ADULTS WITH A SEVERE-TO-PROFOUND HEARING IMPAIRMENT.
INVESTIGATING THE EFFECTS OF LINGUISTIC CONTEXT ON SPEECH PERCEPTION

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ABSTRACT

Linguistic context is known to influence speech perception abilities in adults with normal hearing. Recent reports question the importance of context for adults with a severe-to-profound hearing impairment. The severe reduction and distortion in acoustic input may result in the listener perceiving insufficient acoustic-phonetic cues to allow access to higher level linguistic processing. To investigate this further, a detailed study of the speech recognition of adults with a severe-to-profound hearing impairment (N=34) was undertaken. A series of aided speech recognition tasks, sequentially examined the different levels of processing in the speech perception chain. The investigation concluded that the effects of severe-to-profound hearing impairment did not reduce the listener’s ability to take advantage of contextual cues. There was, however, wide variability between participants in the utilisation of contextual processing. This indicates that to estimate “real-life” speech perception skills, an evaluation of contextual processing ability is required.

1. INTRODUCTION

Different tests of speech perception vary in the amount of contextual cues offered to listeners. As we proceed from tests of segmental perception, to tests of word recognition, and then to tests where those same words are inserted into sentences the amount of available contextual information increases. Closed-set vowel and consonant tests assess how well people perceive speech based primarily on acoustic features. Tests of open-set word perception examine how listeners use the available acoustic trace to withdraw word meanings from their semantic system (1,2). As conversational speech involves the perception of words embedded in sentences, open-set tests of sentence recognition examine the effects of syntactic context, co-articulation, and prosody. Additionally, investigation can take place into contextual factors beyond the stimulus sentence. These factors could include prior knowledge of the sentence topic and/or by making each sentence within the list related as in a narrative. A well-chosen test battery allows the investigation of each level of speech perception, and the relationship between them.

From these assumptions, it appears logical to assume that test materials, high in contextual information, should be easier to perceive. This assumption, however, is not universally accepted. Several authors (3, 4) suggest that if the incoming auditory signal becomes severely distorted, as is often the case for adults with a substantial sensorineural hearing impairment, then the listener may not receive the additional assistance of contextual cues. Similarly, while group performance may show an improvement for materials that are high in context, not all individuals may demonstrate this improvement. Investigation of the variability in contextual processing across participants may be useful in understanding this aspect of speech perception and perhaps, in showing how it could be improved. Possible reasons for poor use of contextual cues in adults with a severe-to-profound hearing impairment are the degree of distortion affecting the acoustic input and/or less efficient linguistic processing abilities.

Mean scores can be used to make comparisons between one type of test and another, but are limited in demonstrating the use of contextual information or in comparing across studies. Boothroyd (5) and Boothroyd and Nittrouer (1) proposed a solution through the use of predictions from probability theory. Two values (k and j) were used to describe the effects of context. The k factor relates to the proportional increase in channels of statistically important information available in the stimulus (1). For example, Boothroyd and Nittrouer (1) found a k value of 1.3 for recognition of known words compared with nonsense syllables, indicating that the influence of lexical context is equivalent to increasing by 1.3 the number of channels of statistically independent information in nonsense syllables. Similarly, the j factor is the effective number of statistically independent parts within a whole. For instance, Boothroyd and Nittrouer (1) found that CVC words of three different phonemes/parts were perceived as if they contained only 2.5 independent parts. Consequently, by using probability theory it is possible to obtain a quantitative estimate of the facilitative effects of context, which provides more information than reporting the mean difference between scores.

In summary, the aim of this investigation is to examine two questions. Firstly, does a severe-to-profound hearing impairment affect a person’s ability to extract contextual information? Secondly, if contextual processing does occur, is it uniform across participants and therefore predictable?
2. METHOD

2.1. Participants

Thirty-four participants with a severe-to-profound sensorineural hearing loss (PTA = 61-98dBHL) participated in this investigation. All participants used oral language as their primary means of communication. All wore currently fitted hearing aids, which adhered to the NAL-R prescription (6) as verified by real-ear measurements and an SPL-o-gram.

