Speech Supplementation Techniques for Dysarthria: A Systematic Review

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BACKGROUND

This systematic review summarizes the results of one segment of the Practice Guidelines for Dysarthria that are being developed through the ANCDS and co-sponsored and funded in part by ASHA, through the office of the VP of Clinical Practices in Speech-Language Pathology, and from the Steering Committee of Division 2. Additionally, co-sponsorship and funding support were received from the Department of Veterans Affairs. The review addresses a set of studies where dysarthric speech is supplemented by a variety of cues in order to increase speech intelligibility.

Definitions

Speech supplementation comprises several different strategies taught to speakers in order to augment the speaker's natural speech by providing additional contextual information to convey the spoken message. It offers additional information, independent of the speech signal, to supplement the distorted acoustic signal that is associated with severe dysarthria. Four general types of speech supplementation are presented in this review:

1) Alphabet supplementation is a strategy in which the speaker provides orthographic information to listeners by identifying the first letter of each word (on an alphabet board or a forward-facing screen) just prior to each spoken word.

2) Semantic or topic supplementation is a strategy in which the topic of a message or a series of messages is provided to listeners just before the message(s) is spoken. The traditional form of topic context is a cue word or phrase that provides information about the intended meaning of an utterance or the intent of the speaker.

3) Gestures may be produced concurrently with speaking. Also known as illustrators, these movements are directly tied to speech and serve to represent visually what is spoken verbally. See Garcia and Cannito (1996) for a review.

4) Syntactic supplementation is used to provide information about the grammar or the word class (e.g., noun, verb, adjective) associated with each word spoken.

Stratifying severity is common in the dysarthria literature, however, there is no consistent definition of levels of severity. Table 1 provides definitions of various levels of dysarthria that will be used throughout this technical report. Note that these definitions are based on functional performance. For example, *severe dysarthria* will be defined as functional but with some reduction in speech intelligibility and *profound dysarthria* as serving some communicative functions such as greetings or response to questions, but intelligibility is markedly reduced. In this document, *speech intelligibility* is defined as the listener's ability to understand a message produced by a speaker with dysarthria. The term *intelligibility* may have modifiers that indicate the type of message (e.g. word intelligibility, sentence intelligibility, paragraph intelligibility and so on) or the type of supplementation (e.g. speech supplemented with alphabet cueing)

Table 1. Definitions of Levels of Severity of Dysarthria.

Mild: Dysarthria is noticeable but intelligibility is unaffected. Speech rate is essentially normal.

Moderate: Speech is intelligible but rate and naturalness are reduced.

Severe: Natural speech is the primary means of communication, although it is not completely understood in all situations. Speech rate and naturalness are markedly affected.

Profound: Natural speech may serve some communicative functions such as greetings or response to questions, but intelligibility is markedly reduced. Function is maintained by supplementing natural speech with other modes of communication.

Anarthric: No useful speech.

Rationale for the Review

For speakers with severe or profound dysarthria, one of the primary goals of speech intervention is to improve communicative function by increasing speech intelligibility. Improved speech intelligibility can be accomplished in at least two ways. First, the adequacy of speech production can be improved. Often this involves focusing on the physiological aspects of speech. Practice guidelines have recently been developed for management of velopharyngeal dysfunction (Yorkston et al., 2001) and respiratory-phonatory dysfunction (Spencer et al., 2002; Spencer, Yorkston, & Duffy, in press). Lindblom (1990) refers to the acoustic signal as, "the tip of the iceberg" (p. 228) because communication is built around information *shared* by the speakers *and* the listener. The current review focuses on a second way of improving function – by providing listeners with extra information to assist them in understanding distorted speech. This "extra information" typically involves signal-independent information about the context of the message (Yorkston, Strand, & Kennedy, 1996). Context is the knowledge shared by communication partners about the time, place, topic, purpose, or any other feature of an utterance or the setting in which the utterance occurs. It may take many forms, including semantic, syntactic, suprasegmental, and pragmatic cues.

The importance of contextual cues can be justified from a theoretical perspective. For example, the model of mutuality (Lindblom, 1990) describes the relationship between severity of dysarthria and the importance of contextual cues. If signal information is rich (high speech intelligibility), then function is high even in the face of little contextual information. However, as the richness of the information from the acoustic signal is degraded, as in severe dysarthria, contextual information (signal-independent information) becomes more critical for maintenance of function. Clinical experience also suggests the importance of contextual information (Garcia & Cannito, 1996b; Hustad, 1999; Vogel & Miller, 1991; Yorkston, Strand et al., 1996). The purpose of this technical

report is to supplement the theoretical perspective and clinical impressions by reviewing the evidence from the growing body of research literature related to the effect of speech supplementation on dysarthric speech.

The Literature Search

The following electronic databases were searched: PsycINFO covering 1300 journals (1987 to January, 2003), MEDLINE covering 4600 journals (1966 to January, 2003), and CINAHL covering 1175 sources (1982 to January, 2003). Initial searches were keywords paired with the term dysarthria, for example, "supplementation," "first letter," "word," "cues," "intelligibility," "comprehensibility." In addition to these electronic searches, hand searches of relevant edited books in the field of dysarthria and ancestral searches of extant references (e.g., studies cited within an article or chapter) were conducted. The general search on the topic of dysarthria yielded 2,199 references (MEDLINE). From this large search, references related to speech supplementation strategies were selected, described, rated, and compiled in a Table of Evidence. Studies to be included were defined as those that reported data on supplementation for speech for at least one person with dysarthria. Thus, articles were excluded that referred to speech supplementation for people whose speech was unintelligible due to hearing impairment or other disorders and articles that provided only general descriptions of speech supplementation strategies.

