Critical Review: Does the addition of tactile stimulation improve speechreading performance for individuals with severe to profound hearing loss?

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This critical review examined the impact of tactile stimulation on speechreading performance for individuals with severe to profound hearing loss. Study designs included: three single subject designs and one within-groups repeated measure. Overall, the evidence supported an improved speechreading performance for this population with the addition of tactile stimulation. Significant training is required with the tactile devices, however, before this improvement can be observed. Future studies should examine ideal training methods and time-lines, and determine whether these would be feasible, before tactile devices can be recommended on a large scale.

Introduction

The development of cochlear implants has greatly improved the oral communication skills of individuals with severe to profound sensorineural hearing loss (SNHL; i.e., Svirsky et al., 2000). Unfortunately, cochlear implants are not universally accessible for all such individuals. Certain physiological and medical conditions preclude implantation, and some individuals who receive a cochlear implant are unsuccessful in its use. Additionally, the vast majority of deaf individuals worldwide live in middle- or low-income countries (World Health Organization, 2006). The cost of an implant is likely prohibitive for these individuals, even if they were able to access such services.

Individuals with severe to profound hearing loss receive a limited amount of speech information through the traditional hearing sense. If their hearing is left unaided, these individuals rely largely on speechreading to understand oral communication. Unfortunately, some groups of phonemes have similar or identical patterns of articulation (referred to as visemes). These sounds may not be accurately differentiated based solely on the observation of articulation. Supplementing information from other unimpaired senses may aid in the discrimination of these phonemes, and improve overall communication.

The sense of touch is not commonly viewed as an aid in communication for normally hearing individuals. It has, however, been used by individuals with severe hearing impairments since the 1920s (Gault, 1926). This originally involved direct contact between the receiver's hand and the speaker's throat and face (the Tadoma method). Portable tactile communication aids were then made available which largely replaced the Tadoma method of communication.

Tactile communication aids transmit speech information that cannot be obtained visually through tactual stimulation of the skin. Devices that provide tactile stimulation as a supplement to the visual cues of speech may improve speechreading abilities of individuals with severe hearing impairments. Such devices may provide a safer, cheaper and less invasive alternative to an implanted auditory prosthetic device.

Objectives

The primary objective of this paper was to critically evaluate literature to examine the impact of supplementing visual stimuli with tactile stimuli in improving speechreading abilities in individuals with severe to profound hearing loss.

Methods

Search Strategy

Computerized databases including PubMed, CINAHL, and Proquest were searched using the following search strategy: (tactile aid OR tactile stimulation) AND (hearing OR speech discrimination OR speechreading OR lipreading). The search was limited to journal articles in peer-reviewed journals published in English before November 2010.

Selection Criteria

Studies were excluded from the critical review if testing did not entail a speechreading component, if testing was focused on detection of non-speech stimuli (environmental sounds), or if testing was limited to supra segmental components of speech (i.e., stress, intonation, etc.). No limits were set on participant demographics (i.e., age, gender, culture, race, socioeconomic status, etc.).

Data Collection

Results of the literature search yielded the following types of articles: single subject 'n of 1' design (3) and within-groups repeated measure (1).

Results

Single Subject Design Studies

Yuan, Reed and Durlach (2005) examined the effect of supplementing speechreading with tactile information on four normal hearing subjects ranging in age from 21 to 32 years. The subjects were tested on three speech recognition tasks (initial consonant voicing, consonant identification, and words in sentences) under three presentation conditions (speechreading only, tactile information only and tactile information + speechreading).

A 2 x 2 stimulus-response confusion matrix was used to summarize the results. Mean signal-detection measures of sensitivity (*d'*) for the initial consonant voicing task were 0.09 for the speechreading only condition. This represented roughly chance performance, and was consistent with the idea that speechreading conveys little to no information regarding initial consonant voicing. The mean *d'* value for the tactile information only condition jumped to 2.4. A similar mean *d'* value (2.5) when the tactile information was supplemented with speechreading further supported the idea that speechreading provides little help in the differentiation of initial consonant voicing. A one-way analysis of variance (ANOVA) indicated no significant difference between the scores obtained with the tactile information only condition and the combined tactile information + speechreading condition on this task [$F(1, 126) = 0.92$, $p = 0.3391$].

In terms of the consonant identification task, percent correct scores were calculated: 34% under the speechreading alone condition, 12% under the tactile stimulation only condition, and 49% under the tactile stimulation + speechreading condition. The order of performance in terms of the conditions were the same for all of the subjects, and the average performance advantage in the speechreading + tactile stimulation condition above the speechreading only condition was 15%. No significant difference was found with regards to mean percent correct scores between performance for the different test conditions on the identification of words in sentences task ($p > 0.05$).

Reed and Delhorne (2006) examined the impact of training on the benefits of tactile stimulation through the study of an individual who routinely used a tactile aid for a number of years. The subject was a 40 year old female with severe-sloping-to-profound hearing loss in her left ear and no measurable hearing in her right ear. Speechreading tests used in this study involved closed set consonant and vowel identification, reception of words in sentences (CUNY and IEEE sentence tests), and connected-discourse tracking. Each of these tests was completed under four conditions: speechreading alone, speechreading + tactile aid, speechreading + hearing aid, and speechreading + tactile aid + hearing aid.

