Augmentative and Alternative Communication, 2003 Vol. 19 (3) September 2003, pp. 187–198

Improving Intelligibility of Speakers with Profound Dysarthria and Cerebral Palsy

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Many individuals with cerebral palsy use natural speech as one mode of communication. Recent research suggests that, for these individuals, speech supplementation strategies, such as topic cues, alphabet cues, and combined cues, can have a significant impact on intelligibility; however, the impact of these strategies when speakers actually implement them while producing connected speech is largely unknown. In the present study, the effects of speaker-implemented topic cues, alphabet cues, and combined cues (compared with a no cues control condition) were studied for three individuals with profound dysarthria secondary to cerebral palsy. Also of interest were listener rankings of each strategy, which were based on speakers' perceived effectiveness. Group results showed that combined cues yielded higher intelligibility scores than no cues, topic cues, and alphabet cues. Conversely, no cues resulted in lower intelligibility scores than alphabet cues and topic cues; and alphabet cues resulted in higher intelligibility scores than topic cues. Most importantly, the magnitude of the benefit from combined cues was approximately 40% across speakers, suggesting that this could be a clinically useful intervention strategy for individuals with profound dysarthria in some situations. Group data for listener effectiveness rankings followed the same pattern of results as intelligibility data. Individual differences among speakers were present and are discussed.

Keywords: Augmentative and alternative communication; Dysarthria; Cerebral palsy; Functional communication; Intelligibility

INTRODUCTION

Many individuals with cerebral palsy have difficulty producing speech that is intelligible across all contexts and with all partners they encounter in daily life. Indeed, a recent demographic study of school-aged children with cerebral palsy suggests that approximately 40% have difficulty being understood (Kennes et al., 2002). Although the severity of the dysarthrias associated with cerebral palsy can range from very mild to complete anarthria, specific speech characteristics are extremely heterogeneous in nature and depend, to a great extent, on underlying pathology (Yorkston, Beukelman, Strand, & Bell, 1999). Voice output augmentative and alternative communication (AAC) systems are powerful tools that are often used to enhance functional communication for those with markedly reduced intelligibility resulting from dysarthria. Nonetheless, many individuals with cerebral palsy do choose to use natural speech as a mode of communication. In fact, research by Kennes et al. (2002) indicated that of 40% of children with cerebral palsy who had difficulty being understood by communication partners, only 14% were completely unable to speak, while 36% were able to use speech in at least some communication situations, despite severe or even profound dysarthria.

For those who have the ability to use it, natural speech it is unquestionably the most efficient and flexible mode of communication because it is native or 'built-in'. Obviously, however, speech must be intelligible to communication partners, and this is a more complex issue than clinical measures may suggest. In reality, intelligibility is a multi-faceted construct that can fluctuate as a result of any one or a combination of variables related to both the speaker and the listener (Connolly, 1986; Hustad, Beukelman, & Yorkston, 1998; Hustad, Jones, & Dailey, 2003). Although these variables are only beginning to be identified and studied, a growing body of

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ISSN 0743-4618 print/ISSN 1477-3848 online © 2003 Taylor & Francis Ltd
DOI: 10.1080/0743461031000121052

research suggests that contextual factors (e.g., predictability of messages, familiarity of communication partner, linguistic cues) play key roles (Garcia & Cannito, 1996; Hustad & Cahill, 2003; Hustad & Garcia, 2002). In fact, research suggests that different low tech AAC strategies, used in conjunction with natural speech, may be promising interventions for increasing intelligibility by enhancing listeners' contextual knowledge (Hustad & Beukelman, 2001; 2002; Hustad & Garcia, 2002).[1] Specifically, alphabet supplementation (Beukelman & Yorkston, 1977; Crow & Enderby, 1989; Hustad & Beukelman, 2001; Hustad & Garcia, 2002), topic supplementation (Carter, Yorkston, Strand, & Hammen, 1996; Dongilli, 1994; Garcia & Cannito, 1996; Hustad & Beukelman, 2001), and combined supplementation (Beliveau, Hodge, & Hagler, 1995; Hustad & Beukelman, 2001) have all been shown to increase intelligibility significantly, relative to habitual speech.[2] Each of these strategies serves to provide listeners with different kinds of contextual information about the content of the speaker's message. For example, topic supplementation provides listeners with broad topical cues that may serve to inform listener expectations for forthcoming messages; alphabet supplementation provides listeners with narrow, word-specific alphabet cues that add redundancy to the speech signal and may serve to reduce the number of possible word choices available to the listener; and combined supplementation provides listeners with topical and alphabet cues that offer both general and specific contextual information.

Hustad and Beukelman (2001) examined the effects of three types of experimentally imposed supplemental cues (topic cues, alphabet cues, and combined cues), relative to a control condition (no cues), on the intelligibility of four speakers with severe dysarthria secondary to cerebral palsy. Results showed that combined cues yielded higher intelligibility scores than any other cue condition and that no cues yielded lower intelligibility scores than any other cue condition. In addition, alphabet cues resulted in higher intelligibility scores than topic cues. This study demonstrated the important impact that linguistic cues alone can have on the intelligibility of speakers with severe dysarthria; however, because these findings were based on a research paradigm in which speakers did not actually implement the strategies, it is difficulty to generalize the results to clinical situations.