SUMMARY OF TABLE OF EVIDENCE

A total of 19 studies were identified, obtained, and rated by two individuals (EH & KY). Characteristics of these studies are summarized in the accompanying Table of Evidence (Appendix 1). Studies are listed in chronological order of publication. The following summarizes the Table of Evidence.

Focus of the Studies

Articles examining the effects of speech supplementation have appeared for more than 25 years although the majority of these studies have been published since 1990 (See Table 2). This review will focus on four types of speech supplementation, alphabet cues (N = 9), semantic cues (N = 9), gestures (N = 6), and combinations of strategies (N = 6). Syntactic cues will not be included in the review because only 2 studies report such information. Note that a number of studies report data on multiple strategies. Of the 19 studies that reported information about speech supplementation, 6 (32%) were case studies or case series and 13 (68%) reported group comparisons. The cumulative number of different subjects (speakers with dysarthria) is small (less than 90). Even this relatively small number may overestimate actual numbers because several studies appear to have used the same subject or group of subjects across studies.

Table 2 Number of studies (number of subjects in parenthesis) examining alphabet, semantic/syntactic, gestural, and combined cues for three timeframes.

Timeframe	Alphabet cues	Semantic Cues	Gestures	Combined Strategies	Total Different Studies
< 1990	2 (8)				2 (8)
1990s	2 (11)	5 (42)	4 (8)	3 (8)	11 (59)
>1999	5 (21)	4 (20)	2 (2)	3 (12)	6 (22)
Total	9 (40)	9 (62)	6 (10)	6 (20)	19 (89)

Speaker Characteristics

Speakers with a variety of medical diagnoses participated in the studies reviewed here (See Table 3). The most common medical diagnoses were cerebral palsy, cerebrovascular accident (CVA), and traumatic brain injury (TBI). Other common diagnoses included amyotrophic lateral sclerosis (ALS) and Parkinson disease. Thus, medical diagnoses were associated with both acquired and developmental dysarthria, as well as various natural courses including recovering, stable and degenerative. Speakers also represented many different types of dysarthria. The type of dysarthria was specified in 12 (63%) of the studies and included flaccid (32% of studies), mixed (32%), spastic (26%), athetoid (5%), and hypokinetic (5%). Although most of the speakers were adults, a wide age range was represented (9 to 87 years). Severity of dysarthria was reported to range from mild to profound, although some reduction in speech intelligibility was noted in all cases indicating that most speakers would be defined as “severe” or “profound” using the definitions provided in Table 1.

Table 3 Number of studies (percentage) reporting data on a variety of medical diagnoses.

Medical Diagnosis	**Number of articles including the diagnosis**
Cerebral palsy	8 (42 %)
Stroke	8 (42 %)
Traumatic Brain Injury	7 (37 %)
Amyotrophic Lateral Sclerosis and Motor Neuron Disease	4 (21 %)
Parkinson Disease	2 (11 %)
Motor Neuron Disease	1 (5 %)
Cerebellar degeneration	1 (5 %)
Tumor	1 (5 %)
Dysgenesis of the cerebellum	1 (5 %)
Myasthenia Gravis	1 (5 %)

Speaker Tasks

For the most part, speakers read prepared sets of words and/or sentences. Stimuli came from a variety of sources including sentences constructed specifically for the study or published lists of words or phrases (Kalikow, Steven, & Elliot, 1977; Nilsson, Soli, & Sullivan, 1994; Yorkston, Beukelman, & Tice, 1996). Exceptions were studies by Crow and Enderby (1989), where speakers named or described pictures and participated in a conversation, and Dowden (1997), where children named pictures.

The amount of practice or training in use of the strategies was not typically specified. Only six of the 19 studies (31%) provided information on whether speakers had practiced using supplementation strategies. When extent of practice was discussed, it appeared that none of the speakers with dysarthria were experienced supplementation users. Rather, they were taught to use the strategy specifically for the study and did not necessarily use it in natural communication settings.

Mode of Presentation

In order to impose control on the experimental conditions, live conditions where interaction occurred between the speaker and listener were not used. Rather, a variety of electronic modes (audio or video) were used to present the stimuli to listeners. Video technology allows for relatively easy manipulation of the video signal to allow one image (e.g., a letter of the alphabet) to be superimposed over another (e.g., a speaker with dysarthria). It is possible to present a video stimulus of a speaker who is not using supplementation (i.e., habitual speech), and to superimpose the letter cue to provide the listener with additional information. In some cases, the alphabet or semantic cues were superimposed electronically. Seven of the 19 articles (44%) used superimposed information while nine of the articles (56%) reported on supplementation that the speaker generated. Three of the articles did not specify how supplementation was presented to the listener. Presentation of cues under experimental conditions may inform research regarding how much information is understood from the unaltered habitual speech signal versus how much the supplemental cue adds. However, it does not closely mimic natural communication.

