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Effects of type of context on use of context while lipreading and listening

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EFFECTS OF TYPE OF CONTEXT ON USE OF CONTEXT WHILE LIPREADING AND LISTENING

by

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Abstract: This study examined the effects of context type on the use of context while lipreading and listening. Results indicate that the ability to use context by type and modality are not global skills, but instead are specific to the context type and perceptual modality in use. Results further suggest that context is more readily used in the visual channel over the auditory channel.

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Introduction

Conversation is key to fostering and maintaining relationships. A degraded auditory signal—such as that caused by a hearing loss—can lead to significant communication breakdowns that require conscious repair in order to continue conversation (Tye-Murray, 2009). In the instance of a communication breakdown, individuals may employ a communication strategy to recover missing information. In a common repair strategy, a person may make a request for contextual information (e.g. "I missed that, what are we talking about?") (Tye-Murray, 2009). The current study was designed to clarify questions regarding the use of context in the auditory and visual channels. The results from this study could support the continued development of a new test of lipreading and context as well as characterize the way individuals use contextual information in settings that require the target to be received via the auditory or visual channels.

Context comes in many forms; it can be topical context (knowing what the sentence will revolve around), sentence-based context, or situational context (Boothroyd, Hanin, & Hnath, 1985; Kalikow, Stevens, & Elliott, 1977; Goebel, Tye-Murray, & Spehar, 2012). The current study focused on sentence-based and situational context.

Sentence-based context can be derived from the content of a sentence. It "…imposes constraints on the set of alternative words that are available as responses at a particular location in a sentence, and … [means] that the intelligibility of words increases when the number of response alternatives decreases" (Kalikow et al., 1977, p.1338). For example, in the sentence "*I saw elephants at the zoo,"* each word in the sentence provides further constraints for the final word. *I saw* could be followed by a seemingly infinite number of words, but when followed by the words *elephants*, *at*, and *the*, the word *zoo* becomes a most likely final word. A test of

sentence-based context is the Speech Perception in Noise Test (SPIN), (Kalikow et al., 1977; Bilger, Neutzel, & Rabinowitz, 1984). This assessment contains lists of High Predictability and Low Predictability sentences with which clinicians can examine an individual's use of sentence-based context.

Situational context is derived from the surroundings during conversation (Goebel et al., 2012). For example, while at a baseball game, a communication partner may assume that conversation will most likely revolve around topics concerning the stadium or recent plays on the field. This type of context can be examined with a developing test call the Illustrated Sentence Test (IST, described below) (Tye-Murray, Spehar, Hale, Myerson, & Sommers, submitted). In this assessment, context is provided in the form of a context-rich picture containing relevant information about a target sentence, which is presented for lipreading. See Figure 1 for an example.

As previously mentioned, individuals with hearing loss must often use contextual information in different settings in order to maintain fluidity of conversation. They may use residual hearing abilities to pick up contextual cues in the auditory channel, or they may rely on visual cues that are lipread to understand what is said. For this reason, it is important to understand differences between how one may use contextual information differently depending on whether the target information is received auditorily or visually. Furthermore, it is important to characterize how contextual information is used depending on the type of context provided.

Many studies have evidenced the benefit that older and younger individuals receive when context is provided in the auditory channel (Pichora-Fuller, 2008; Sommers & Danielson, 1999; Dubno, Ahlstrom, & Horwitz, 2000). For example, Sommers and Danielson (1999) studied younger and older adults with normal hearing on their ability to benefit from contextual

information in the SPIN test sentences. They calculated the percent correct performance for final-word identification of the High Predictability and Low Predictability sentences when presented in a difficult Signal to Noise Ratio (SNR). The authors found that both groups of participants (older and younger) received significant improvements from the addition of contextual information in the auditory channel.

Assessment of lipreading and the use of contextual information is more difficult. One of the biggest pitfalls to avoid is a floor effect due to the difficulty of the task, especially when the context is provided within the sentence (e.g. sentence-based context) (Gangé, Seewald, & Stouffer, 1987). Gangé et al. (1987) reported that individuals lipreading the SPIN test sentences could not understand words well enough to perform above floor level. This made the assessment of lipreading and use of context difficult.

To avoid floor effects, tests of lipreading and context have been developed with many different types of contextual stimuli. Pelson and Prather (1974), Tye-Murray et al. (submitted), and Goebel et al. (2012) all used a picture presented before the target sentence to provide situational context. Garstecki and O'Neill (1980) used contextual scenery projected behind the person being lipread. Additionally, Smith and Kitchen (1972) presented written topic words as a form of context for participants before lipreading a sentence. Results from these studies all demonstrated that when lipreading a target sentence, contextual information benefits lipreaders who have normal hearing (Smith & Kitchen, 1972; Pelson & Prather, 1974; Tye-Murray et al., submitted; Goebel et al., 2012) and who are hearing impaired (Pelson & Prather, 1974; Garstecki & O'Neill, 1980; Tye-Murray et al., submitted).

When investigating how people use contextual information during conversation, it is important to consider if individuals use context differently when they are lipreading or when they

are listening. This use of context may be a skill which can be improved through practice or training. To begin understanding this ability, this study will investigate the use of context across different modalities. The current study is designed as a follow-up to Goebel et al. (2012), which considered within subjects differences in the ability to benefit from contextual information when perceiving targets in the auditory and visual channels. The study was conducted with two primary goals. First, the authors wanted to further develop the IST as a measure of lipreading and context. Because this test was originally designed for use with children, the authors wanted to determine if this assessment could be used in an adult population. Second, the authors wanted to determine if there were differences between how individuals would benefit from contextual information when the target was presented auditorily (sentence-based SPIN sentences) or visually (situational IST sentences). To complete this second goal, the authors used the SPIN test in the auditory assessments and the IST in the visual assessments.

In the lipreading portion of the Goebel et al. (2012) study, young adult participants completed the IST in two lipeading conditions. In the context condition, they were provided with a picture that contained contextual information about the target sentence prior to seeing the lipreading target. In the no-context condition, participants saw only the target sentence to be lipread. Participants were scored on their percent correct understanding of keywords in each condition, and a normalized benefit score was calculated.