Only two studies have involved actual speaker implementation of cues that were visible to listeners. Beukelman and Yorkston (1977) examined the effects of speaker-implemented alphabet cues on intelligibility, while Hustad, Jones, and Dailey (2003) examined the effects of speaker-implemented alphabet, topic, and combined (alphabet and topic) cues on intelligibility. Results of both studies showed that speaker implementation of alphabet cues had a marked impact on intelligibility (up to 45% improvement relative to habitual speech), but Hustad et al. found that topic cues did not enhance intelligibility relative to no cues, and that combined cues did not enhance intelligibility relative to alphabet cues. Findings showed that both combined cues and alphabet cues yielded higher intelligibility scores than topic cues and no cues. Hustad et al. also found that rate of speech decreased by approximately 70% when speakers implemented alphabet and combined cues as compared with topic and no cues. Data from Beukelman and Yorkston (1977) and Hustad et al. (2003) suggest that speech intelligibility may increase when speakers implement strategies because of the joint effects of reduced speech rate and the linguistic information provided by alphabet cues.

It is important to note that all of the previous studies that have examined speech supplementation strategies have focused on individuals with moderate to severe dysarthria. Little is known about the impact of these strategies on the speech intelligibility of individuals with profound dysarthria (below 10% intelligible). These individuals are an important clinical population for whom access to multiple communication modes and strategies is critical because of the severity of their communication difficulties.

The purpose of the present study was to examine the effects of speaker-implemented speech supplementation strategies (topic cues, alphabet cues, and combined cues), relative to a control condition (no cues), on the intelligibility of three individuals with profound dysarthria as they used each of the strategies. A contrived and experimentally controlled communication situation was employed in which speakers produced standard stimuli that were rehearsed, and listeners viewed the speakers on a videotape that was digitally optimized.

Listener rankings of each of the strategies were also of interest; in particular, whether listener rankings of perceived communication effectiveness were consistent with intelligibility results (i.e., whether listeners give the highest rank to the strategy for which speech was most intelligible). Previous research by Hustad (2001), in which cues were superimposed on habitual speech, showed that effectiveness ratings were highest for combined cues and lowest for habitual speech. In the present study, we sought to verify this for speaker-implemented strategies. The following specific research questions were addressed:

1. Across all speakers, are there differences in intelligibility scores among speaker-implemented strategies (no cues, topic cues, alphabet cues, and combined cues)? Are there differences with regard to pattern and magnitude of benefit from strategies among individual speakers?
2. Across all speakers, are there differences in listener rankings of communication effectiveness for each strategy? Are there differences with regard to listener rankings among individual speakers?

METHOD

Speakers with Dysarthria

Three individuals with profound dysarthria secondary to cerebral palsy, each of whom used AAC, participated in this study as speakers. Two speakers had athetoid quadriplegia and associated mixed spastic-hyperkinetic dysarthria; one had spastic diplegia and associated spastic dysarthria. Speakers met the following inclusion criteria: (a) they were able to produce connected speech consisting of at least eight consecutive words; (b) their speech intelligibility was below 10%, as measured by the Sentence Intelligibility Test (Yorkston, Beukelman, & Tice, 1996); (c) they used speech as a mode of communication in some situations; (d) they were native speakers of American English; (e) they had functional literacy skills at or above the sixth grade level; (f) they had corrected or uncorrected vision within normal limits per self-report; (g) they had hearing within normal limits per self report; and (h) they were able to accurately direct select letters and orthographically represented phrases from an 8½ in. by 14 in. display with cells that were 1 in. by 1 in. in size. Demographic information for each speaker is presented in Table 1; perceptual features of speech as assessed by a certified speech language pathologist are presented in Table 2.

Stimulus Material

Four narrative passages and their associated topic cues were employed as speech stimuli for this study. Details regarding linguistic characteristics and development of these stimuli are elaborated elsewhere (Hustad, 2001; Hustad & Beukelman, 2001; 2002). In brief, passages consisted of 10 syntactically and semantically predictable sentences that systematically varied in length between five and eight words. Each passage contained a total of 65 words and represented a sixth grade reading level. Passages used in the present study pertained to a sporting event, a natural disaster, purchasing a vehicle, and Independence Day (i.e., a national holiday). See the Appendix for a sample passage and topic cue.

Strategy Instruction

The speakers with dysarthria completed four experimental tasks. In three of the tasks, they produced each of the four narrative passages while implementing a different speech supplementation

TABLE 1 Demographic Information for Speakers with Dysarthria

	Speakers		
	1	2	3
Age	24	37	32
Gender	male	male	male
Medical diagnosis	cerebral palsy: athetoid quadriplegia	cerebral palsy: spastic	cerebral palsy: athetoid quadriplegia
Primary mode of communication as per self report	voice output AAC device and natural speech	voice output AAC device and natural speech	voice output AAC device and natural speech
AAC system	Liberator™	Liberator™	Liberator™
Length of time AAC system used	9 years	5 years	10 years
Selection method	direct selection using hands	direct selection using hands	direct selection using a head pointer
Mobility	power wheelchair	no assistive devices necessary	power wheelchair
Education	completed high school	completed high school; attended college for 2 years	completed high school; attended college for 2 years
Employment	currently taking college courses	part time clerical work	self-employed web page developer