Listeners and Listening Task

Undergraduate or graduate level students most commonly served as listeners, although rehabilitation professionals or speech pathologists took part in three of the studies (16%). In two studies, both familiar and unfamiliar listeners participated. A total of 537 listeners took part in these studies of speech supplementation. None of the studies included the general public or non-native speakers of American English as listeners.

Outcome measures

The most common outcome measure, used in 13 of the studies (68%), was intelligibility measured by the accuracy of listener transcription of the speaker's message). Intelligibility was accompanied by measures of speaking rate or speech duration in 5 studies (26%). Comprehension, measured by asking listeners questions about a narrative produced by the speakers, was the outcome measure in 2 studies (11%). Other outcome measures, all used in a single study, were acoustic measures, phonetic transcription, listener attitudes, and an anecdotal comment about change in participation.

Results

Results indicate consistent improvement in outcome measures with cueing in structured, experimental situations. Because many of the studies reported individual data, cross-study comparisons are possible and are reported for alphabet and semantic cues in the following section. Gestural cues are not included in this cross-study comparison because of the small number of subjects reported. Three of the six studies focusing of gestures were case reports involving the same speaker. Caution is warranted in interpreting the following cross-study comparison because methods for measuring intelligibility along with type and severity of dysarthria vary from study to study.

Alphabet Cues

Alphabet cues may function in at least two ways. First, the identity of the first letter of the word narrows the range of possible words and, second, the strategy encourages the speaker to separate words, another potential benefit to the listener. In order to estimate the magnitude of benefits gained from alphabet cues, data from individual subjects were compiled across studies. Six studies reported data for individual speakers (Beliveau, Hodge, & Hagler, 1995; Beukelman, Fager, Ullman, Hanson, & Logemann, 2002; Beukelman & Yorkston, 1977; Crow & Enderby, 1989; Hustad & Buekelman, 2001; Hustad & Garcia, 2002). Data were reported on word intelligibility for 11 speakers and sentence intelligibility for 21 speakers (See Table 4).

Table 4.Word and sentence intelligibility scores with and without alphabet cues for individuals.

		Words			Sentences		
Reference	Subject	No cues	Alpha cues	Gain	No cues	Alpha cues	Gain
Beukelman & Yorkston (1977)	1	12	24	12	16	64	48
	2	8	25	17	33	66	33
Crow & Enderby (1989)	1	19	29	10	75	93	18
	2	44	69	25	88	99	11
	3	26	34	8	68	93	25
	4	2	10	8	25	38	13
	5	89	98	9	95	100	5
	6	11	16	5	5	24	19
Beliveau, Hodge, & Hagler (1995)	1	12	26	14			
	2	1	6	5			
	3	6	17	11			
Hustad & Beukelman (2001)	1				15	37	22
	2				11	34	23
	3				30	44	14
	4				19	33	14
Beukelman et al. (2002)	1				2	52	50
	2				2	32	30
	3				7	76	69
	4				43	66	23
	5				50	77	27
	6				62	87	25
	7				63	92	29
	8				87	100	13
Hustad & Garcia (2002)	1				31	58	27
Mean		20.9	32.2	11.3	39.4	65.0	25.6

Figure 1 illustrates word intelligibility habitually (without cues) and with alphabet cues for 11 speakers with dysarthria rank ordered by habitual intelligibility scores. Note that alphabet cues increased intelligibility for all speakers (mean gain = 11.3%; range 5-25%).