In the listening portion of the study, Goebel et al. (2012) used the SPIN test sentences presented in the High Predictability (context) and the Low Predictability (no-context) conditions. In the context sentences, contextual information was considered any part of the sentence preceding the final word, while the final word was considered the target. In the no-context conditions, the final word remained the target. An adaptive staircase method was used to vary the

SNR to fifty percent correct performance on final word recognition when listening for both lists. The differences between the SNRs in the two conditions were considered the benefit derived from context.

The results from Goebel et al. (2012) suggested that the IST could be used with adults. Participants performed in a range of lipreading abilities, avoiding floor level performance in the no-context condition, and ceiling level performance in the context condition. Not surprisingly, the authors found a significant improvement from context in lipreading and listening for all participants. When comparing the benefit from context between sentence-based auditory stimuli in the SPIN test and situational visual stimuli in the IST, the authors found no correlation between the benefit scores for the lipreading and listening tasks; there was no measureable relationship between benefit from context in the two modalities.

The lack of correlation between benefit from context in the auditory and visual channels may have important implications in rehabilitative research. It could suggest that the ability to use contextual information is specific to the modality in which the target was perceived rather than a global skill utilized the same way for lipreading in the visual channel and listening in the auditory channel. In order to determine if this is true, further investigation must be conducted to account for limitations in this study.

The major limitation in the Goebel et al. (2012) experiment was the lack of consistent contextual type between the lipreading and listening tests. Because the lipreading assessment was completed with situational context in the IST and the listening assessment was completed with sentence-based context in the SPIN test, one must be sure whether or not the context type affected the relationship between the benefit scores. It should be determined if the lack of

correlation would remain or if a correlation would appear between the two modalities when the type of context is held constant throughout testing.

The current study controlled for the possible limitations of the Goebel et al. (2012) experiment in order to examine the reliability of its results regarding the relationship between use of context in the auditory and visual channels. The study also continued evaluating the IST for use in an adult population. Adapted versions of the IST and the SPIN sentences were created for use in both modalities. In creating these adaptations, the study attempted to overcome obstacles of previous floor level performance found in other studies in lipreading SPIN sentences as well as provides appropriate controls for examining the nature of contextual benefit across modality.

The current investigation considered two research questions. The results from these questions have direct implications for aural rehabilitative strategies and training. First, the study investigated if the use of context varies by modality when the type of context is held constant. The experimental design examined how individuals differ in their ability to lipread or listen to a target when the type of contextual information is the same in every condition. Benefit scores were calculated when participants lipread and listened to IST sentences and when they lipread and listened to target words in the SPIN sentences in context and no context conditions. These scores were examined for correlations and differences when the target was delivered auditorily and when it was delivered visually. It was expected that significant correlations between benefit for lipreading and listening scores would be found when the type of context was held constant. This outcome would suggest that the use of context is not a modality-specific skill, but that it is a global skill used similarly regardless of the modality in which it is provided.

The second research question was an inverse of the first. The study examined if the ability to benefit from context would vary by the type of context used when the modality was

held constant. In other words, would the benefit scores from the IST and SPIN test co vary or show any differences when compared in the listening-only and the lipreading-only conditions? It was expected that these scores would also show a relationship, and that individuals would use contextual information similarly regardless of the type of context provided. Additionally, it was hypothesized that there would be no differences between the average benefit scores for the two types of context.

Understanding the nature of how context is used in both the auditory and visual channels can help rehabilitation specialists in the future to develop specific training programs tailored to the needs of hearing impaired patients. The results from this study can indicate whether training should be tailored toward specific types of context or the use of context in general, and they can help determine if training should be focused on the auditory and visual channels separately due to different uses of context in each modality.

Methods

Participants

Participants were 20 young adult females, aged 21 to 30 years (*M*=23.73 years, *SD*= 1.86 years). All participants were screened for normal hearing (20 dB HL or better) with pure tone thresholds at octave frequencies 250 through 8000 Hz. Screening procedures were completed using a calibrated Madsen Auricle audiometer and TDH-49 headphones. Participants were screened for corrected or uncorrected vision of 20/40 or better on a Snellen Eye Chart. Written consent was obtained from all participants. This study was approved by the Washington University School of Medicine Human Research Protection Office.

Stimuli

Illustrated Sentence Test. The IST is modeled after Pelson and Prather (1974) (Tye-Murray et al, 2012). It is an open set lipreading assessment that uses context-rich illustrations presented before sentences to be lipread. It consists of 120 sentences each using vocabulary from the Bamford-Kowal-Bench Sentences (Bench, Kowal, & Bamford, 1979). Each target sentence has a corresponding picture, which is intended to provide situational context to the individual taking the test. In the context conditions, the participant is presented with a contextual picture for 1.5 seconds followed by a target sentence, which she was instructed to repeat. In the no-context conditions, participants lipread the sentence and repeat what they see or hear with no picture clue. All sentences were presented in 4-talker babble at 62 dB SPL.

For the current study, the IST stimuli were adapted for use in both the lipreading/listening and context/no-context conditions using 4 lists of 25 sentences. See Table 1 for an overview of test conditions. In the lipreading conditions, the test was administered as described above for assessing lipreading with and without situational context. Testing the auditory condition was

similar; however, stimuli were presented so that the participant could not see the talker, but would only hear her speaking. Pilot testing determined that an SNR of -8 provided enough difficulty while listening to avoid ceiling effects in the context condition and floor effects in the no-context condition. In both conditions of the IST, participants were instructed to repeat the entire sentence they lipread or heard.

SPIN Sentences. The SPIN sentences were used to assess the use of sentence-based context. Audiovisual recordings of the SPIN sentences were created in order to test in both auditory and visual conditions. Two lists (24 sentences each) of the High Predictability (context) and two lists (24 sentences each) of the Low Predictability (no- context) sentences were recorded. An example of a high predictability sentence is *"Cut the bacon into strips."* An example of a low predictability sentence is *"Bob heard Tom called about the strips."* The speaker was a young adult female with a Midwest dialect. The digital audio and video samples of the recordings were edited using Adobe Premiere Elements and leveled for amplitude using Adobe Audition. Pilot testing determined that a -4 SNR provided enough difficulty while listening to avoid ceiling and floor effects in the two context conditions.