TABLE 2 Perceptual Speech Characteristics of Participants with Dysarthria

	Speakers		
	1	2	3
Speech diagnosis	Mixed spastic-hyperkinetic dysarthria	Spastic dysarthria	Mixed spastic-hyperkinetic dysarthria
Articulatory characteristics	• slow, labored, imprecise • prolonged sounds and intervals • irregular articulatory breakdown	• slow, labored, imprecise • marked distortion of consonants and vowels	• slow, labored, imprecise • irregular articulatory breakdown • marked vowel distortion
Phonatory characteristics	• phonatory arrests • pitch breaks • abrupt variations in loudness • difficulty coordinating onset and offset of voicing during connected speech	• wet vocal quality • strained-strangled	• wet vocal quality • strained-strangled • reduced loudness • abrupt and forced initial onset of voicing pitch breaks
Respiratory characteristics	• reduced inhalatory and exhalatory control • short phrases	• shallow inhalation	• reduced exhalatory control • short phrases
Resonatory characteristics	• mild hypernasality	• marked hypernasality	• mild hypernasality
Intelligibility on SIT*	6%	7%	9%

* Speech Intelligibility Test

strategy (topic cues, alphabet cues, and combined cues); in the fourth task they produced the same four passages using habitual speech. Strategies were blocked, with all four passages (40 sentences) recorded consecutively for each strategy condition (i.e., speakers first learned and mastered one strategy, then produced all of the narrative passages for that strategy prior to introduction of the next strategy). To control for a potential order effect associated with learning the different strategies, each speaker completed the four experimental tasks in different orders. In addition, the four narrative passages were presented in different orders within tasks and among speakers.

Prior to recording the experimental narrative passages, the first author (KCH) instructed speakers in the use of each target strategy. Instruction involved a verbal description of how the strategy would be used, the purpose of the strategy, and experimenter modeling of the strategy. Speakers practiced using the strategy on a set of rehearsal sentences (which were similar to the experimental passages) until they were able to use the strategy comfortably with 100% accuracy. For the topic cues condition, strategy use involved correctly pointing to the pre-determined topic of each utterance on a pre-made communication board prior to speaking the utterance. For the alphabet cues condition, strategy use involved correctly pointing to the first letter of each word while speaking. The timing of letter selection and speech production was controlled in the alphabet cues condition, so that speakers either selected the letter and simultaneously produced the target word or selected the letter and produced the target word immediately afterward. For the combined cues condition, speakers pointed to the topic of each sentence then pointed to the first letter of each constituent word, following the same accuracy and timing requirements as those for alphabet cues and topic cues. After reaching mastery criterion, speakers were recorded using each strategy while producing the experimental narrative passages.

During recording, speakers were required to use each strategy with 100% accuracy for topic and letter selection and produce verbatim all words within each sentence for each narrative passage. Speakers were asked to repeat any sentence in which they (a) selected an inappropriate first letter or topic, (b) spoke the word before indicating the first letter, and (c) did not produce the target sentence exactly as written. Across all speakers, less than 10% of the test sentences that comprised narrative passages had to be repeated. All three of the speakers learned the strategies very rapidly and had no difficulty implementing them while producing the experimental passages. Prior to recording test sentences, learning time for each strategy was less than 15 minutes for each speaker.

Recording the Speakers

Using digital video and digital audiotape along with a high quality lapel microphone, speakers were recorded in a quiet environment within their homes. Lighting was controlled to eliminate shadows, and speakers were seated in front of a chroma blue background. Video recordings focused on the speakers' upper body so that the 8½ in. × 14 in. communication board that was mounted on speakers' laps and the speakers' facial features were clearly visible. For all speech stimuli, an orthographic representation was provided on a laptop computer, which was positioned directly in front of the speaker but out of the camera's view. In addition, a verbal model was presented for each sentence. Speech stimuli were presented via two modalities to optimize the naturalness of speakers' productions so that they sounded as conversational as possible.

Constructing Stimulus Tapes

Digital video recordings were transferred to a personal computer via a Firewire™ (1394) card, maintaining the sampling rate and frame size of the original recording (video = 29.97 frames per second, 640 × 480 frame size). Video recordings were edited using Adobe Premiere™ 6.0 (computer software) for Macintosh, and audio recordings were edited using SoundForge™ 4.1 (computer software) for Windows. Editing involved separating digital recordings of the four narrative passages for each speaker and experimental condition into 160 constituent sentences (40 for each experimental condition) to remove unwanted productions on the original tapes. For the audio samples, individual sentences for each speaker were amplitude normalized so that the peak amplitude of each sentence was 69 dB.

Because video-taping took place from directly in front of the speakers, it was difficult to clearly see the topic and/or letter cue to which they were pointing on the videotape; this problem was compensated for by digitally enhancing the videos so that cues to which speakers were pointing were clearly visible, just as they would be if listeners had been sitting next to the speakers. For the topic cues condition, the topic of each sentence was represented orthographically in a box to the right of a speaker's face on the videotape and was shown for a duration of 3 s, which started immediately prior to the onset of speech and corresponded approximately with the pointing gesture of the speaker. Similarly, for the alphabet cues condition, the first letter of each word was represented in a box to the right of a speaker's face on the videotape. The onset of each grapheme corresponded to the physical pointing gesture of the speaker and was displayed for the duration of the target word, as indicated by visual inspection of the speech waveform. For combined cues, the topic was presented for a duration of 3 s, starting prior to the onset of speech and corresponding with the speaker's pointing gesture; then, the first letter of each word was presented following the speaker's pointing gesture and lasting for the duration of the word.