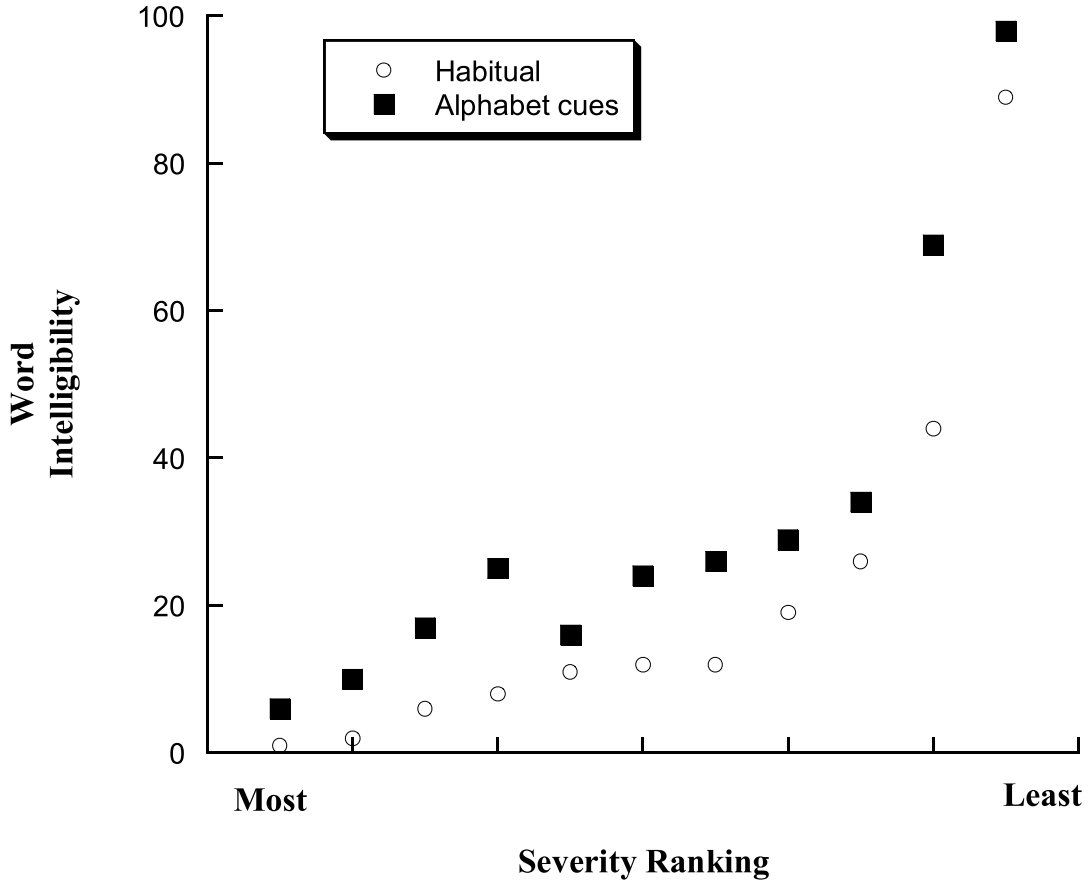
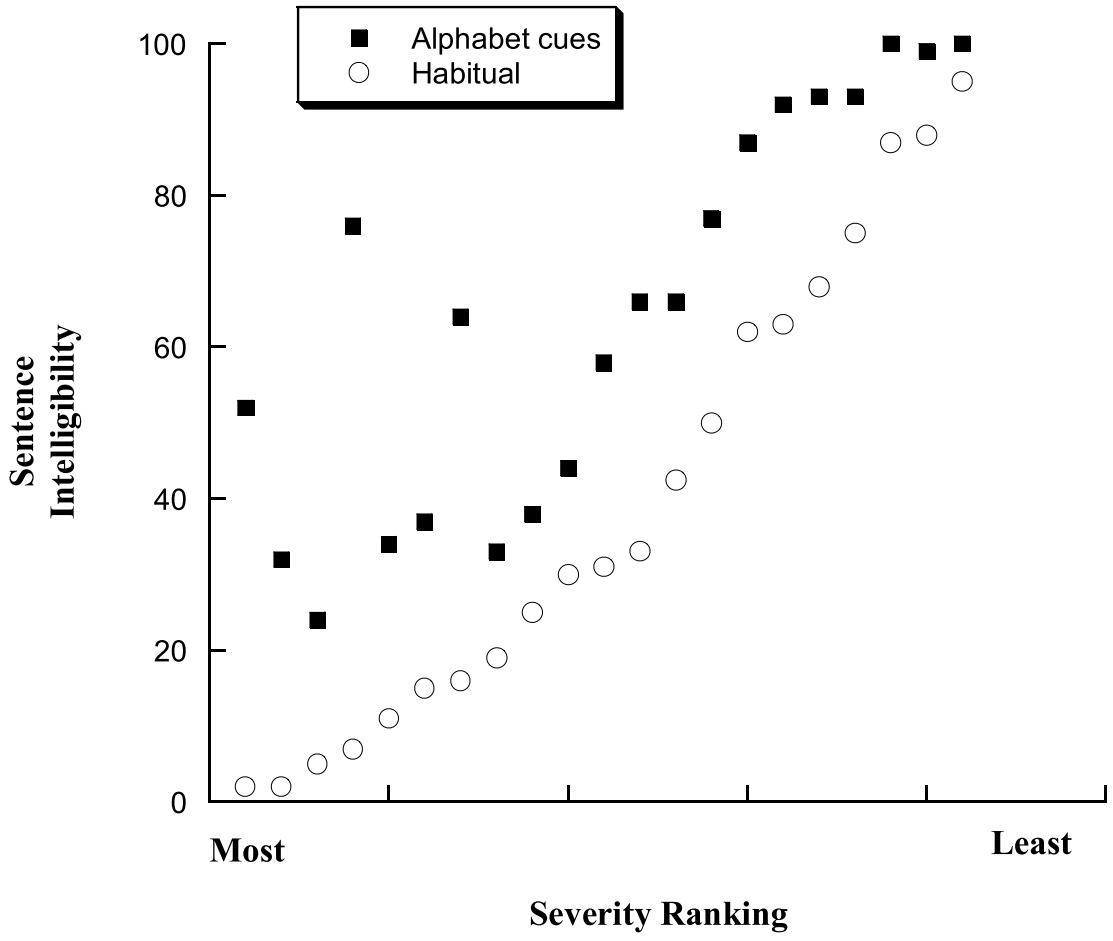


Figure 2 illustrates sentence intelligibility habitually (without cues) and with alphabet cues for 21 speakers with dysarthria. Note that alphabet cues increased intelligibility for all speakers (mean gain = 25.6%; range 5-69%). The most improvement was noted for the more severely involved speakers; however, greater variability was also noted in this severity range.



Semantic Cues

The information provided by semantic or topic cues may serve as a preparatory set for listeners, thereby helping them to anticipate and/or narrow expectations for the content of the forthcoming message (Hustad & Beukelman, 2000). In order to estimate the magnitude of benefits gained from semantic cues, data from individual subjects were compiled across studies. Six studies reported data for individual speakers (Beukelman et al., 2002; Carter, Yorkston, Strand, & Hammen, 1996; Dongilli, 1994; Dowden, 1997; Hammen, Yorkston, & Dowden, 1991; Hustad & Buekelman, 2001). Data on word intelligibility for 33 speakers and sentence intelligibility were reported for 26 speakers are reported in Table 5.

