

**Critical Review:
Evidence for improved speech intelligibility with the use of speech supplementation strategies
in adults with cerebral palsy**

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This critical review examines the evidence for improved intelligibility with the use of speaker-implemented speech supplementation strategies in adults with dysarthric speech secondary to cerebral palsy. Included in this review are five single subject design studies. Overall, research findings suggest that speech supplementation strategies, such as alphabet cues, topic cues and iconic hand gestures, can be effective in improving intelligibility in selected adults with dysarthric speech secondary to cerebral palsy. The conclusions of this critical review should be considered with caution due to the small number of subjects that were examined across the five studies (n=12). Clinical and future recommendations are discussed.

Introduction

Cerebral palsy (CP) is a developmental, nonprogressive, neurologically based motor impairment (Hustad, Auken, Natale, & Carlson, 2003a; Hustad & Garcia, 2002, 2005). Some defining speech characteristics of CP include overall deficits in motor skills resulting in poor articulation and respiratory support. There is a lack of recent statistical data outlining the prevalence of adults with CP and co-occurring speech and communication difficulties. According to past literature, up to 88% of individuals with CP have dysarthria (Wolfe, 1950, as cited in Hustad & Garcia, 2002, 2005).

Dysarthria is a “collective term used for a group of speech disorders that arise from disruptions in the neuromotor control of the muscular activities necessary for the production of speech” (Darley, Aronson, & Brown, 1975 as cited in McNeil, 2009, p. 116). The dysarthric speech characteristics in CP are fairly stable over time and therefore Hustad and Garcia (2005) concluded that the communication challenges faced by adults are comparable to those faced by a younger cohort. Approximately 40% of children with CP are unable to meet all communication needs using speech as the sole method. Of these communicatively impaired children, 26% produce some functional natural speech and 14% do not (Keenes et al., 2002 as cited in Hustad & Garcia, 2005, p. 996-997).

Many adults who have dysarthric speech secondary to CP choose natural speech as a mode of communication (Hustad et al., 2003a, Hustad, Jones, & Dailey, 2003b; Hustad & Garcia, 2005). Dysarthric speech patterns vary in intelligibility depending on the severity level. Intelligibility is defined as the “degree to which the acoustic signal is understood by a listener” (Yorkston, Strand, & Kennedy, 1996, p. 55). A decrease in

intelligibility has important social and clinical implications. Therefore, it is imperative that improvement of an individual’s intelligibility become a primary goal of treatment. Since many adults with CP have chosen to use natural speech, clinicians need to determine how to improve communicative effectiveness and how to best provide services to this population.

The functionality of natural speech varies depending on many factors, including but not limited to, the acoustic signal, the complexity of the message, the environmental context and the communication partner (Hustad & Garcia, 2005). Therefore, it is crucial that individuals with CP are provided with a variety of modes of communication including various strategies to supplement speech in different situations when reduced intelligibility is of concern.

Speech supplementation strategies are used by speakers to augment natural speech by providing supplementary contextual information to a distorted acoustic signal (Hanson, Yorkston, & Beukelman, 2004). These strategies are often used by speakers with dysarthria. Speech supplementation strategies that were examined in the present review include 1) alphabet cues, 2) topic cues, 3) combined alphabet and topic cues, and 4) iconic hand gestures.

1) Alphabet supplementation is an aided strategy in which a speaker uses an alphabet board to identify the first letter of each constituent word of a message either immediately before or during the production of that word.

2) Topic supplementation is an aided strategy in which a speaker provides a listener with a key word or phrase about the intended meaning of a message and then produces the target message.

3) Combined alphabet and topic supplementation is an aided strategy in which a speaker first provides a listener with semantic information (key word or phrase) and then provides orthographic information (first letter of each word) immediately before or during production of the target words and message.

4) Iconic hand gestures is an unaided strategy in which a speaker produces gestures and movements while speaking, that relate to the verbal message.