Videotapes of each speaker in each strategy condition presented the following sequence of elements: (a) written and auditory instructions for the task, which directed listeners to watch and listen only, (b) a sentence number, (c) a target sentence, (d) a sentence number, and (e) a target sentence. The second through fifth items were repeated until each of the 10 sentences comprising the passage was presented. Following this first presentation of all 10 stimulus sentences, the following items were presented: (a) written instructions directing listeners to write down what they heard during the interval between each sentence; (b) a sentence number; (c) a target sentence; (d) written instructions to transcribe the preceding sentence; (e) a sentence number; (f) a target sentence; and (g) written instructions to transcribe the preceding sentence. Again, the second through fifth items were repeated until all 10 sentences were completed.

Listeners

Because it was imperative that the order of the presentation of the cue conditions be completely counterbalanced for each speaker, 24 different listeners viewed tapes of each of the three speakers, for a total of 72 listeners without disabilities. Members of each group viewed videotapes of one speaker in each of the four experimental conditions: no cues, topic cues, alphabet cues, combined cues. Listeners met the following inclusion criteria: (a) they passed a pure tone hearing screening at 25 dB SPL for 250 Hz, 500 Hz, 1 kHz, 4 kHz, and 6 kHz bilaterally; (b) they were between 18 and 45 years of age; (c) they had no more than incidental experience listening to or communicating with persons having communication disorders; (d) they were native speakers of American English; and (e) they had no identified language, learning, or cognitive disabilities according to self-report. All of the listeners were either currently attending or had completed college or graduate school. As such, college-level literacy skills were assumed. The mean age of listeners in each group ranged from

20 to 23 years. Gender composition was 14 males and 58 females. Because gender was not a variable of interest, no effort was made to balance the number of male and female listeners.

Experimental Task

Presentation of Stimuli to Listeners

Listeners viewed the broadcast quality (NTSC) digital videotapes individually in a quiet, sound treated listening environment. During the experiment, each listener was seated at a desk and positioned approximately 3 feet away from a 25-inch television monitor to which one external speaker and a digital video cassette player were attached. The peak output level of stimulus material was approximately 65 dB SPL from where listeners were seated and was measured periodically to assure that all listeners heard stimuli at the same output level.

The order of the presentation of cue conditions was counterbalanced so that in each speaker-group individual listeners viewed the cue conditions in a different order. Each of the four narrative passages was presented in only one experimental condition, so that all listeners heard four unique narratives across the four experimental conditions. Furthermore, assignment of individual narratives to the four experimental conditions was evenly distributed across speaker groups and cue conditions, thus the averages for each condition reflected listener performance across all narratives. Ultimately, no two listeners within any one speaker group received narratives in the same order or the same assignment of narratives to cue conditions.

Administration Instructions to Listeners

The experimenter provided the following explanation to listeners: (a) they would complete four different listening tasks, each of which would last a total of about 60 min; (b) all of the tasks would involve the same individual, who had a speech impairment associated with cerebral palsy; and (c) for each task, the speakers would produce a different set of grammatically correct and meaningful sentences that would form a 10-sentence short story; (d) for one of the tasks they would see the speaker pointing to the topic of the story prior to producing each sentence (topic cues); for another of the tasks, they would see the speaker pointing to the first letter of each word while simultaneously speaking (alphabet cues); for another of the tasks they would see the speaker pointing to the topic and the first letter of each word while speaking (combined cues); and for the final task they would see the speaker talking without any strategies (no cues).

The experimenter informed the listeners that the purpose of the study was to determine whether particular kinds of information could help people like themselves to better understand the speaker.

In addition, the experimenter explained that, for each task, they would listen to two presentations of the same 10-sentence story. During the first presentation, listeners would simply listen without writing anything down; and during the second presentation, they would follow the instructions on the video tape, directing them to write down exactly what they thought the speaker was saying, taking their 'best guess' if they were unsure. The experimenter also explained that she would be controlling the videotape from an adjacent control room and that the listeners could take as much time as necessary to write down their responses. Upon completion of all four tasks, listeners were directed to rank each strategy, with 1 reflecting the most effective strategy and 4 reflecting the least effective strategy.

Scoring and Reliability

Intelligibility for each listener in each of the four experimental tasks was calculated by dividing the number of words identified correctly by the number of words possible for each task. Individual words were judged as incorrect or correct based on whether they matched the target word phonemically. Misspellings and homonyms were accepted as correct.

Inter-scorer reliability involved having a judge (who was not involved in initial scoring of intelligibility data) re-score all transcription data for six of the 72 listeners (two listeners from each speaker-group). The original transcription results (in percent intelligibility) for the same listener across each of the four tasks were then compared with the re-scored transcription results. Point-by-point agreement across all six listeners was 96%, calculated by dividing agreements by agreements plus disagreements and multiplying by 100.

Experimental Design

A 3×4 split-plot design (Kirk, 1995) was employed for this study. The within subjects measure was cue condition, and its four categories were no cues, topic cues, alphabet cues, and combined cues. The between subjects measure was speaker-group, with a different group of 24 listeners assigned to each of the three speakers.

RESULTS

Two sets of analyses were completed. For intelligibility data, a parametric split-plot analysis of variance (ANOVA) was employed with the Greenhouse-Geisser adjustment applied to degrees of freedom. For rank data on communication effectiveness, the Friedman's Analysis on Ranks, a non-parametric repeated measures equivalent to ANOVA, was used. Follow-up contrasts focused on examining group differences and individual differences for relative effects of each speech supplementation strategy. The Type I error rate was partitioned among all statistical tests using the Dunn Bonferroni procedure (Kirk, 1995; Marascuilo & Serlin, 1988).