One-way ANOVAs were completed on percent correct scores for each speech reception test, and post-hoc Scheffe tests were then conducted to determine the significance of the differences between the different conditions. At a phonemic level, the tactile aid provided no added benefit beyond the speechreading alone condition ($p > 0.05$).

At a words in sentences level, the tactile aid provided a significant added benefit beyond the speechreading alone condition for the more difficult IEEE sentences ($p < 0.05$). This was not the case however with the less complex CUNY sentences task, on which the subject scored 82% correct under the speechreading alone condition. Although performance improved to 90% correct when speechreading was supplemented with a tactile aid, the difference was not found to be significant ($p > 0.05$). Such a successful baseline performance left little room for significant improvement.

At a continuous discourse level, performance was measured using mean tracking rates. This procedure involved the presenter reading from a prepared text and the subject repeating back what was said. The presenter was responsible for repeating the words that were missed or incorrectly identified by the subject. The procedure was timed, and a tracking rate was scored based on the number of relayed words per minute (wpm).

The subject's mean tracking rate increased when using the tactile aid to supplement speechreading vs. when using hearing aids, or when using speechreading alone. These differences were not found to be significant however [$F(3, 28) = 1.48$, $p = 0.2415$]. And although improvements were observed in speech reception scores when speechreading was supplemented with tactile stimuli, these improvements were not found to be significant under all test conditions.

Plant (1998) attempted to quantify the impact of a significant training period using tactile stimulation on

speechreading performance using a longitudinal study design. This study involved a 41 year old male subject with a severe-sloping-to-profound bilateral sensorineural hearing loss. A speech tracking procedure similar to the procedure used in the Reed and Delhorne (2006) study was used to both train, and evaluate, the subject's speechreading performance with tactile stimulation. The training and testing took place over a period of 18 months.

The subject's speech tracking rate was found to be 19 to 37% higher when speechreading was supplemented with tactile stimulation vs. the speechreading alone condition. Furthermore, performance when using the tactile aid in conjunction with speechreading was found to generally increase across the training period (31.4 wpm, 37.6 wpm, 41.3 wpm, 38.2 wpm, 37.8 wpm, 46.1 wpm, and 49.1 wpm). Additionally, the wpm improvement above speechreading alone when using tactile information increased steadily across the training sessions until the last training session, in which a different presenter was used (+19%, +25.5%, +25.6%, +27.3%, +36.8%, +29.5%).

Following the training sessions, the subject was administered 20 lists of the CUNY Sentence Test via speechreading alone, and speechreading supplemented with tactile stimulation. Mean percent correct scores were 29.8% for speechreading alone, and 39.9% when the sentences were presented via speechreading and tactile stimulation. The subject was also tested on a task of consonant identification, and scored 47% correct with speechreading alone, and 60.1% when speechreading was supplemented with tactile information. Unfortunately, the paper failed to report whether observed improvements above speechreading alone were statistically significant.

Within-group Studies

Andersson, Lyxell, Ronnberg and Spens (2001) examined the effects of both single-channel and multi-channel tactile aids on speechreading performance both initially, and following 10 hours of practice with the devices. Their study involved 14 adult subjects who presented with bilateral severe or profound hearing loss. The subjects' speechreading abilities were assessed via a speech tracking procedure similar to that used in the Reed and Delhorne (2006) and Plant (1998) articles described above.

The results of a 2 (pre-/post-training) x 3 (speechreading conditions) repeated measures ANOVA demonstrated a significant training effect on speechreading performance at a continuous discourse level when using the multi-channel tactile aid [$F(1, 39) = 10.20$, $p < .05$, $MSe = .06$]. Speechreading performance in this condition significantly improved when compared with baseline performance. This was not the case with the single-channel tactile aid or for the visual only speechreading condition. Additionally, no significant effects were observed on speechreading performance at a single word level.

Unlike the Plant (1998) article, this study calculated the statistical significance of the results. However, the article only presented mean information, and failed to provide any individual data. Such data would be beneficial in determining whether these devices will truly benefit people on an individual basis.

Discussion

The Yuan, Reed and Durlach (2005) article found improvements when supplementing speechreading with tactile information at a consonant identification level, but found that this improvement disappeared at a words in sentence level. A possible explanation for this may be the design of the tactile device itself. It was designed to only convey information regarding initial consonant voicing. One could say this goal was achieved, based on the improved results when using the tactile aid in the initial consonant voicing and consonant identification tasks. However, the utility of this information for identifying phonemes in other positions within speech is unknown. This may have contributed to the observed lack of benefit on the sentence level task, which required subjects to identify consonants in all positions within words. Nevertheless, the results of the article provide evidence to the fact that tactile aids may be useful in effectively transmitting certain components of speech.

Yuan, Reed and Durlach (2005) suggested that the observed lack of benefit at the sentence level may have been a result of insufficient training on the task. The increased amount of tactile information required to be processed relative to the isolated syllables condition used in the initial consonant voicing and consonant identification exercises increased the difficulty of this task. This may have caused it to require a greater amount of practice for an improved performance to be observed compared with the less advanced isolated syllables tasks.