It is important to note that a primary question in the current study was to compare the use of two types of context (*situational* and *sentence-based*) when lipreading and listening, while at the same time allowing for the comparison of modality (*auditory* and *visual*) within each type of context. Refer to Table 1 for test conditions. Additionally, because developing the IST was also a major focus, it was important to ensure that the comparisons across the two types of context were not confounded by the way in which the context was provided. To maintain the ability to compare across types of context and modality in a manner consistent with the IST, the SPIN

stimuli were created in a way that held the modality of the context constant while only changing whether the context was or was not provided.

To ensure the reception of the context in the SPIN sentences, contextual information was always delivered auditorily, at a level in which the participants could hear the context. This means that regardless of whether or not the participant was lipreading or listening to the target word, the delivery of the contextual information was always the same. The SPIN sentences were modified in this way for two reasons. First, to compare across modality in the same test (*IST* or *SPIN test*), the context in the lipreading sentences needed to match the context in the listening sentences. Otherwise, it would be impossible to determine how much context was lost due to the difficulty of lipreading the entire sentence. By always delivering the contextual information in the SPIN sentences via the auditory channel, this study allowed for a more direct comparison between modalities when the target was perceived via lipreading or listening. Secondly, the consistent delivery method of the contextual information in the SPIN sentences allowed for a more direct comparison of the type of context when the modality for perception of the target was same. For example, in the IST, the picture is always the method of providing context when lipreading or listening. Similarly, when using the SPIN sentences, the context was always provided in the auditory channel while the perception of the target word was via lipreading or listening. With the context delivery method held constant across context type, comparisons could consider ability to use contextual information when perceiving the target across context type. A detailed description of the modified SPIN test sentences is provided below.

In both the listening and lipreading conditions of the SPIN test, the context portion of the sentence (all but the final word) was delivered auditorily. In both the context and no context conditions of the lipreading presentations, participants saw a picture of the speaker with her face

in the final position of the word preceding the target, while they listened to the first part of the sentence. This was presented at -4 SNR. When the target word in the sentence was reached in the lipreading sentences, participants saw the speaker say the final word, but did not hear it. In assessing listening performance, participants continued listening to the final word while the image on the screen remained frozen (also on the final sound of the penultimate word). See Figure 2 for a graphical representation of the timing for SPIN sentence construction.

Procedure

Following consent and screening, four lists from both the IST and SPIN test were administered during the test session. For the IST and SPIN test assessments, participants received a listening context, listening no-context, lipreading context, and lipreading no-context condition. Test lists were counterbalanced to avoid list effects, and test order was counterbalanced to avoid learning effects in both assessments. Participants sat in a sound-treated booth in front of an ELO 17-inch touch screen monitor, and verbal instructions for the tests were given for each test condition. All auditory stimuli were presented through loudspeakers positioned at +/- 45 degrees azimuth from the participant.

For the IST, eight practice sentences were given at the beginning of testing. Participants were instructed to listen to or lipread the entire target sentence and repeat it verbally to the examiner. If participants could not hear or lipread the entire sentence, they were instructed to repeat any words or phrases they understood. Guessing was encouraged. Scoring was calculated based on percent keywords correct for all conditions (excluding articles a, an, the). Percent correct and benefit scores were calculated for each list.

For the SPIN sentences, one practice sentence was administered prior to each list and repeated until the participant felt comfortable with the task. Participants were instructed repeat

the last word of the sentence that they listened to and/or lipread. Guessing was encouraged. Percent correct and benefit scores were calculated based on final word responses for each list.

Results

Average percent correct scores and difference scores were calculated for the Listening Context, Listening No-context, Lipreading Context, and Lipreading No-context lists in both the IST and SPIN test. Additionally, absolute benefit difference scores were calculated for each condition. For the purposes of this study, benefit is functionally described as the difference between the conditions without context and those conditions with context.

Participant Scores and Absolute Differences

IST Sentences. Lipreading scores revealed an average score of 80.1% correct (*SD*=9.7; *Min*=.537; *Max*=.921) in the context condition and 41.3% correct (*SD*=18.7; *Min*=.123; *Max*=.807) in the no context condition. Listening scores revealed an average score of 71.3% correct (*SD*=11.8; *Min*=.457; *Max*=.886) in the context condition and 40.4% correct (*SD*=13.0; *Min*=.118; *Max*=.739) in the no context condition. See Table 2 for a listing of the means and standard deviations by condition.

SPIN Sentences. Lipreading scores revealed an average score of 50.6% correct (*SD*=16.3; *Min*=.250; *Max*=.875) in the context condition and 13.1% correct (*SD*=7.8; *Min*=0.00; *Max*=.333) in the no context condition. Listening scores revealed an average score of 60.8% correct (*SD*=14.9; *Min*=.375; *Max*=.833) in the context condition and 29.2% correct (*SD*=14.9; *Min*=.083; *Max*=.583) in the no context condition. Again, refer to Table 2 for a listing of means and standard deviations by condition.

Benefit from Context

When lipreading the IST sentences, participants improved an average of 38.8 percentage points between the no context and context conditions (t (19)=12.3, p<.05*).* Likewise, when listening to the target sentence in the IST, participants improved 30.9 percentage points between

the no context and context conditions (*t* (19)=15.1, *p*<.05*).* For lipreading the target word in the SPIN test, participants improved an average of 37.5 percentage points between the no context and context conditions (*t* (19)=10.5, *p*<.05*).*Finally, when listening to the target word in the SPIN test, participants improved an average of 31.7 percentage points between the no context and context conditions (*t* (19)=10.4, *p*<.05*).*