Group Analyses

Mean intelligibility scores across all three speakers for each of the cue conditions were as follows: 7.09% ($SD = 5.25$) for no cues; 10.85% ($SD = 7.20$) for topic cues; 33.34% ($SD = 16.85$) for alphabet cues; and 46.66% ($SD = 17.40$) for combined cues. These data are displayed graphically in Figure 1. ANOVA revealed that the main effect for cue conditions was significant, $F\ (2.30,\ 158.53) = 226.08$, $p < 0.001$ and the interaction between cue conditions and speakers was significant, $F\ (4.60,\ 158.53) = 7.74$, $p < 0.001$. A series of six contrasts that examined all pairwise differences among cue conditions demonstrated that combined cues had significantly higher intelligibility scores than alphabet cues, topic cues, and no cues. Alphabet cues had significantly higher intelligibility scores than topic cues and no cues, and topic cues had significantly higher intelligibility scores than no cues. Statistics for these tests are shown in Table 3.

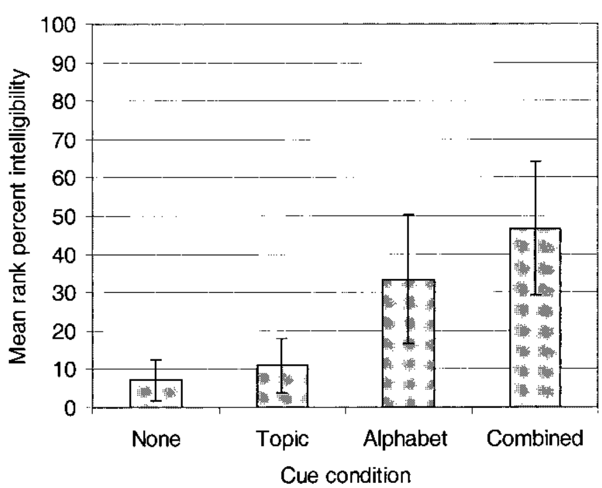

FIGURE 1 Mean percent intelligibility ($\pm SD$) across speakers by cue condition.

Mean effectiveness rankings for cue conditions across all three speakers were as follows: 3.90 for no cues; 2.71 for topic cues; 2.20 for alphabet cues; and 1.18 for combined cues. Figure 2 provides a graphic display of rank data. The Friedman omnibus ANOVA for these ranks was significant, $\chi^2\ (3,\ N = 72) = 165.26$, $p < 0.001$. A series of six Wilcoxon-signed rank follow-up tests revealed that combined cues were ranked significantly better than no cues, topic cues, and alphabet cues with regard to listener perception of communication effectiveness. Alphabet cues were ranked significantly better than no cues and topic cues, and topic cues were ranked significantly better than no cues. Statistics are shown in Table 4.

Speaker 1

Mean intelligibility for Speaker 1 in each of the cue conditions was as follows: 5.35% ($SD = 4.42$) for no cues; 8.76% ($SD = 4.61$) for topic cues; 30.25% ($SD = 14.55$) for alphabet cues; and 45.42% ($SD = 15.37$) for combined cues. These data are displayed graphically in Figure 3. A series of six contrasts that examined all pairwise differences among cue conditions for Speaker 1 demonstrated that combined cues had significantly higher intelligibility scores than alphabet cues, topic cues, and no cues. Alphabet cues had significantly higher intelligibility scores than topic cues and no cues, and topic cues had significantly higher intelligibility scores than no cues. Statistics for these tests are shown in Table 3.

Mean effectiveness rankings for cue conditions for Speaker 1 were as follows: 3.79 for no cues; 2.71 for topic cues; 2.23 for alphabet cues; and 1.27 for combined cues. Figure 4 provides a graphic display of rank data. A series of six Wilcoxon-signed rank follow-up tests for Speaker 1 revealed that combined cues were ranked significantly better than no cues, topic cues, and alphabet cues with regard to listener perception of communication effectiveness. Alphabet cues and topic cues were ranked significantly better than no cues; however, the difference between alphabet and topic cues was not significant. Statistics are shown in Table 4.

Speaker 2

Mean intelligibility for Speaker 2 in each of the cue conditions was as follows: 7.20%