Andersson, Lyxell, Ronnberg and Spens (2001) conducted a study examining the effects of single-

channel and multi-channel tactile aids on speechreading performance at an initial level and then following 10 hours of practice. Speechreading performance was found to decline initially when using the tactile aids for the sentence level tasks. The authors postulated that the new information interfered with speech processing, and that subjects initially had difficulties integrating the visual and tactile messages. This theory was supported by the fact that the initial decline in performance was not observed when testing using single words. The single word task required the subject to process only a small amount of tactile information, which would correspondingly limit the processing delay.

Following training however, speechreading performance was significantly improved when subjects utilized the multi-channel tactile aids. This improvement was not sufficient enough to increase performance above the unaided visual speechreading condition however. The authors suggested that additional training with these devices was necessary to obtain the desired benefits from the addition of tactile information.

It should also be noted that all testing for the study was conducted in Swedish. All of the participants in the study were native speakers of Swedish, so language proficiency should not have been a problem. However, all of the other studies in this critical review were English-based. This may reduce, to some extent, the ability to compare across the studies, and generalize the conclusions of the Andersson et al. (2001) study to speakers of other languages.

Reed and Delhorne (2006) conducted a study on a subject who routinely used a tactile aid for a number of years to examine whether such devices would provide more benefit with increased training and use. A significant benefit was observed when the subject used the tactile aid in conjunction with speechreading above the speechreading alone condition for the more difficult sentences. However, when less complex sentences were the stimuli, this was not the case. This was deemed to be less of an indictment of the utility of the tactile device itself, and more a result of the subject's speechreading proficiency with these less complex sentences.

The authors of the study were interested in assessing the impact of extended training using tactile aids on their utility as communication aids in a cross-sectional study. To meet this criteria, a subject was required who had already spent a considerable amount of time using a tactile aid in lieu of hearing aids. However, tactile information is used in conjunction with visual information in individuals with good eyesight. This meant that the individual had had at least an equal amount of experience in speechreading as they had using tactile information. Such experience would no doubt increase proficiency on both tasks. This is a positive in terms of the individual's overall communication abilities; however it made finding a statistically significant difference between the conditions of speechreading and speechreading + tactile aid difficult. Unfortunately, this limited the level of evidence that this study could provide to this critical review.

Plant (1998) was also interested in the impact of training on the utility of tactile aids. He used a similar procedure to assess the subject's proficiency using the devices as in the Reed and Delhorne (2006) article. However he utilized a longitudinal design to test the subject over a period of 18 months.

The subject demonstrated improved performance at a sentence level when speechreading was supplemented with tactile stimulation. Additionally, performance was found to generally increase across the training period. These results demonstrated a consistent and growing advantage when speechreading is accompanied by tactile information. The design of the study allowed the author to better isolate the improved performance when using tactile stimulation apart from speechreading proficiency.

This data lends evidence to the idea that the improvements observed when using the tactile aid to supplement speechreading can be attributed mainly to increased proficiency processing tactile information, and not an increased proficiency in speechreading. This is not to say that the skill of speechreading cannot be improved upon. However, the subject in this study had been living with a profound hearing loss for over 10 years (spending most of that time without hearing aids), and would therefore have likely cultivated that skill to a great extent prior to his participation in the study.

Caution must be taken in interpreting these results, however, as the research is not without limitations. One such limitation of this study was the live voice presentation of the stimuli during the training and evaluation of the subject. With such a speech tracking procedure, characteristics of the speaker can have a substantial effect on the performance of the receiver of the information. These characteristics may include a slower rate of speech, greater articulation, etc. The author of the study, who was obviously not blind to

the given stage in the experiment, was the speaker throughout the training and testing period up until the last session. This left open the possibility for conscious or unconscious bias to impact the results.

The studies described above involved tactile aids with differing numbers of channels, differing places of stimulation, and different testing and training methods. Still, there are consistencies between the results of the studies that allow some inferences to be drawn. Firstly, tactile devices will not improve speechreading performance at a sentence level initially (i.e., Yuan et al., 2005; Andersson et al., 2001), and may in some cases hinder performance (i.e., Andersson et al., 2001). Secondly, multi-channel aids outperform single-channel aids (i.e., Yuan et al., 2005; Andersson et al., 2001). Thirdly, user's speechreading performance will increase with training (i.e., Plant, 1998; Andersson et al., 2001).

It seems apparent that tactile devices can provide useful information to supplement speechreading with appropriate training. Whether the real-world performance benefit is worth the time and effort involved requires further research. A greater number of longitudinal studies with a larger number of subjects and varying training methods should help to make this picture a little clearer.

Clinical Implications

Overall, the evidence provides support that individuals with severe-to-profound hearing loss can improve their speechreading with the use of tactile stimulation. This improvement will only occur with adequate training with the devices and in the integration of tactile and visual stimuli. Future research must focus on what classifies as *adequate* training, and just how much real world communication benefit can be achieved with these devices. Such additional research is necessary before these devices can be recommended on a large scale basis.

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