Analysis of Variance to investigate the relationships in the current study. Potential differences among the conditions were examined using a three-way omnibus multivariate ANOVA with repeated measures. The three main effects entered into the ANOVA were the repeated measures of modality (auditory target or visual target), context type (situational or sentence-based), and the presence of context (context or no-context). Two main effects showed differences. Results from the analysis of the main effects indicate that, overall, performance in the IST test was higher than performance in the SPIN test (*F*(1,19)=135.0, *p*<.05) and that performance was better when context was provided (*F*(1,19)= 946.5, *p*<.05). Overall performance in the auditory and visual target conditions, however, were not different (*F*(1,19)= 3.2, *p*>.091). Of particular importance to the current investigation and to the goals of the study are the potential interactions that may have occurred among the conditions. The interaction between target modality and the presence of context (*F*(1,19)= 5.6, *p*<.05) indicated that context in general provided more benefit when participants were required to lipread the target word compared to listening. This is shown in Figure 3 as a larger improvement from context for the visual only performance versus the auditory only performance. The second interaction was conducted between context type and modality. The results of this analysis did not yield a difference between the two conditions, indicating that there was no difference in the degree of benefit when going from a no-context to a context condition across the two types of context

($F(1,19)=.008$, $p>.931$). This is shown in Figure 4. There was no three-way interaction for modality, context type, and presence of context ($F(1,19)=.116$, $p>.738$). The lack of a three-way interaction indicated that any benefits associated with the addition of context could not be attributed to any particular test or modality. However see below for a discussion on this issue. This is seen in Figure 5 as all four comparisons are relatively equal.

Correlations

Correlational analyses focused on two major questions. The first question examined the ability to use context in a different modality when the type of context is held constant. In the IST, the ability to use situational context while listening did not predict the ability to use situational context while lipreading (r (18) =.290, p=.22) (see Figure 6). Likewise, in the SPIN test, the ability to use sentence context while listening did not predict the ability to use sentence context while lipreading r (18) =-.183, p=.45) (see Figure 7).

The second question asked if the ability to use context in a single modality would generalize across types of context provided. For lipreading, the ability to benefit from sentence-based context did not predict the ability to benefit from situational context, or vice versa (r (18) =-.401, p=.08) (see Figure 8). For listening, the ability to benefit from sentence-based context also did not predict the ability to benefit from situational context, or vice versa (r (18) =.002, p=.99). The ability to use situational context while listening did not predict the ability to use sentence context while listening (see Figure 9).

Discussion

The purpose of this study was to better characterize the ways in which individuals use different types of contextual information and if this information is used differently by the auditory and visual modalities. Investigating these patterns for the use of context may provide researchers and clinicians with a better understanding of how contextual information is processed. For example, one of the primary goals of the current study was to determine if the use of context is a global skill, applied similarly to perception of speech in the auditory and visual channels, or if context provides benefit dependent on the modality with which it was applied. An understanding of this process may lead to the future development of aural rehabilitation strategies and programs that are specific to patients' abilities and that reflect the nature of how people use different types of context.

The first question in this study considered if the use of context would vary by modality when the contextual type was held constant and if performance in one modality would predict performance in the other. Results from the two way ANOVA demonstrated that context provided more benefit to speech perception when lipreading than when listening. While the results for this study suggest no difference between the benefit from context to lipreading in the IST versus the SPIN test, close examination of Figure 5 suggests that performance in the IST may have influenced this result more than that of the SPIN test. In this figure, it appears that the slope of the line for the IST is steeper than that of the SPIN test. In the correlation analysis, benefit from context while lipreading did not correlate with benefits from context while listening in either the IST or SPIN test. This suggests the ability to apply contextual information is either not the same processes or the process is differentially applied across the two modalities.

The second study question sought to investigate if the degree of benefit from context would vary by context type when the modality was held constant. The current study also wanted to examine if performance with one type of context would predict performance with the other. Results from the ANOVA as well as examination of the correlations in this study suggest that the type of context provided did not affect lipreading or listening differently. In the correlation analysis looking at lipreading across the two context types, benefit from situational context in the IST did not predict benefit from sentence-based context in the SPIN test. The same results were true for listening across the two types of context. Results of the correlation analysis for when modality is held constant suggests that when using the same perceptual channel, the benefit from one type of context does not predict the benefit afforded by the other.

The results from the measures of absolute benefit for lipreading show an interesting relationship between lipreading and the addition of context. There was a larger benefit from context in the visual channel relative to the auditory channel when the context type was held constant. This means that context may be more readily used when primarily relying on vision for speech perception. Recall also, that these results appear to be driven more by participants' performance for lipreading in the IST. This is possibly because vision-only speech perception (lipreading) was primed by the visual situational context provided by the IST picture. Because the contextual picture already activated the visual system, participants may have been more likely to benefit from context when they were lipreading in the same channel.

As mentioned above, the benefit from situational context while lipreading did not correlate with sentence-based context while lipreading, and benefit from situational context while listening did not correlate with sentence-based context while listening. These results suggest that the ability to use different types of context may not be a global skill. Instead,

individuals may have differing abilities to use different types of context while using the same perceptual channel. The implications of these results for aural rehabilitation specialists are important because they suggest that training and repair strategies for using one type of context may not generalize to other types. This indicates that rehabilitation programs may need to incorporate the different types of context and help patients learn how to use them in difficult listening situations.

In addition to the lack of correlation by context type, this study also demonstrated no correlations in the benefit afforded from context by modality; use of context while lipreading did not correlate with the use of context while listening with either situational or sentence context. This further suggests that the use of context is not a global skill and cannot be generalized across modalities. In other words, using contextual information while lipreading is not the same skill as using contextual information while listening. Once again this has implications for aural rehabilitation and training. In the future these results may guide rehabilitation specialists to make recommendations and initiate training programs that are modality specific so that patients can more effectively improve their skills for the use of context in both the auditory and visual channels. Additionally, rehabilitation programs could determine what type of contextual training should be done on an individual basis based on that patient's needs.

Finally, a main goal in this study was to continue the development of the IST by examining its effectiveness in testing adults. Much like the Goebel et al. (2012) study, the results from the IST for both lipreading and listening revealed a wide range in performance for both the context and no-context conditions of the test. The replication of these results suggests that the IST may be a feasible test for assessing lipreading and listening ability along with the ability to use context across the lifespan. Although no relationships were found between conditions across

the two tests, the development of an audiovisual version of the SPIN test produced a similarly effective range for context and no-context performance.