TABLE 3 Follow-up Contrasts for Individual Speaker Intelligibility Data

Contrast	Mean difference	df	Standard error for contrast	*t*
CC – NC (all speakers)	39.58	71	2.07	19.05*
CC – TC (all speakers)	35.82	71	2.06	6.28*
CC – AC (all speakers)	13.33	71	2.12	4.17*
AC – TC (all speakers)	22.48	71	2.12	10.59*
AC – NC (all speakers)	26.25	71	1.99	13.15*
TC – NC (all speakers)	3.76	71	.84	4.43*
CC – NC (Speaker 1)	40.07	23	3.13	12.78*
CC – TC (Speaker 1)	36.65	23	3.06	11.97*
CC – AC (Speaker 1)	15.16	23	3.64	4.17*
AC – TC (Speaker 1)	21.49	23	2.98	7.21*
AC – NC (Speaker 1)	24.90	23	2.96	8.43*
TC – NC (Speaker 1)	3.42	23	1.14	2.99*
CC – NC (Speaker 2)	49.04	23	3.62	13.54*
CC – TC (Speaker 2)	45.96	23	3.29	13.97*
CC – AC (Speaker 2)	12.00	23	3.66	3.28*
AC – TC (Speaker 2)	33.95	23	3.70	9.17*
AC – NC (Speaker 2)	37.04	23	3.31	11.19*
TC – NC (Speaker 2)	3.08	23	1.42	2.18
CC – NC (Speaker 3)	29.63	23	2.97	9.98
CC – TC (Speaker 3)	24.84	23	3.07	8.08*
CC – AC (Speaker 3)	12.82	23	3.86	3.32*
AC – TC (Speaker 3)	12.02	23	2.94	4.08*
AC – NC (Speaker 3)	16.80	23	2.86	5.87*
TC – NC (Speaker 3)	4.79	23	1.81	2.64

NC = no cues; TC = topic cues; AC = alphabet cues; CC = combined cues; *$p < 0.001$.

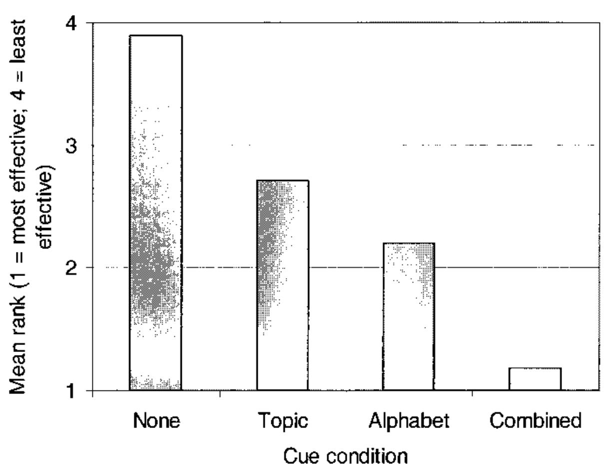

FIGURE 2 Mean listener effectiveness rankings across speakers by cue condition.

TABLE 4 Wilcoxon-Signed Rank Follow-up Statistics (z-values) for Listener Ranking of Strategies on Perceived Communication Effectiveness

	Speakers			
	All speakers	Speaker 1	Speaker 2	Speaker 3
CC – NC	7.67*	4.06*	4.81*	4.47*
CC – TC	7.10*	4.20*	4.52*	3.63*
CC—AC	6.02*	3.05*	4.35*	3.27*
AC – TC	3.62*	1.76	2.92*	1.65
AC – NC	7.42*	4.05*	4.52*	4.33*
TC – NC	7.04*	3.60*	4.35*	4.35*

NC = no cues; TC = topic cues; AC = alphabet cues; CC = combined cues; *$p < 0.001$.

(*SD* = 5.92) for no cues, 10.29% (*SD* = 5.76) for topic cues, 44.25% (*SD* = 17.90) for alphabet cues, and 56.25% (*SD* = 17.98) for combined cues. Contrasts that examined all pairwise differences among cue conditions for Speaker 2 demonstrated that combined cues had significantly higher intelligibility scores than alphabet cues, topic cues, and no cues. Alphabet cues had significantly higher intelligibility scores than topic cues and no cues. The difference between no cues and topic cues was not significant.

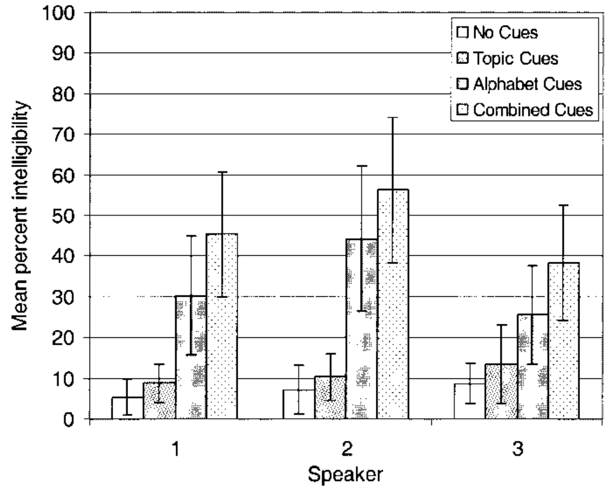

FIGURE 3 Mean percent intelligibility ($\pm SD$) by speaker and cue condition.

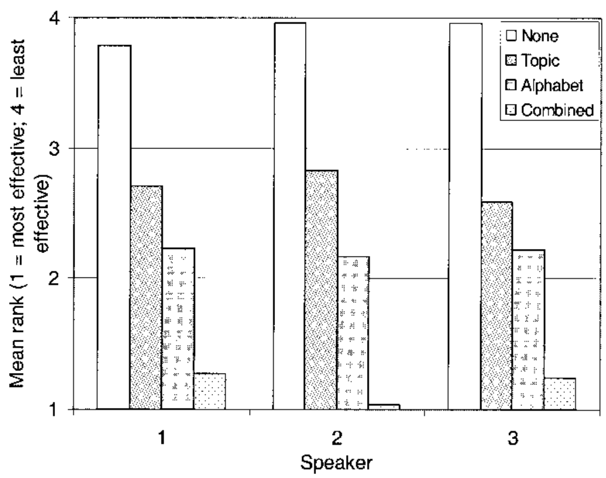

FIGURE 4 Mean listener effectiveness rankings by cue condition and speaker.