Adults with dysarthric speech secondary to CP may require communication strategies to supplement a poor acoustic signal. Research on the use of speaker-implemented speech supplementation strategies in adults with dysarthric speech secondary to CP has been limited. Speaker-implemented speech supplementation strategies have been documented in the literature and the efficacy of these strategies will be reviewed.

Objectives

The primary objective of this paper is to critically evaluate the existing literature regarding the evidence for improved speech intelligibility with the use of speech supplementation strategies in adults with CP. The secondary objective of this paper is to propose evidence-based practice recommendations for clinical application and future research.

Methods

Search Strategy

Computerized databases including CINAHL, SCOPUS, PubMed, and the Universities library search engine were searched using the following search strategy: (cerebral palsy) AND (adult) AND (speech supplement*) OR (speech supplement* strateg*) OR (augmentative communicat*) OR (AAC) OR (intelligib*). Some articles were accessed through the citations of previously searched articles. The search was limited to articles written in English.

Selection Criteria

Studies selected for inclusion in this critical review were required to investigate the use of speaker-implemented speech supplementation strategies in adults with dysarthric speech secondary to CP. Studies were limited to those whose objective was to report intelligibility scores using speech supplementation strategies compared with habitual speech. No limits were set regarding the methodological design, the type of CP, the type or severity of dysarthria, or the type of speech supplementation strategy utilized.

Data Collection

Results of the literature search yielded five single subject design studies congruent with the aforementioned selection criteria.

Results

Methodological Similarities

All five reviewed studies used single subject designs and investigated the use of cue conditions and the effects on speech intelligibility for adults with dysarthric speech secondary to CP. There were two groups of participants, speakers and listeners.

The first author in all studies (KCH) provided the speakers with a verbal description and a model depicting alphabet cues, topic cues and combined alphabet and topic cues. For the iconic hand gestures cue condition, the speakers watched a video of another individual producing the test sentences and gestures. Speakers were given rehearsal sentences to practice using each strategy until they reached mastery criterion meaning that each speaker was able to use the strategy comfortably with 100% accuracy. Speakers were video and audio recorded in their home in a quiet environment where loudness levels and lighting were controlled. An orthographic representation and verbal model of each sentence were provided to the speakers prior to each production. Speakers produced each narrative passage in each of the strategy conditions and produced all passages using habitual speech. Repetitions were allowed in order to ensure 100% accuracy.

Stimulus tapes were constructed. The following modifications were made: unwanted sentences were deleted, the tapes were amplitude normalized, the videos were digitally enhanced and a grapheme and/or topic were placed in a box by the speakers face.

KCH provided the listeners with instructions describing the purpose of the study, the speakers they would be seeing and hearing on the video and how to transcribe. The listeners were in a quiet sound attenuated room and output levels were monitored. Listeners were instructed to transcribe verbatim and to guess if unsure.

Listener ratings were used to determine intelligibility scores for the speakers. The scores were obtained by applying listener statistics to individual speakers' speech samples. Among the five studies, there were a total of 384 listeners (ranging from 24 to 144 within each study). A parametric split-plot analysis of variance (ANOVA) and pairwise contrasts using *t*-tests were completed.

Comparing Three Cue Conditions

The subsequent three studies by Hustad et al. (2003a, 2003b) and Hustad (2005) investigated the use of three cue conditions including alphabet cues, topic cues, and combined cues relative to a habitual (i.e. noncued) speech control condition.

The first study by Hustad et al. (2003a) included three adult male speakers with a medical diagnosis of CP. Speaker 1 and 3, aged 24 years and 32 years had a speech diagnosis of profound mixed spastic-hyperkinetic dysarthria and speaker 2, aged 37 years had a speech diagnosis of profound spastic dysarthria. 72 listeners without disabilities, 14 male and 58 female, mean age 20-23 years, transcribed.