Limitations of current research

The findings described here could have many implications for aural rehabilitation. It is important though, to address certain limitations of this study. First, in order to maintain consistency for the manner in which context was delivered, it was necessary to modify the SPIN test sentences in way that caused a crossing of modalities before the target was presented. For example, in the visual condition the target was lipread while the context was presented auditorily in -4 SNR. While the modifications made to the sentences in the SPIN test allowed for appropriate comparison to the IST, these modifications altered the sentences, making them appear in a manner that was unlike everyday conversation. Future research may continue searching for a way to adapt other types of context, or context tests into speech testing so that they can be used to assess lipreading. One thought for future studies is to consider using the same actor or actress for all tests that require comparison of performance across context type and/or modality. Although essentially half of the comparisons were made with measures analyzed as the benefit in performance within a talker, some comparisons were made across talkers. In the current study, it is possible that some of the differential performance was the result of a difference in the readability of a talker.

A second possible limitation of this study is the small number of participants recruited to be in this study. When considering the three-way interaction performed in this study, the figures demonstrate that the slope of the lines between the no-context and context conditions may not be similar; however, a two-way interaction yielded a difference when contextual type was held constant. This presence of a two-way interaction that does not remain in the three-way analysis is

meant to suggest that the there was no difference in the benefit derived from the two tests; however, this assumes that there were enough data points to make a comparison at the level of a three-way interaction. It is important to point out that the addition of more participants may allow for a clearer picture in which both the two-way and three-way analyses can more clearly characterize the use of contextual information by modality and type of context.

Future Research

One possible way to test whether the modality of the situational context is influencing perception differently depending on the modality of the target would be to deliver situational context via the auditory channel. This would allow for a comparison with the picture modality in the IST in order to determine if participants received more benefit from context while listening or when lipreading. To do this, one could play an audio clip of sounds related to the target sentence (e.g. *birds chirping* for the sentence "We saw eggs in the bird's nest.") in place of the contextual picture of the IST. This is comparable to the auditory context provided by Garstecki and O'Neil (1980), finding that auditory context aids visual-only speech perception. If the participants still saw more improvement from context in the lipreading condition, the current study results would be confirmed. However, if the results showed more benefit from context in the auditory channel, one could conclude that the modality in which the context is delivered is important for determining the amount of benefit from context in the modality that perceives the target. The study would ask if auditory situational context would produce benefit from context that was greater when the target was received in the visual channel (consistent with the current study) or if it would act as a prime for perception in the auditory channel.

A second study for future research would consider if the ways in which individuals use context type and context modality changes with aging. Sommers and Danielson (1999) and

Pichora-Fuller (2008) found that older individuals benefit more from the use of context than older individuals. In a future version of the current study, it would be informative to consider if the use of context type and context modality generalizes with age or remains a separate skill.

Conclusions

Characterization of how individuals use contextual information has both theoretical and clinically relevant applications. Clinically, this information may help audiologists and other rehabilitation specialists with finding ways to help hearing impaired patients stay involved in spoken conversation. Results suggest that clinicians should help patients to train their skills with different types of context and in both the auditory and visual channels. This way, clinicians can equip them to function with greater ease in a number of challenging listening situations. The understanding that the greater absolute benefit afforded by context to the visual channel, can help scientists further characterize how a patient's surroundings and other non-auditory factors can influence the use of contextual information and speech perception. Equipped with this information, researchers and clinicians can continue to help hearing impaired patients to function better in difficult listening situations through the provision of communication strategies and a greater understanding of how individuals use the context that surrounds them in everyday situations.

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Table 1. *Overview of test conditions*

	Visual	Auditory
Situational Context—IST	1.Context: Percent correct IST—Visual-only with picture 2. No-Context: IST—visual-only without picture	1. Context: Percent correct IST—Auditory-only with picture high noise (at -8 SNR) 2. No-Context: Percent correct IST—Auditory-only without picture in noise (at -8 SNR)
Sentence-based Context—SPIN test	1. Context: Percent correct SPIN test—Visual-only High Predictability list 2. No-Context: Percent correct SPIN test—Visual-only Low Predictability list	1. Context: Percent Correct SPIN test—Auditory-only High Predictability list (at -4 SNR) 2. No-Context: Percent Correct SPIN test—Auditory-only Low Predictability list (at -4 SNR)

Table 2. *Means and Standard Deviations for Percent Correct Perception in the IST and SPIN test*

	Lipreading Target	Listening Target
IST Context	*M*=80.1% (*SD*=9.7)	*M*=71.3% (*SD*=11.8)
IST No-Context	*M*=41.3% (*SD*=18.7)	*M*=40.4% (*SD*=13.0)
SPIN Test Context	*M*=50.6% (*SD*=16.3)	*M*=60.8% (*SD*=14.9)
SPIN Test No-Context	*M*=13.1% (*SD*=7.8)	*M*=29.2% (*SD*=14.9)

Figure 1. Example of an illustrated sentence test picture for the target sentence, *"The family ate dinner at the table."* Used with permission from the Tye-Murray Lab at Washington University in St. Louis School of Medicine, 2013.

<table>
<tr><td colspan="3">-4 SNR</td></tr>
<tr><td rowspan="3">Auditory</td><td colspan="2">----------Frozen Face----------</td></tr>
<tr><td>----------Auditory Context----------</td><td>Auditory-only Target</td></tr>
<tr><td>“Cut the bacon into…”</td><td>“…strips.”</td></tr>
<tr><td rowspan="3">Visual</td><td>----------Frozen Face----------</td><td>----Lipread Target----</td></tr>
<tr><td>----------Auditory Context----------</td><td>Visual-only Target</td></tr>
<tr><td>“Cut the bacon into…”</td><td>“…strips.”</td></tr>
</table>

Figure 2. Graphical representation of SPIN test sentence construction. Sentences with an auditory target were presented at a -4 SNR with a frozen face visual stimulus. Sentences with a visual target were presented with auditory context in a -4 SNR and received the final (target) word via vision-only.