Mean effectiveness rankings for cue conditions for Speaker 2 were as follows: 3.96 for no cues, 2.83 for topic cues, 2.17 for alphabet cues, and 1.04 for combined cues. Wilcoxon-signed rank tests revealed that combined cues were ranked significantly better than no cues, topic cues, and alphabet cues with regard to listener perception of communication effectiveness. Alphabet cues were ranked significantly better than topic cues and no cues, and topic cues were ranked significantly better than no cues.

Speaker 3

Mean intelligibility for Speaker 3 in each of the cue conditions was as follows: 8.70% (SD = 4.95) for no cues; 13.49% (SD = 9.66) for topic cues; 25.51% (SD = 12.09) for alphabet cues; and 38.33% (SD = 14.32) for combined cues. Pairwise contrasts demonstrated that combined cues had significantly higher intelligibility scores than alphabet cues, topic cues, and no cues. Alphabet cues had significantly higher intelligibility scores than topic cues and no cues. The difference between no cues and topic cues was not significant.

Mean effectiveness rankings for cue conditions for Speaker 3 were as follows: 3.96 for no cues, 2.59 for topic cues, 2.22 for alphabet cues, and 1.24 for combined cues. Wilcoxon-signed rank tests revealed that combined cues were ranked significantly better than no cues, topic cues, and alphabet cues with regard to listener perception of communication effectiveness. Alphabet cues and topic cues were ranked significantly better than no cues; however, the difference between alphabet and topic cues was not significant.

DISCUSSION

In the present study, we examined the effects of speaker-implemented speech supplementation strategies on intelligibility and listener rankings of communication effectiveness for three speakers with profound dysarthria resulting from cerebral palsy in a contrived and experimental communication situation. This study was the first of its kind to examine the effects on intelligibility of actual implementation of all three strategies (topic cues, alphabet cues, and combined cues) by speakers with profound dysarthria.

Group Findings

The statistical results for intelligibility scores across speakers in the present study were generally consistent with the findings of Hustad and Beukelman (2001), in which cue conditions were superimposed on the habitual speech of individuals with severe dysarthria. Findings of both studies showed that no cues resulted in lower intelligibility scores than any other cue condition, combined cues resulted in higher intelligibility scores than any other cue condition, and alphabet cues resulted in higher intelligibility scores than topic cues. Not all of these differences in the present study would be considered clinically significant, however. For example, the difference between intelligibility scores associated with topic cues and no cues was 4%. When considering speakers whose mean intelligibility was 7%, it would be unlikely that a strategy that enhanced intelligibility an additional 4% would be worth the effort. For alphabet and combined cues, the magnitude of pairwise group differences was very similar to the findings of Hustad and Beukelman (2001). This observation was somewhat surprising, given the important methodological differences between the two studies. One explanation for this difference may be related to the increased severity of dysarthria among speakers in the present study. This is, for speakers who have profound intelligibility challenges, the potential to increase intelligibility via strategy use may be restricted to a greater extent than for individuals-with less severe dysarthria. Perhaps the acoustic signal was so compromised that both linguistic cues and rate changes via implementation of alphabet and combined supplementation had a lower ceiling with respect to the potential impact on intelligibility.

Results of the present study were somewhat different from the findings of Hustad et al. (2003), in which speakers with moderate to severe dysarthria actually implemented speech supplementation strategies. The key difference between the two studies was that Hustad et al. found combined cues did not enhance intelligibility relative to alphabet cues, while in the present study we found that combined cues increased intelligibility by an additional 13%, relative to alphabet cues. Results suggest that, for speakers with profound dysarthria, topic cues make a greater contribution to intelligibility when they are combined with alphabet cues than when they are presented in isolation. The differential effect of topic cues between the two studies also seems to be related to the severity of the speakers' dysarthria. Perhaps topic cues for speakers with less severe dysarthria provided information that was redundant to what listeners were able to derive from the acoustic signal and thus did not enhance intelligibility, either alone or in combination with alphabet cues. For speakers with profound dysarthria, topic cues in combination with alphabet cues seemed to provide new information that served to increase intelligibility—perhaps because so little information was available via the acoustic signal.

A critical finding of the present study was that intelligibility improved by an average of 40% when speakers implemented combined cues relative to habitual speech. This is a remarkable effect, the magnitude of which is rarely, if ever, seen in speech-related interventions; however, the average intelligibility score when speakers used combined cues was still only 46%. Clearly, the use of combined cues as a sole communication strategy would probably not be adequate to meet the communication needs of the speakers in the present study across all contexts and partners. It is also important to note the tremendous variability in listener performance, with intelligibility scores for combined cues across speakers ranging from 19% to 91%. This range suggests that, for some listeners, a speaker's use of combined cues would indeed enable almost perfect understanding. For other listeners, however, this strategy did not provide enough information to improve intelligibility meaningfully.

Analysis of overall listener rankings of the three strategies and the habitual speech (no cues) condition further corroborates intelligibility results (i.e., listeners ranked speakers most effective when they used combined cues followed by alphabet cues, topic cues, and no cues). These results are also consistent with previous research examining Likert ratings of effectiveness for speech supplementation strategies when cues were experimentally imposed. Hustad (2001) explained similar findings by suggesting that listeners may perceive speakers as making a greater effort to be understood when more supplemental information is presented (i.e., combined cues provided the greatest quantity of information). In the present study, it might be expected that this effect would be magnified because listeners were able to see speakers as they used the strategies.

