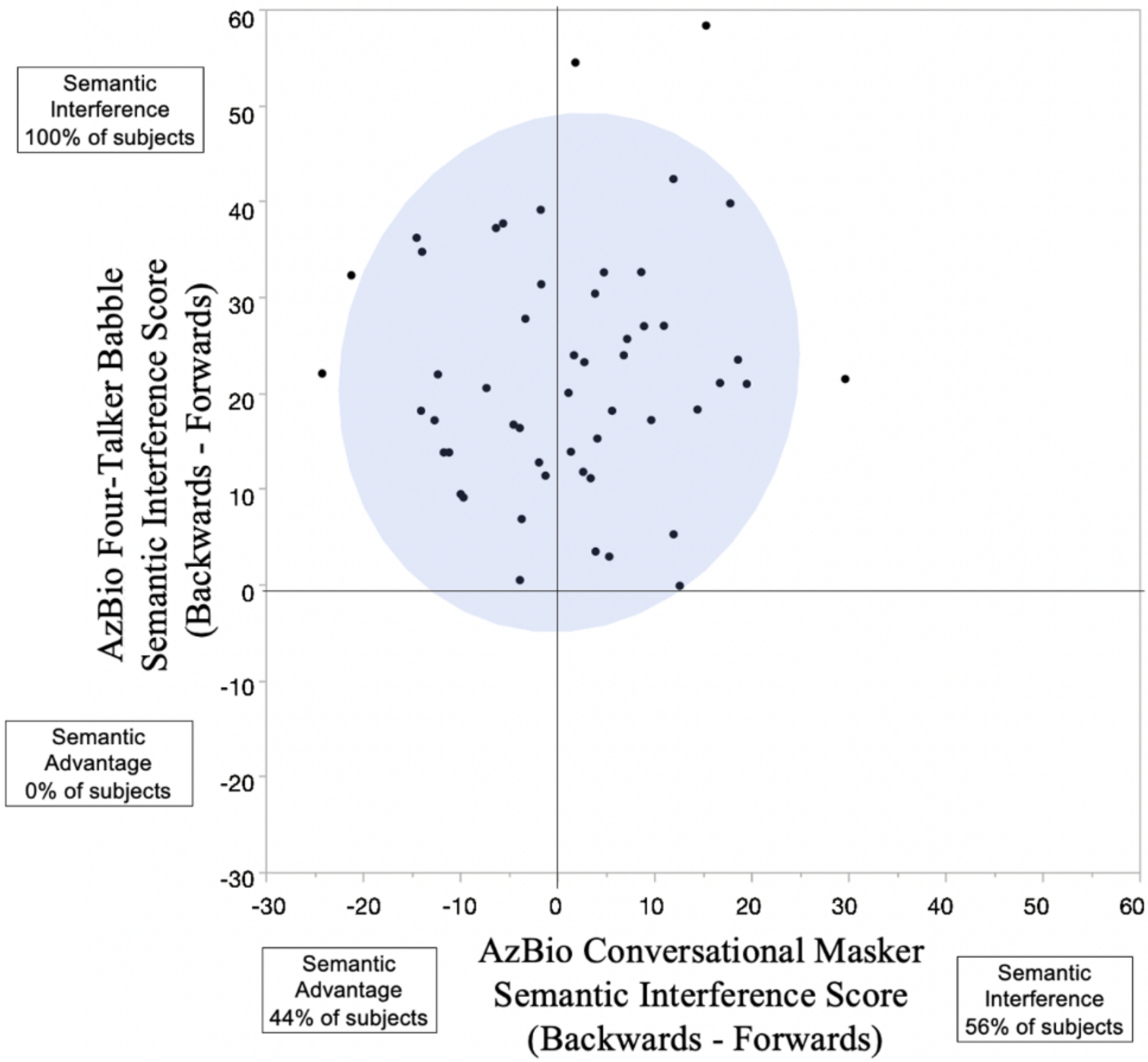

Figure. 5 Scatterplot of semantic inference for four-talker babble vs. conversational masker.