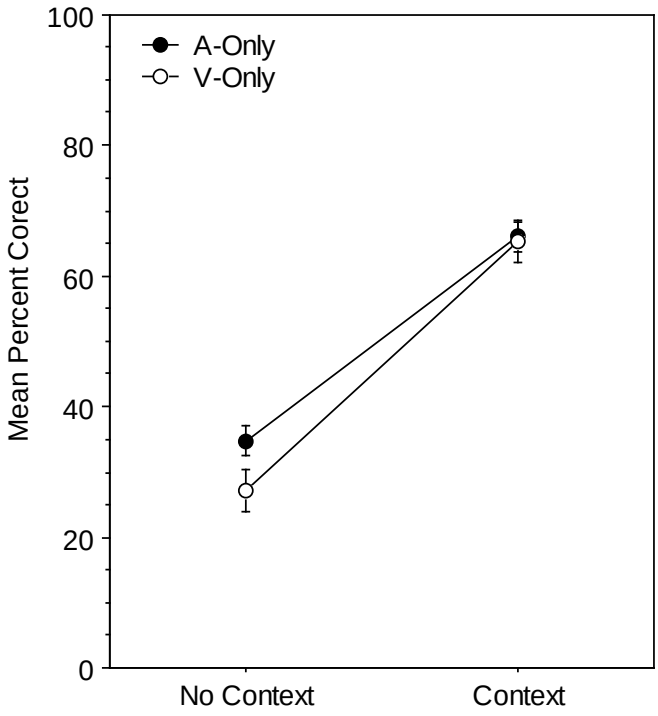

Figure 3. Two-way interaction between modality and presence or absence of context when type of context is held constant. Benefit is described as the difference in percent correct performance between the no-context and context conditions of each test. Analysis indicated a two-way interaction between modality and the use of context ($F(1,19) = 5.6$, $p < .05$). There was a greater benefit between no-context and context conditions when the target was lipread versus when the participant listened to the target

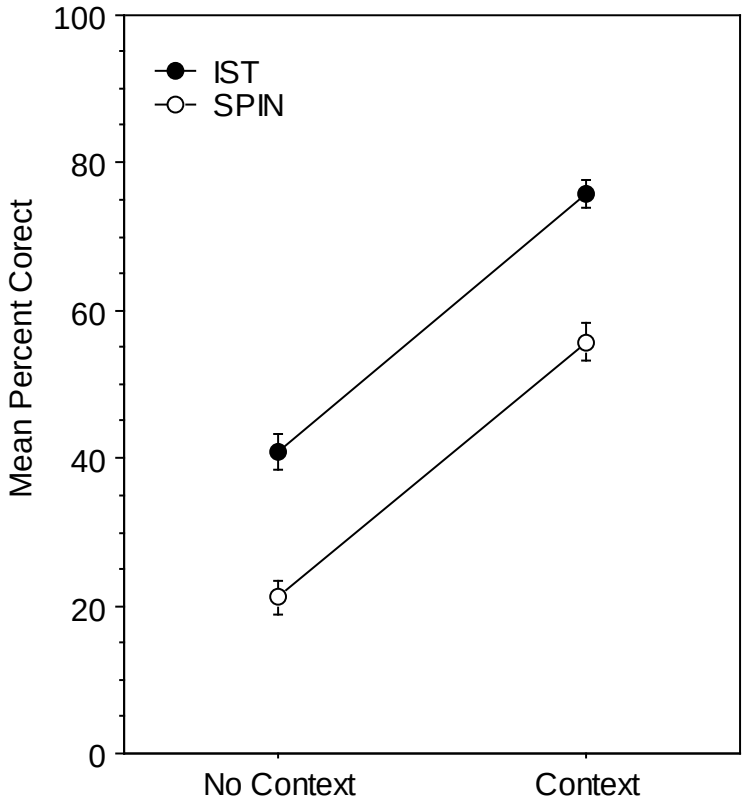

Figure 4. Two-way interaction between context type and the presence or absence of context when type of context is held constant. Benefit is described as the difference in percent correct performance between the no-context and context conditions of each test. Analysis indicated that there was no difference in the degree of benefit when going from a no-context to a context condition across the two types of context ($F(1,19)=.008$, $p=.931$)

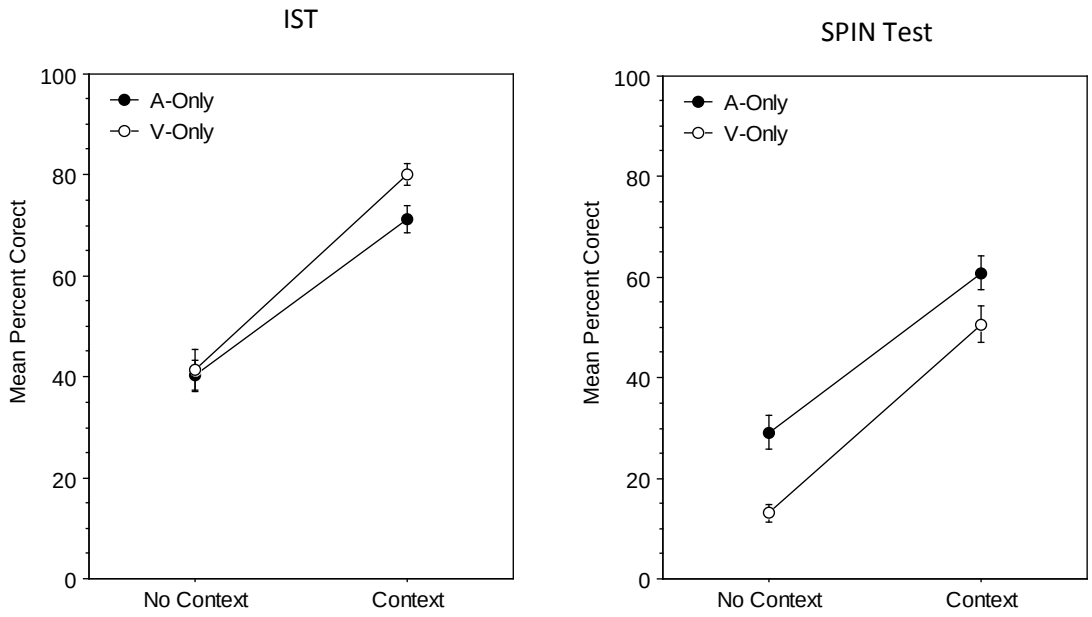

Figure 5. Three-way ANOVA comparing contextual type, modality, and presence or absence of context. Benefit is described as the difference in percent correct performance between the no-context and context conditions of each test. The lack of difference in slope for each line indicates no three-way interaction between these variables ($F(1,19)=.116$, $p=.738$).