Individual Differences Among Speakers

There were several individual differences among the speakers with respect to pattern and magnitude of benefit associated with the use of each strategy. In particular, the difference between intelligibility scores for topic cues and no cues was not statistically significant for Speaker 2 or Speaker 3. Again, however, it is important to consider the notion of what constitutes a meaningful clinical change. Although this difference was statistically significant for Speaker 1, the absolute value of the difference was very small and not likely to result in important improvements in communication.

For all of the speakers, intelligibility was maximized when they used combined cues and minimized when they used habitual speech with no cues. Descriptive data from Speaker 3 suggests that he benefited from combined cues to a lesser extent than either of the other two speakers. There are two possible reasons for this difference. First, Speaker 3 used a head pointer to direct-select topics and letters on an alphabet board, which resulted in more movement during cue selection. It is possible that this movement distracted listeners, thus making it more difficult for listeners to concentrate on his speech. Another possible explanation relates to Speaker 3's extensive experience using a head pointer to type on a computer keyboard. Because he was so proficient with typing, he was able to very rapidly select letters for alphabet supplementation with little perceived change in his rate of speech. Ultimately, intelligibility improvements associated with alphabet supplementation may in part be related to reduced rate of speech caused by the extra time necessary to select the first letter of each word (Beukelman & Yorkston, 1977; Hustad et al., 2003). Listeners also have additional processing time to decode individual words when the rate is reduced (Hustad & Beukelman, 2000; Hustad and Sassano, 2002) and this, too, may have contributed to improvements in intelligibility in the current study. Because of Speaker 3's rapid selection of cues and relatively short duration of words, listeners may not have had enough processing time to optimally decode his speech.

For Speakers 1 and 3, communication effectiveness rankings differed somewhat from the pooled data. For both of these individuals, effectiveness rankings were tied for alphabet cues and topic cues. Because listeners ranked the strategies after completing all of the intelligibility tasks, it is possible that when listeners viewed speakers using alphabet and topic cues alone, they perceived speakers as making less of an effort to improve the understandability of their speech relative to combined cues. In any case, for each speaker, combined cues received the best ranking as well as the highest intelligibility score, suggesting that listeners had insight into their performance on intelligibility measures.

Clinical Implications

Results of the present study demonstrate that combined cues and alphabet cues, used in conjunction with natural speech, can be powerful strategies for enhancing intelligibility to strangers, even for speakers who have profound dysarthria. Across all three speakers, intelligibility improved by an average of 40% when combined cues were implemented and by 26% when alphabet cues were implemented. Because speech supplementation strategies are low-cost, and simple low-tech communication boards are easily replaceable, they may be particularly useful strategies in some communication situations where voice output AAC may not be readily accessible or practical. Having a greater number of potential communication tools and modes may ultimately enhance the likelihood that speakers with profound dysarthria will be able to communicate successfully across all contexts of their lives.

Limitations and Future Directions

The present study was experimental and involved speakers who produced pre-determined utterances comprised of short narratives. Unfamiliar listeners viewed the speakers and transcribed narratives. Although speech stimuli were developed to be ecologically valid, they probably did not truly reflect the content, form, and use of language in spontaneous oral discourse. In addition, in real communication situations, a speaker and a listener have the opportunity to interact with one another, and this interaction plays an important role in achieving mutual understanding. Consequently, results of the present study may underestimate the true impact of speech supplementation strategies in real dynamic interactions, particularly for communication partners who have some familiarity with the speaker. Finally, the listening conditions in this study were idealized and the influence of noise and other competing stimuli on intelligibility were not addressed. Future research is needed to evaluate the influence of speech supplementation strategies on speaker success in real dynamic communicative interactions where the speaker generates his or her own language, the listener is able to request clarification, and different levels of background noise are present. A larger number of speakers who vary with respect to severity and type of cerebral palsy and dysarthria should also be studied, in order to increase generalizability of results.

Acknowledgements

This research was in part supported by a New Investigator grant from the American Speech, Language, and Hearing Foundation. The authors wish to express special thanks to the individuals with cerebral palsy who participated in this study and to Dr Robert Prosek for the use of his laboratory space for collecting data from listeners.

Endnotes

1 Several authors (see Yorkston, Strand, & Kennedy, 1996; Dowden, 1997) have used the term *comprehensibility* to refer to measures of intelligibility when linguistic-contextual cues are provided to listeners. Although in this study we address the impact of linguistic-contextual cues, we have elected to use the term *intelligibility* rather than comprehensibility. This decision was primarily based on a desire to be consistent with the terminology used in our previous work (see Hustad, 2001; Hustad & Beukelman, 2001; Hustad, Jones, & Dailey, 2003).

2 Detailed descriptions of these strategies are provided elsewhere (see Hustad, 2001; Hustad & Beukelman, 2000; 2001; 2002).

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Appendix

Sample Narrative Passage and Topic Cue

Passage 1, Topic: Purchasing a Vehicle

Jason needed to buy a car.
He wanted a new car.
He considered two different models.
Four wheel drive was a desired feature.
Jason liked the large pickup trucks.
Sport utility vehicles were his favourite.
He did not have much money to spend.
He bargained with a salesman for two hours.
The final price was within his budget.
A used Jeep was what he purchased.