Discussion

The hypothesis of this study was that poorer speech perception in noise ability would be found for conditions with semantic content as opposed to masker conditions without semantic content. The results of the current study support this hypothesis. These results are consistent with the findings of Calandruccio et al. (2018) who reported that on average, study participants had poorer thresholds for semantically meaningful than semantically anomalous masker conditions. The results of the present study reflect the findings of Calandruccio et al. (2018) because each forward condition (semantically meaningful) had lower scores on the AzBio than the backwards condition (semantically anomalous) on each of the masker types. The results of the present study are also consistent with Wilson et al. (2012) who reported better performance (4.4%) on the backward-babble condition (at 0 dB S/N) than in the forward-babble condition ($p = 0.41$).

According to Medwetsky (2011), the act of processing speech is complex and incorporates many different areas of the brain. Speech recognition in noise ability can be impacted by many factors. One of those potential factors is the presence of Central Auditory Processing Disorder (CAPD). However, CAPD can have multiple definitions. Many authors have stated that CAPD is related to speech in noise deficits (ie., Musiek et al., 2018) but this is not always clear. People with CAPD may perform within normal parameters for speech in noise testing (Vermiglio, 2014). The current study did not include testing for the presence of CAPD (a very broad category of auditory functions), instead, speech recognition in noise ability was evaluated (a very narrow focus of auditory function).

Research on speech perception in noise abilities has been conducted since the 1920s (Fletcher, 1929); however, this type of testing has not seen widespread clinical use (Mueller, 2016). The results of the present study revealed that poor speech recognition in noise ability may exist in the presence of normal pure-tone thresholds. All of the subjects in the current study had pure-tone thresholds in the normal range of ≤25 dB HL in the 250-6000 Hz range. However, some participants exhibited very poor performances even though they had normal pure-tone thresholds. With the findings from the current study and others such as Calandruccio et al. (2018) and Wilson et al. (2012), it is important to continue investigating speech perception in noise to further our understanding of speech perception in the presence of background noise for the field of audiology.

Conclusions

A significant main effect for masker condition was observed in the present study. Poorer speech perception was found for the forward masker conditions than for the same masker conditions in reverse. Greater semantic interference was found for the four-talker babble conditions as opposed to the conversational masker conditions. This is likely due to the greater semantic content of the four-talker babble masker than the conversational masker. The results support the hypothesis and are consistent with Sperry et al. (1997) who found that the meaningful masker had a significantly more detrimental effect on speech perception in noise ability than the non-meaningful speech maskers.

Other factors that can impact speech recognition in noise could be the environment in which speech is being heard, the level of the background noise in the environment, and the type of background noise. The patient who is struggling to understand speech in background noise may also have other underlying conditions unrelated to hearing but rather related to attention-deficient or learning disorders.

Clinical Implications

Speech in noise testing can provide information that the audiogram cannot. Both measures are needed to be able to get a complete measure of the auditory ability of the patient. Without speech in noise testing, the audiologist is lacking important information about the patient's ability to understand speech in everyday life, and this may affect treatment recommendations. The current study may provide guidance for the development of clinical protocols for determining semantic interference for clinical patients, which would be beneficial to the patients and audiologists. A patient's ability to understand speech in background noise in its many different forms may provide their audiologist with additional information about how to provide the highest standard of care for their patient to improve their quality of life.

Study Limitations

Limitations of this study included a limited age range and gender variation among the participants and a limited number of masker conditions. Studies evaluating a wider age range and more diverse participants may provide additional information regarding the impact of semantic interference and other factors that contribute to difficulty in competing noise.

Future Research

It is recommended that future research examine the effect of alternative maskers on speech perception in noise abilities or all age ranges. Age or gender may contribute to the ability to understand speech in noise. These two variables were not evaluated in regards to speech perception in noise abilities in the current study. Future research should determine participant factors responsible for the wide range of semantic interference across subjects. Another study using similar methods could also be conducted using participants that have various degrees of hearing loss.

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