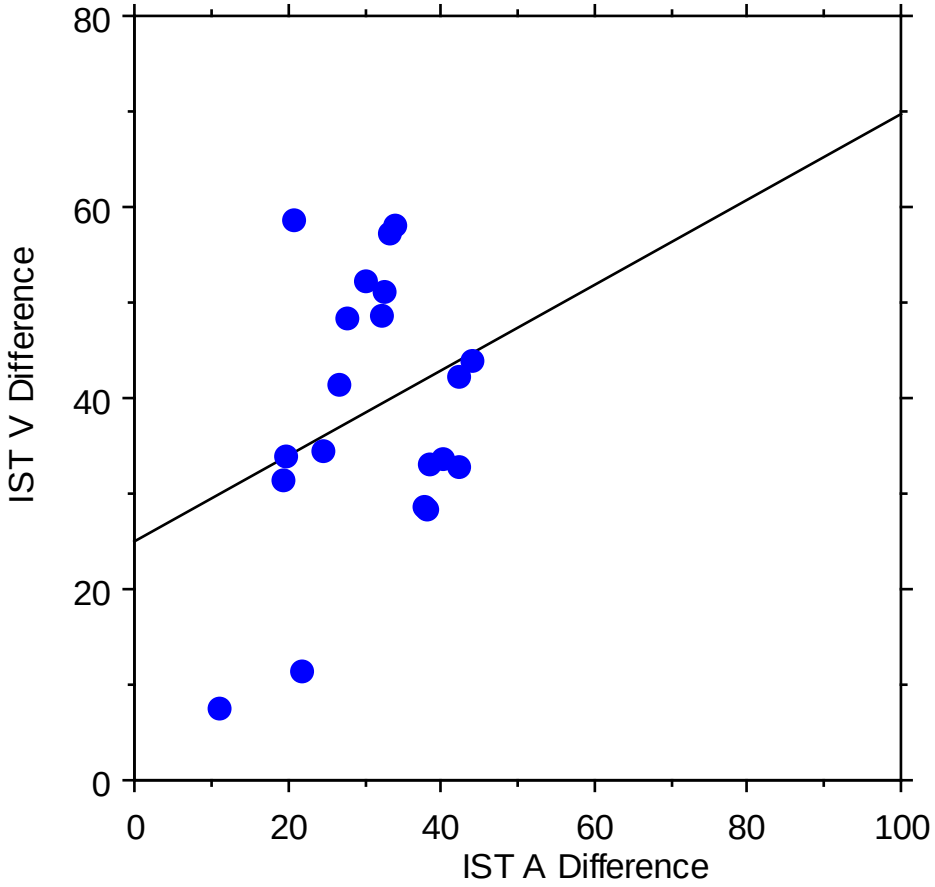

Figure 6. Benefit from situational context while listening versus lipreading. Benefit is described as the difference in percent correct performance between the no-context and context conditions of each test. In the IST, the ability to use situational context while lipreading did not predict the ability to use situational context while listening (r (18) =.290, p=.22).

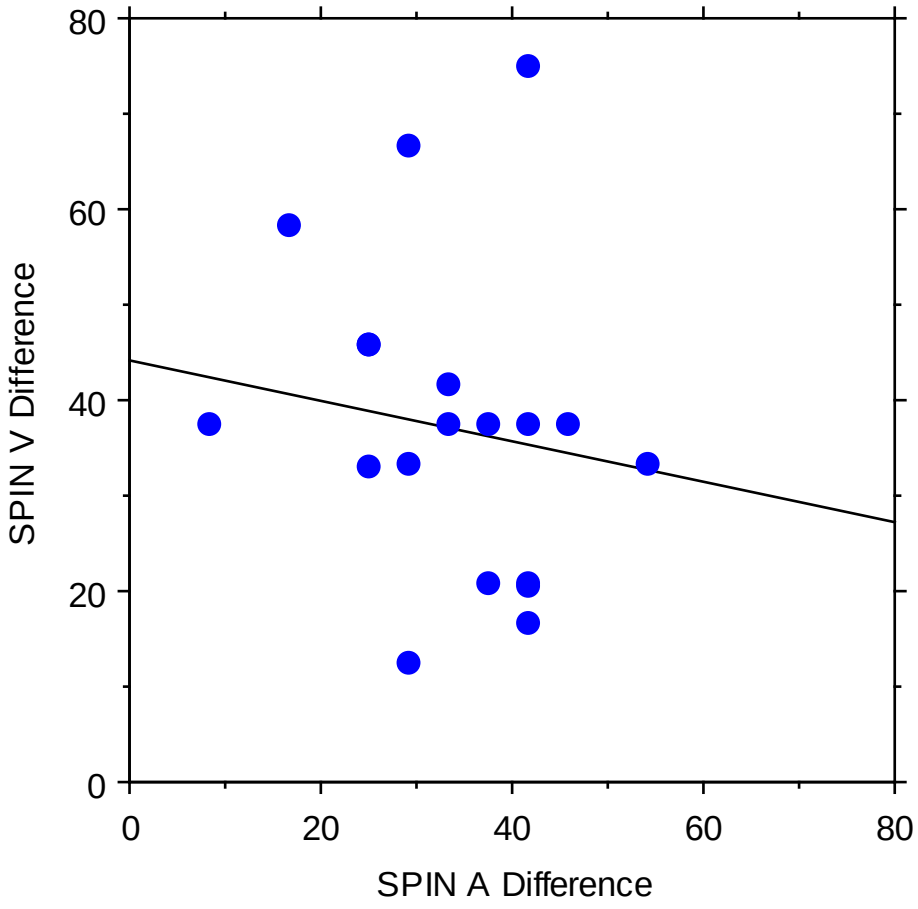

Figure 7. Benefit from sentence-based context while listening versus lipreading. Benefit is described as the difference in percent correct performance between the no-context and context conditions of each test. In the SPIN test, the ability to use sentence-based context while listening did not predict the ability to use sentence-based context while lipreading r (18) =-.183, p=.45).