Group findings (based on listener statistics) revealed that combined cues resulted in significantly higher intelligibility scores than no cues, topic cues, and alphabet cues. Pairwise contrasts among individual speakers indicated a significant increase in intelligibility when comparing no cues and combined cues. Mean intelligibility for each of the speakers during habitual speech and while using combined cues, respectively, were: speaker 1: 5.35% (SD = 4.42) and 45.42% (SD = 15.37); speaker 2: 7.20% (SD = 5.92) and 56.25% (SD = 17.98); speaker 3: 8.70% (SD = 4.95) and 38.33% (SD = 14.32).

Additionally, listeners ranked the communication effectiveness of each cue condition using a Likert scale (1-most effective; 4-least effective). A non-parametric repeated measures equivalent to ANOVA revealed that combined cues were rated more effective than no cues, topic cues, and alphabet cues. This result was statistically significant.

A second study by Hustad et al. (2003b) included four adult speakers with a medical diagnosis of CP. Speaker 1, male, aged 33 years had a speech diagnosis of severe mixed spastic-hyperkinetic dysarthria. Speaker 2 and 4, females, aged 58 years and 42 years had a speech diagnosis of severe spastic dysarthria. Speaker 3, female, age 33 years had a speech diagnosis of severe mixed-spastic ataxic dysarthria. There was an additional speaker in the study with spastic dysarthria secondary to traumatic brain injury however this speaker's results will not be included in this review due to previously mentioned selection criteria. 120 listeners without disabilities, 30 male and 90 female, mean age 20.46-21.43 years, transcribed.

Pairwise contrasts (based on listener statistics) demonstrated that for all four speakers with CP, combined cues and alphabet cues resulted in significantly higher intelligibility scores than no cues and topic cues. The difference between combined cues

and alphabet cues as well as no cues and topic cues was not statistically significant. Through an analysis of individual speakers, results of the study demonstrated that when compared with no cues, combined cues resulted in greater intelligibility scores than alphabet cues. Mean intelligibility for each of the speakers during habitual speech and while using combined cues, respectively, were: speaker 1: 20.92% (SD = 10.56) and 70.79% (SD = 18.86); speaker 2: 40.17% (SD = 12.21) and 67.12% (SD = 18.58); speaker 3: 36.56% (SD = 13.25) and 76.57% (SD 12.32); speaker 4: 60.67% (SD = 16.77) and 89.50% (SD = 10.89).

Additionally, the study examined differences in speech rate when speech supplementation strategies were implemented by the speakers. An ANOVA revealed that combined cues and alphabet cues decreased speech rate. The difference between combined cues and alphabet cues was significant, with alphabet cues decreasing speech rate to a greater degree.

In the third study, Hustad (2005) included one adult male speaker age 52 years with a medical diagnosis of CP and a speech diagnosis of mild spastic dysarthria. 24 listeners without disabilities, 12 male and 12 female, mean age 20.7 years, transcribed.

Pairwise contrasts (based on listener statistics) demonstrated that alphabet cues resulted in significantly higher intelligibility scores than no cues, topic cues and combined cues. Approximate mean intelligibility during habitual speech was 80% and when using alphabet cues was 91%. The difference between alphabet cues and combined cues as well as no cues and topic cues was not statistically significant.

Additionally, listeners attitude rankings for each cue condition were identified using a Likert scale (1-disagree strongly; 7-agree strongly). A non-parametric ANOVA revealed that alphabet cues were given a higher attitude rating than no cues and this result was statistically significant. Combined cues also resulted in higher attitude ratings than no cues and topic cues. The difference between attitude ratings for alphabet cues and combined cues was not statistically significant.

Comparing Two Cue Conditions

The subsequent two studies by Hustad and Garcia (2002, 2005) investigated the use of two cue conditions including alphabet cues and iconic hand gestures relative to a habitual (i.e. noncued) speech control condition.