Table 5. Word and sentence intelligibility scores with and without semantic cues.

		Words			Sentences		
Reference	Subject	No cues	Semantic cues	Gain	No cues	Semantic cues	Gain
Hammen et al (1991)	1	0	9	9			
	2	0	18	18			
	3	1	7	6			
	4	1	17	16			
	5	2	18	16			
	6	4	25	21			
	7	3	14	11			
	8	3	22	19			
	9	7	42	35			
	10	9	40	31			
	11	15	53	38			
	12	15	59	44			
	13	17	48	31			
	14	25	67	42			
	15	25	62	37			
	16	35	76	41			
	17	43	81	38			
	18	53	86	33			
	19	60	93	33			
	20	66	93	27			
	21	83	97	14			
Dongilli (1994)	1	0	30	30	0	8	8
	2	5	31	26	0	1	1

	3	45	76	31	63	70	7
	4	40	88	48	77	84	7
	5	52	80	28	69	86	17
	6	54	93	39	82	98	16
	7	72	96	24	98	98	0
	8	95	98	3	99	99	0
Carter et al. (1996)	1, 2 3				72	75	3
	4, 5, 6				29	38	9
Dowden (1997)	1	20	60	40			
	2	10	46	36			
	3	20	60	40			
	4	4	25	21			
Hustad & Beukelman (2001)	1				15	24	9
	2				11	21	10
	3				30	37	7
	4				19	32	13
Beukelman et al. (2002)	1				2	5	3
	2				2	5	3
	3				7	59	52
	4				43	53	10
	5				50	55	5
	6				62	96	34
	7				63	74	11
	8				87	97	10
Mean		26.8	54.8	28.1	44.5	55.2	10.7

Figure 3 illustrates word intelligibility without cues and with semantic cues for 33 speakers with dysarthria (rank ordered by habitual intelligibility scores). Note that semantic cues increased word intelligibility for all speakers (mean gain = 28.1; range 3-48%). Largest gains were noted in the mid-range of severity.