2.2. Materials

The speech perception materials used in this investigation consisted of the following speech perception test lists:

- Closed-set test of the 12 vowels of Australian English.
- Closed-set test of the 24 consonants of Australian English.
- Open-set test of word recognition (CNC) (7, 8).
- Open-set test of sentence recognition (CUNY) (9).
- Connected Speech Test version 2 (CSTv2) (10).

Tests at the sentence level were also conducted in background noise (four-talkers superimposed) to replicate environments more typical of everyday listening conditions. An Australian male speaker pre-recorded all materials on CD.

2.3. Procedure

All test materials were presented via loudspeaker in the free field. The loudspeaker was located one metre away from the participant at 0° azimuth. The materials were presented at 70dBSPL (peak level). Where appropriate, background noise (four talkers superimposed) was presented from the same loudspeaker. A period of practice was included within the design as well as a random order of presentation. This reduced the effects of practice and test order.

3. RESULTS AND DISCUSSION

As discussed previously, testing of words in sentences aids the recognition of the individual word. This is facilitated by the increase in linguistic information now available to the person with a hearing impairment. This increase comes from the addition of syntactic, semantic and pragmatic information. It was hypothesised by some researchers that adults with a severe-
to-profound hearing impairment would be unable to access this information (3, 4). Fortunately, the results of the present study found that participants with a severe-to-profound hearing impairment were able to take advantage of linguistic cues and contextual processing across a varied range of speech perception measures. The presentation of words in sentences resulted in a 70% ($k = 1.7$) increase in the number of statistically independent channels available to the participant.

![Figure 1](image.png)

**Figure 1:** Comparison between the $k$ values (CUNY compared with CSTv2) at each signal-to-noise level.

As expected, the increase in context available with the CSTv2 sentences, where the sentences are related not only to a central topic but also to each other, is considerable. Comparisons between the CUNY sentence lists and the CSTv2 paragraph pairs found that a decrease in signal-to-noise ratio from $+15$dBSNR to $+5$dBSNR resulted in an increase in the use of contextual information (Figure 1). Additionally, the $k$ value showed a consistent increase from 1.3 for tests of word perception, to 1.7 for tests of sentence perception to over 2.4 for contextually related sentences. Consequently, contextual processing appears to increase, for this population, not only as the tests become increasingly linguistically based, but also as the acoustic conditions deteriorate with background noise. It is important, however, to note that this improvement with context was not uniform. Figure 2 shows clearly that some participants demonstrated large gains in information transmitted with the addition of contextual cues whereas other participants showed little or no improvement. Additionally, this variability was independent of pure-tone average and the other speech perception tests. Therefore, if we wish to estimate a person’s “real-life” speech perception skills then we need to begin to evaluate the effects of contextual processing in quasi “real-life” communication situations.

![Figure 2](image.png)

**Figure 2:** Comparison between CUNY sentences and CSTv2 sentences at $+5$dBSNR showing the wide degree of variability in performance between participants.

### 4. CONCLUSION

The results of the present study demonstrate that adults with a severe-to-profound hearing impairment continued to take advantage of contextual cues in a variety of speech perception assessments, across many levels of speech perception. Hence, poor residual hearing capacity does not diminish the potential for later lexical and/or contextual processing. As expected contextual and linguistic processing of the speech signal is greater in tests with a higher linguistic load. Additionally, the improved performance of individuals as the tests became more conversational indicates that traditional tests of speech perception may underestimate “real-life” speech perception abilities.

The variability observed between participants shows that people differ markedly in their ability to use contextual cues. This may help account for the clinical observation that some adults report very different abilities in understanding speech in their normal communication environment, despite identical audiometric configuration. Through the continued development of contextually based assessments researchers may learn more about factors, other than audiomeric information, that help prediction of speech perception performance. Additionally, the ability to estimate the effect of contextual skills may assist in aural rehabilitation following the fitting of an amplification device or cochlear implant, in terms of predicting the amount of time required to acclimatise.
The present study shows that there exists the potential for linguistic or contextual processing within a variety of speech perception tests which assess performance from non-word segmental processing to open-set perception of context-laden sentences. It appears that no test of speech perception is completely isolated from the effects of linguistic skills and knowledge.

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6. REFERENCES