The study by Hustad and Garcia (2002) included one adult female speaker age 42 years with a medical diagnosis of CP and a speech diagnosis of moderate to

severe spastic dysarthria. 24 female listeners without disabilities, mean age 20.6 years, transcribed.

Pairwise contrasts (based on listener statistics) revealed that both alphabet cues and iconic hand gestures resulted in significantly higher intelligibility scores than no cues. The difference between alphabet cues and iconic hand gestures was not statistically significant. The study examined differences in speech intelligibility in each cue condition when speakers were given stimulus sentences with either high or low predictive value. It was demonstrated that sentences that were high predictive resulted in significantly higher intelligibility scores than sentences that were low predictive. This result remained consistent regardless of cue condition.

Mean intelligibility in each of the cue conditions with low predictive stimulus sentences were: habitual speech 30.69%, gestures 49.74%, and alphabet cues 57.97%. Mean intelligibility in each of the cue conditions with high predictive stimulus sentences were: habitual speech 56.16%, gestures 72.07%, and alphabet cues 71.20%.

The other study by Hustad and Garcia (2005) was noted to be an extension of the study by Hustad and Garcia (2002). Included in this study were three adult speakers with a medical diagnosis of CP. Speaker 1, female, age 42 years had a speech diagnosis of severe spastic dysarthria. Speaker 2, female, age 33 years had a speech diagnosis of severe mixed spastic-ataxic dysarthria. Speaker 3, male, age 37 years had a speech diagnosis of severe spastic dysarthria. 144 listeners without disabilities, gender not specified, mean age 20-23 years, transcribed.

Pairwise contrasts (based on listener statistics) revealed that for speakers 1 and 2, alphabet cues resulted in significantly higher intelligibility scores in both the audio-only and the audio-visual presentation mode than no cues or gestures. For both speakers in both cue conditions, the audio-visual presentation mode resulted in higher intelligibility scores. In the audio-visual presentation mode, approximate mean intelligibility during habitual speech and while using alphabet cues, respectively, were: speaker 1: 45% and 77%; speaker 2: 35% and 69%.

Pairwise contrasts (based on listener statistics) revealed that for speaker 3, iconic hand gestures resulted in significantly higher intelligibility scores than no cues in the audio-visual presentation mode. In the audio-visual presentation mode, speaker 3's approximate mean intelligibility during habitual speech was 8% and while using iconic hand gestures it was 48%.

Also for speaker 3, alphabet cues resulted in significantly higher intelligibility scores than no cues in the audio-only presentation mode. In the audio-only presentation mode, mean intelligibility during habitual speech was 7% and while using alphabet cues it was 21%.

Additionally, listeners rated the overall helpfulness of each strategy using a Likert scale (1-not helpful; 7-very helpful). A non-parametric ANOVA revealed that both iconic hand gestures and alphabet cues were rated to be more helpful than no cues. This result was statistically significant.

Discussion

The literature reviewed suggests that the use of speech supplementation strategies in adults with dysarthric speech secondary to CP does improve intelligibility. Within the studies, there exist strengths and limitations related to the participants, procedures, measurements and statistical analyses.

Participants

An overwhelming similarity between all five studies was that they all had poor power due to an inadequate speaker sample size. There were a total of 12 speakers across the five studies. This greatly limits the generalization of the results as all possible outcomes would not have been observed. A strength within the studies was that all speakers were treated equally during experimental testing. The speakers were similar at baseline with regards to age (ranging from 24 to 58 years, mean age of 39 years), medical diagnosis, speech diagnosis, educational level (high school or above), selection method (direct) and communication strategies (three speakers used speech only and five speakers used speech and voice output communication devices). This can be seen as both an advantage as well as a limitation. The inclusion criteria for speakers controlled for potential confounding variables due to the similarities among speakers. However, since the speakers shared such similar characteristics, this is a factor that limits generalization. For example, results may not be applicable to those speakers who have poorer cognition or a low level of motor function. Therefore, all of the studies had limited external validity. Although the inclusion criteria were clearly stated for speaker selection, the process used to select speakers was not described in any of the studies. Also, it was not reported whether any of the speakers had used any of the tested speech supplementation strategies in the past.