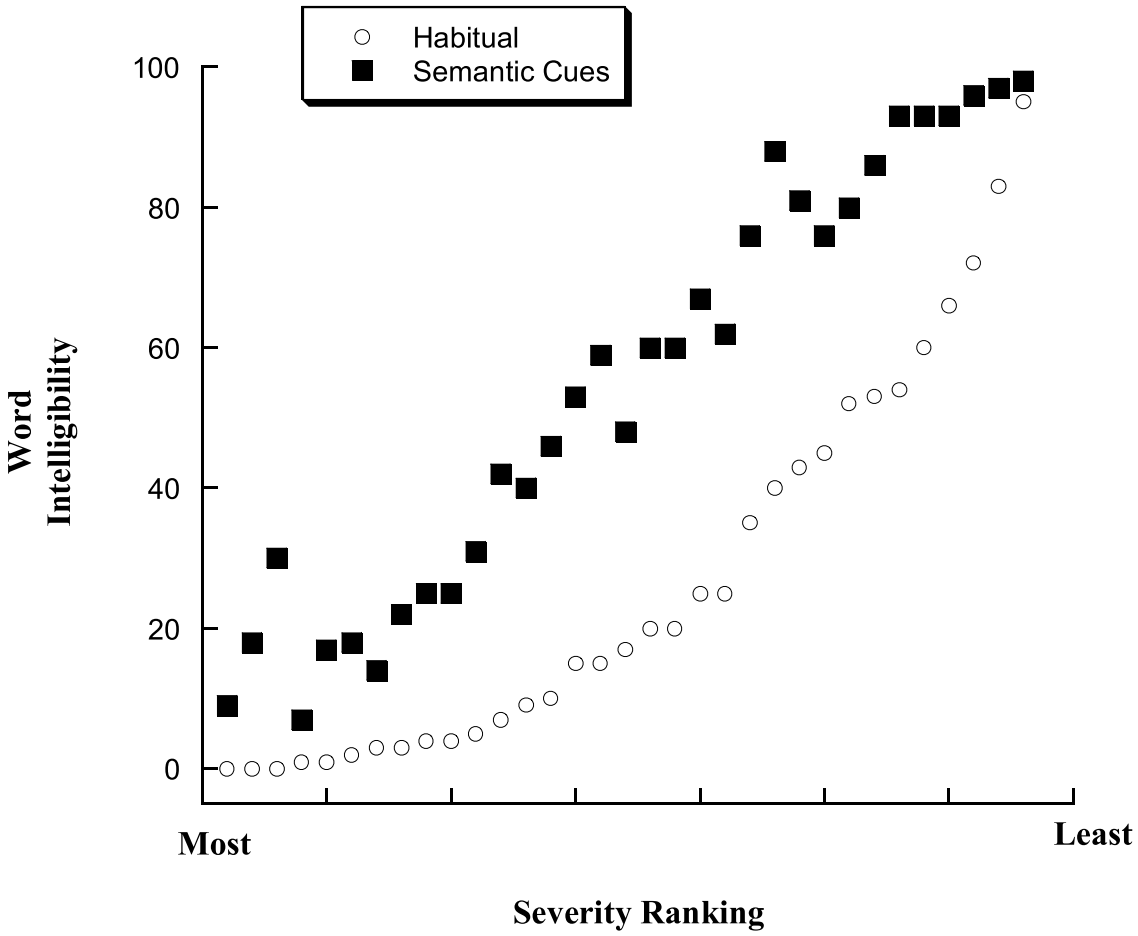
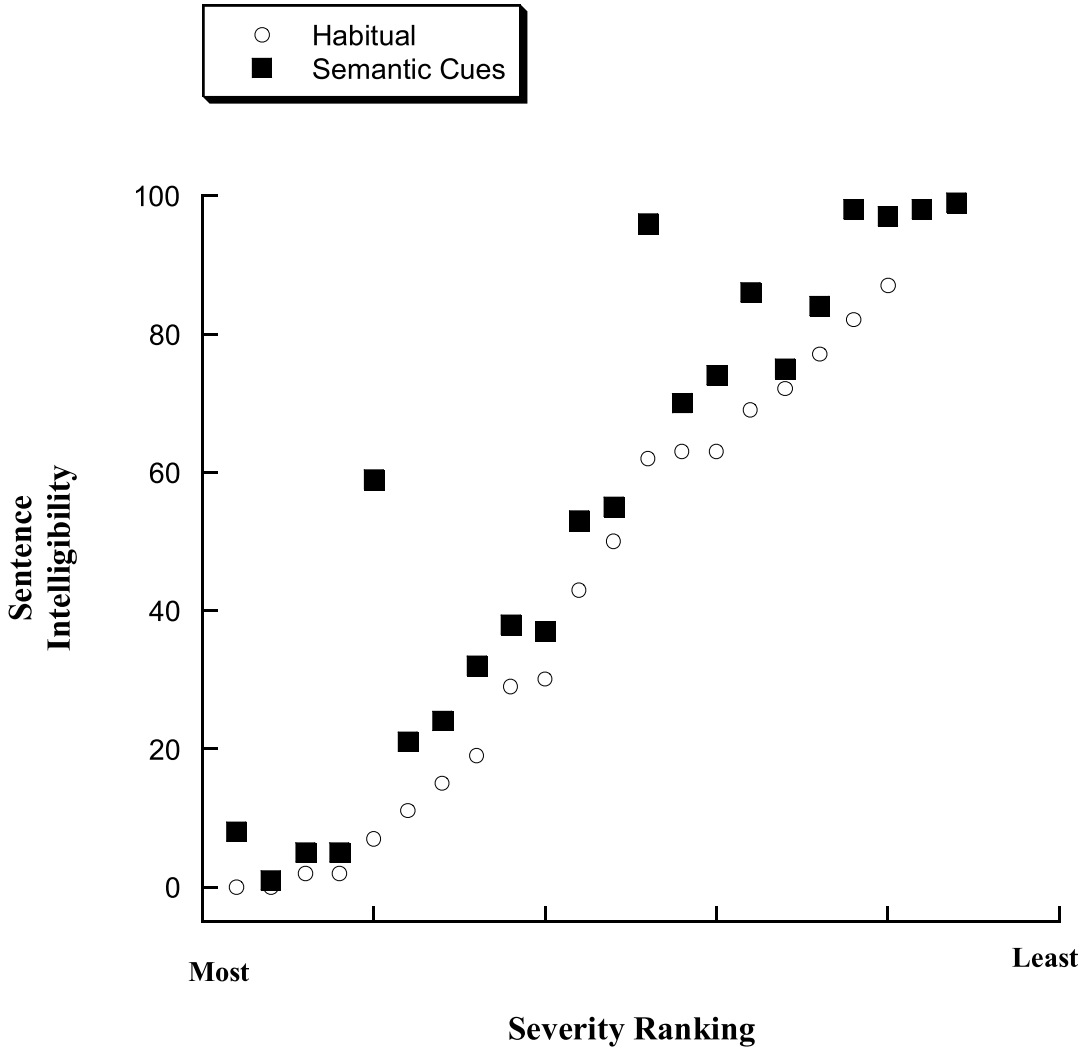


Figure 4 illustrates sentence intelligibility habitually (without cues) and with semantic cues for 26 speakers with dysarthria. Note that semantic cues increased intelligibility for all speakers (mean gain = 10.7%; range 0-52%), but these gains were generally small.



Summary of Studies

Intelligibility of words and sentences improved for all speakers regardless of cueing strategy. For alphabet cues, sentence intelligibility improved more than word intelligibility with a mean gain of 25.6%. Word intelligibility improved for semantic cues, more than sentence intelligibility with a mean gain of 28.1%. The amount of benefit varied considerably from speaker to speaker, with the greatest variability and benefit in speakers with more severe dysarthria.

Limitations in Interpreting the Experimental Studies

The studies examined in this review provide useful information that suggests a strong, consistent benefit of various cueing strategies and gives some support to ideas about why the strategies work. However, a number of limitations prevent broad generalization to natural communication environments.

Lack of spontaneous speech: Most of the studies imposed a variety of controls on communication that are not typically found in natural settings. For example, speakers often produced utterances that had been prepared for them, thus the speech does not represent spontaneous utterances.

Practice with supplementation: For the most part, speakers appeared to have little practice or training with the strategies. Communication in any mode improves with practice. Whether speakers are practiced in the use of speech supplementation may influence the intelligibility of their speech.