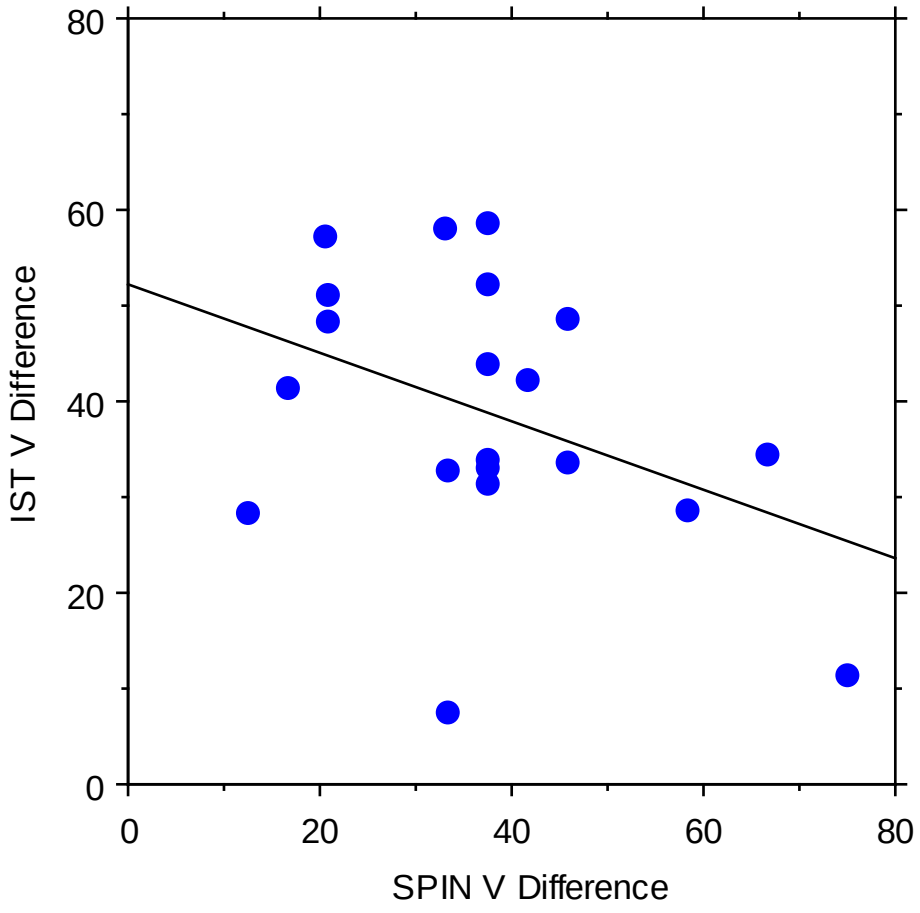

Figure 8. Benefit from sentence-based versus situational context while lipreading. Benefit is described as the difference in percent correct performance between the no-context and context conditions of each test. For lipreading, the ability to benefit from situational context did not predict the ability to benefit from sentence context, or vice versa (r (18) =-.401, p=.08).

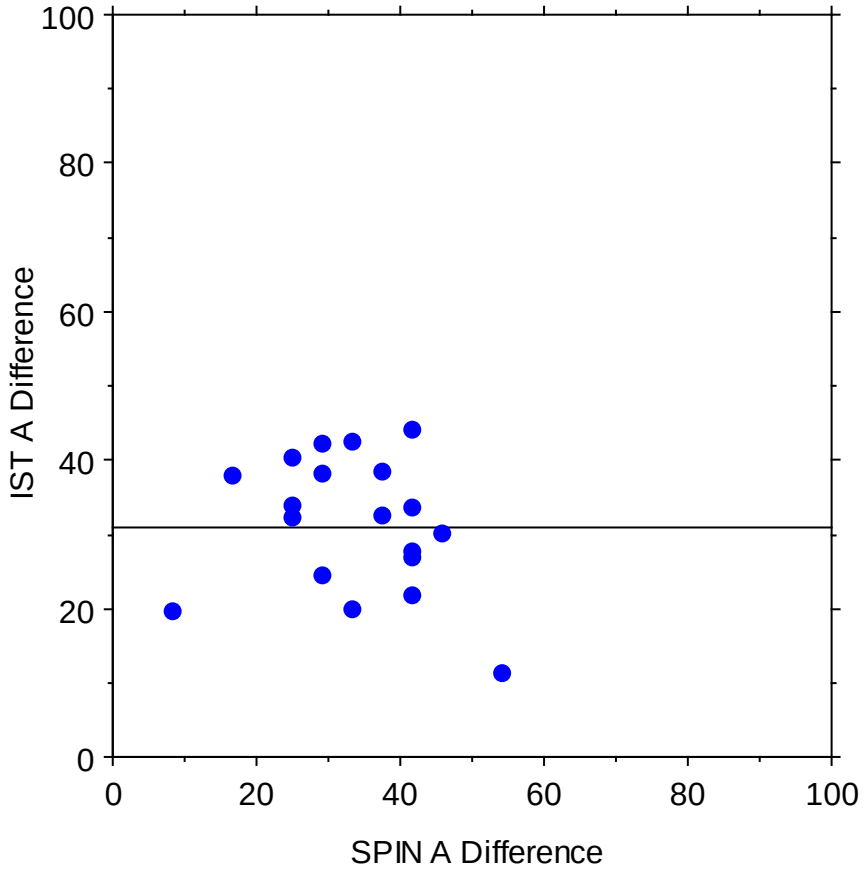

Figure 9. Benefit from sentence-based versus situational context while listening. Benefit is described as the difference in percent correct performance between the no-context and context conditions of each test. For listening, the ability to benefit from sentence-based context did not predict the ability to benefit from situational context, or vice versa (r (18) =.002, p=.99).