Procedures

All of the studies used a single subject experimental design meaning that the speakers acted as their own

controls. This type of design was appropriate as it allowed for individual differences among speakers to be analyzed. A methodological strength that was apparent in all studies was randomization and counterbalancing. For speakers and listeners, to prevent an order effect, each cue condition and passage were presented in randomized order. To prevent a learning effect, the task presentation order was counterbalanced. The procedures in all of the studies were clearly outlined allowing them to be reproduced. A potential nuisance variable that could affect the findings of the studies includes researcher bias. All of the studies were conducted by the same primary researcher (KCH), the researcher provided directions to both speakers and listeners and the researcher scored the listener transcriptions. Also, there was no double blind as all of the speakers and listeners were aware of the purpose of the studies. The speech stimuli consisted of pre-determined utterances spoken in a monologue fashion, the speakers had limited exposure to the supplementation strategy, there was no interaction between speaker and listener and the speaking and listening conditions were idealized. Therefore, all of the studies had limited content validity as they do not truly reflect the speakers' performance and true intelligibility scores.

Measurements

For inclusion in all of the studies, listeners were of a younger cohort (approximate mean age of 20-23 years in all studies), had no disabilities, had no more than incidental exposure interacting with individuals with communication disorders, and passed hearing and vision testing. Results should be interpreted with caution due to the listener groups in the studies. The intelligibility scores given to each speaker by the listeners may not be an accurate representation of how others would rate intelligibility. Ecological validity is limited in Hustad et al. (2003a, 2003b) because the listeners heard the stimulus sentences twice before transcribing and this could have resulted in enhanced intelligibility scores.

All of the reliability measures were based on listener statistical analyses. In Hustad et al. (2003a, 2003b) inter-scorer reliability was carried out by having a unique judge rescore transcription data for two listeners per speaker revealing a Pearson product-moment correlation coefficient of 0.95 in both studies. In Hustad and Garcia (2005), reliability measures were also undertaken. Inter-scorer reliability was carried out by having a unique judge rescore transcription data for 36 of the 114 listeners revealing 95.30% agreement. Intra-scorer reliability was carried out by having the same judge involved in the initial scoring rescore transcription data for 36 of the 114 listeners revealing 99.72% agreement. The studies by Hustad (2005) and

Hustad and Garcia (2002) did not report if there were any reliability measures taken.

To correct for multiple comparisons and control for type 1 error rate, the Bonferroni procedure was completed in Hustad (2005), Hustad et al. (2003a, 2003b) and Hustad and Garcia (2005). It was not reported in Hustad and Garcia (2002) if the Bonferroni procedure was used therefore reviewers should be aware that type 1 error may be a concern in this one study.

Statistical Analyses

A parametric split-plot ANOVA and pairwise contrasts using *t*-tests were utilized within the reviewed literature. Although previously mentioned, it is important to reiterate that the statistics within the studies were applied to the listeners as opposed to the speakers. Therefore, all five studies need to be interpreted with caution due to this limitation. The objective of the reviewed literature as well as this paper was to determine if the implementation of speaker-implemented speech supplementation strategies would improve intelligibility. Unfortunately, the literature does not provide a very clear or powerful answer to the proposed question. Due to a total speaker sample size of 12, applying statistics is suggested to be unrealistic. With a total listener sample size of 384, is suggested to be more appropriate to apply statistics, thus what the experimenters have done. When the studies are reviewed independently, the level of evidence and the validity of the studies are suggestive. When all five studies are reviewed concurrently, due to the overall consensus that alphabet cues and combined cues improve intelligibility to the greatest extent, the level of evidence and validity of the studies are slightly compelling.