Lack of live interactions: The mode of presentation of the utterance to the listener was either audio or video recording. Thus, live interactions between the speaker and listener were not examined.

Acceptance of supplementation: Few of the studies focused on speaker or listener attitudes toward supplementation. Clinical experience suggests that supplementation is frequently not used consistently, despite benefits and indications. Speaker and listener acceptance may be a key to understanding why this happens.

Superimposed vs. speaker-imposed: Finally, some of the studies used letter or word cues that were superimposed over habitual speech (using video editing techniques), while in other studies the speakers were physically pointing to the letters or words. It was not always clear whether the supplementation was superimposed or speaker-imposed. This discrepancy makes it difficult to interpret findings because it is likely that the stimuli that included speaker-imposed supplementation altered the acoustic signal by slowing rate, in addition to providing contextual information.

Despite these limitations, results of these studies have a number of clinical ramifications that are discussed in the following section.

CLINICAL IMPLICATIONS

The following section presents the clinical implications of studies of speech supplementation by posing a series of question that assist clinical decision making. Answers to the following questions cannot be drawn directly for data in the literature, rather the answers represent clinical opinion that is consistent with evidence in the research literature.

Who is a good candidate for speech supplementation?

Individuals with many different medical diagnoses and types of dysarthria have been shown to benefit from speech supplementation strategies. Thus, medical diagnosis and type of dysarthria do not appear to be critical determiners of successful strategy use.

Unlike type of dysarthria, severity of dysarthria is important in selection of appropriate candidates. Although speakers with speech intelligibility scores over 80 percent may receive some benefit in increased intelligibility scores, the reduction in speaking rate and naturalness that accompanies use of strategies may be unacceptable to them. For speakers with severe or profound dysarthria, supplementation may be beneficial, if intelligibility can be increased to a level above 80%. Speakers with more severe dysarthria appear to be the best candidates for speech supplementation.

Cognition must also be considered when identifying appropriate candidates. Use of speech supplementation strategies in natural settings imposes some cognitive demands on the speaker not imposed during ordinary speaking activities. These include the demands of selecting and indicating the alphabet or topic cue, tolerance for using a one-word-at-a-time speech style for alphabet cueing, and skills to manage or train unfamiliar communication partners. Intact pragmatic language skills are critical for speakers to use supplementation effectively. Clinical experience suggests that individuals with intact cognition have few problems meeting these cognitive demands. However, either speaker or partner training may be needed for some speakers with reduced cognitive function.

All of the strategies reviewed here involve some level of motor function to select the letter or topic or to perform the gesture. Thus the techniques are most appropriate for individuals who have sufficient motor function to perform these activities easily. In some circumstances, an individual can use a light beam to identify the first letter or topic to supplement natural speech.

Although speaker and listener acceptance of supplementation strategies indirectly influences the use patterns of speech supplementation, most of the speaker and listener participants in the literature had no prior experience with supplementation. Therefore, caution is warranted in drawing direct implications from the research literature because attitudes prior to training may not accurately reflect attitudes toward supplementation after appropriate training and experience with the techniques in natural settings.

In summary, speech supplementation strategies may be considered for speakers with severe or profound dysarthria, regardless of medical diagnosis or type of dysarthria. The best candidates exhibit dysarthria that interferes with communication function in natural settings, have adequate pragmatic and cognitive skills, and sufficient motor function to generate the cues.

What strategy is best?

Each of the speech supplementation strategies has both advantages and disadvantages (See Table 6). Clinical decision making involves weighing the cost versus benefits of each strategy. For example, alphabet cueing can be used to communicate any message regardless of content. If the message is not understood, the alphabet board is available so that the speaker may spell the message letter by letter in order to resolve the communication breakdown. For some, speech production is improved. Alphabet cueing requires little training and is a low cost alternative. Despite these advantages, alphabet cueing has a number of disadvantages in that it slows speaking rate and may disrupt prosody. Listeners must take an active role in constructing the message. They must watch as letters are indicated and repeat each word as the speaker produces it. This interaction pattern may be viewed as unnatural by the listener. An external board or keyboard device must be present.

Table 6. A summary of the advantages and disadvantages of speech supplementation strategies.

Alphabet cueing

Advantages

- Can be used with any utterance regardless of semantic content
- Useful in resolving communication breakdowns
- May require speaker to separate words thus providing boundaries to assist the listener
- May allow some speakers to improve production by minimizing respiratory demands or allowing them to include word-final consonants
- Often minimal training required
- Low cost

Disadvantages

- Slows speaking rate
- May disrupt prosody
- Listener needs to watch
- Some literacy and cognitive requirements
- Produces an atypical interaction pattern, especially if listener repeats every word after the speaker
- Requires an external device such as an alphabet board or keyboard

Illustrative Gestures

Advantages

- No external device is required
- Such gestures are a natural part of many conversations
- For some speakers, prosody is improved
- Low cost
- Minimal training requirements

Disadvantages

- Some messages do not have a corresponding illustrative gesture
- Resolving communication breakdowns may be difficult
- Adequate upper extremity function is required.