Recommendations

The information obtained from this critical review paper can be applied clinically. When treating an adult with dysarthric speech secondary to CP, it is essential that clinicians examine the available evidence-based research. Questions arise regarding what type of individual is a good candidate to use speech supplementation strategies and what intelligibility score is considered to be adequate for functional communication. In 2004, Hanson et al. reviewed speech supplementation techniques for dysarthria. The authors proposed that a good candidate has an intelligibility score that can be improved above 80%. To date, there is no agreement regarding how much change is needed in order for intelligibility scores to be identified as functionally important. Beukelman et al. (2002, as cited in Hanson et al., 2004) suggested that intelligibility needs to improve functional communication regardless

of the percentage of improvement. The reviewed literature discussed that the documented improvements in intelligibility may not represent a clinically significant change and the use of speech supplementation strategies as sole communication methods may not be adequate to meet all communication needs. Clinicians need to consider the importance of additional modes of communication.

There are a variety of considerations that clinicians need to take into account before adopting speech supplementation strategies. Many factors can impact intelligibility and ultimately functional communication. Hustad et al. (2003a) stated that one needs to consider contextual factors such as the predictability of messages, the familiarity of the communication partner and linguistic cues. In Hustad and Garcia (2002) they showed that a linguistic context provided by alphabet cues and a paralinguistic context provided by iconic hand gestures had an affect on the functionality of communication. They highlighted the “value of developing treatment programs that emphasizes the importance of contextual influences to understanding dysarthric speech” (Hustad & Garcia, 2002, p. 284).

Within clinical practice, clinicians also need to consider the diagnostic severity level of the CP in addition to the speech disorder severity level. When examining the reviewed literature, alphabet cues were ranked as the most efficacious cue in improving intelligibility in adults with mild and severe dysarthria. Combined cues were shown to be advantageous in improving intelligibility in adults with severe and profound dysarthria. It was suggested that for speakers with mild dysarthria, topic cues or combined cues did not improve intelligibility because this strategy may have been providing redundant information to the listeners whereas for speakers with severe dysarthria, combined cues may offer new information to the listeners due to a poorer acoustic signal (Hustad et al., 2003). Thus severity levels along with individual differences are important to contemplate. Furthermore, each strategy has its advantages (e.g. cost, ease of training) and disadvantages (e.g. loss of prosody) which should be considered (Hanson et al., 2004).

Although collectively, all of the studies have a level of evidence that is slightly compelling, some future recommendations include but are not limited to the following. Studies need to be conducted to include a larger sample of speakers so that statistics can be applied appropriately. Studies also need to focus on different severity levels for both CP and dysarthria to improve knowledge regarding which speech supplementation strategies are most effective for the different severity levels. Additionally, a greater

emphasis needs to be placed on determining the learning requirements and cognitive demands placed on speakers when using the speech supplementation strategies in natural environments during real dynamic communication interactions. The speakers’ acceptance of the augmentative communication device is also of importance.

In Hustad et al. (2003b) it was suggested that alphabet cues may improve speech intelligibility because of a corresponding reduced speech rate. This notion should be explored further to identify the effects that such a strategy has on speech intelligibility.

Studies need to be conducted where the main focus and purpose is on the speakers and their final intelligibility as opposed to the mean intelligibility differences between cues. For example, although speech supplementation strategies improved intelligibility in the reviewed studies, some of the speakers continued to have intelligibility scores under 80%. Thus, the effect of speech supplementation strategies on both speech intelligibility and functional communication should be considered of utmost importance in future studies of speakers with CP.

Conclusion

Overall, the research findings illustrate that speech supplementation strategies can be effective in improving intelligibility in selected adults with dysarthric speech secondary to CP. Clinicians need to assist clients in choosing speech supplementation strategies based on individual preferences as well as choosing strategies that have an important impact on communication.

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