Illustrative gestures have the advantage that an external device is not required. Because they are a part of many conversations, listeners may view them as more natural than other types of cueing. For some speakers, prosody may be improved. The disadvantage of gestures is that not all messages have a corresponding illustrative gesture. Resolving communication breakdowns may be difficult with gestures, thus an alternative mode such as an alphabet board may be required for this function. Like other supplementation strategies, adequate upper extremity function is needed.

The advantages and disadvantages of semantic cueing vary depending on how the cues are delivered. For some, frequently occurring topics are listed on the side of an alphabet board. Although this approach gives easy and quick access to the topics, not all topics can be listed. Others may introduce a topic by spelling out a key word. The advantage of this approach is that any topic may be introduced; the disadvantage is that extra time is needed to spell the word.

Some studies indicate that multiple cues result in improved outcomes as compared with single cues or habitual (natural) speech (Beliveau et al., 1995; Dowden, 1997; Hustad, 2001; Hustad & Beukelman, 2002; Hustad & Buekelman, 2001). While combined cues provide extra benefit to the listener, they may also place extra cognitive and motor demands on speakers. In addition they may produce a slower rate than single cues. The advantages and disadvantages of combined cues warrant further investigation.

In summary, practical advantages and disadvantages occur for each speech supplementation strategy. In addition, evidence from experimental studies suggests considerable speaker-to-speaker variability in extent of the benefit. Together this suggests that selection of strategies or combinations of strategies must be made on an individual basis in the clinical setting.

How much change can be expected?

The question of how much change to expect is a difficult one to answer. If one relies strictly on the evidence from the experimental studies, one might speculate that on average a speaker might expect a gain of 25% in sentence intelligibility when a listener is provided with alphabet cues. Closer inspection of these data suggests a large range of potential gain (from 5 to 70% improvement). Caution must also be exercised in translating this evidence into clinical practice because the conditions reported in the experimental studies may not reflect the gains that could be expected in natural communication settings. In clinical practice, we must consider a "range of intelligibility potentials" for a particular speaker, depending on a number of factors, including the physical setting, listener familiarity, nature of the linguistic message, motivation, effort level and so on (Kent, Miolo, and Bloedel, 1994 (pp. 81-82) cited in Dowden, 1997).

Another related and important question is how large of a change is needed in order to be functionally important? Again this is a difficult question because the answer at least in part depends on the severity of the dysarthria. A gain of 20% may be functionally important for a speaker whose habitual intelligibility is 75% because it would result in functional speech (95% intelligibility). The same 20% gain may not be important for the severely involved speaker who moves from 5 to 25% intelligible. Most listeners attempting to communicate with someone who is 25% intelligible find it to be a very difficult task. Goosens' and Crain (1986) recommended that a minimum increase of 20% or greater in intelligibility scores compared with no-cues would be required for the improvement to be considered clinically significant. Beliveau, Hodge and Hagler (1995), however, suggest that these guidelines may be too conservative for speakers with low levels of intelligibility. Others have suggested that gains must be examined in terms of

whether or not they move speakers into the range of functional communication rather than considering some absolute number (Beukelman et al., 2002). The main criterion is that the improvement must be judged in terms of function by the speaker and listeners. Treatment efficacy (i.e., benefit under ideal conditions) is typically measured by increases in intelligibility. However, other measures may carry more ecological validity, such as expanding the number of potential communication partners or expanding the communicative situations in which the speaker is able to participate.

In summary, there are a variety of potential measurements of change in dysarthric speech through supplementation. While intelligibility is an important basic measure of change, other outcome measures (i.e., benefit under average conditions) should be used and documented to further understand the significance of the changes effected by speech supplementation.

Does speech production change?

Most of the studies examined in this review focus on changes in listener performance by measuring changes in speech intelligibility or comprehension. These changes in listener performance may be the result of at least two factors – the extra information provided by the cueing strategy, or improved speech production. Some studies (Beukelman & Yorkston, 1977; Crow & Enderby, 1989; Garcia & Cobb, 2000; Garcia, Dagenais, & Cannito, 1998) report changes in speech as the result of strategy use. For example, one of the speakers reported by Beukelman and Yorkston (1977) improved with supplemented speech as compared with habitual speech when pointing to initial letters with the alphabet board concealed from the listener. In other words, speech intelligibility improved even when listeners were unable to see the cues. Crow and Enderby (1989) reported increased articulatory accuracy as measured by phonetic transcription when speakers used alphabet supplementation. Garcia, Dagenais, and Cannito (1998) found acoustic changes in a speaker who used natural gestures. Not all reports of changes in speech were positive. Use of gestures had the negative effect of increasing rate and reducing sentence intelligibility for a speaker with ALS (Garcia & Cobb, 2000). With some noted exceptions, speech supplementation appears to have a beneficial effect on speech production. This improvement in speech production is most likely to occur in cases where rate reduction is an appropriate target for intervention.

What role does the listener play in the communication process?

When implementing speech supplementation strategies, listeners play the active role of integrating information from multiple sources in order to interpret the message. Consensus exists that listeners are critical to successful communication with speakers with severe dysarthria. Early reports identified listener skills and experience as potentially important factors (Hunter, Pring, & Martine, 1991; Vogel & Miller, 1991). Later studies have begun to systematically examine the performance and attitudes of the listener (Carter et al., 1996; Dowden, 1997; Garcia & Cannito, 1996a; Hustad, 2001). Results suggest that listeners prefer multiple cues. Hustad (2001) found that unfamiliar listeners rated speaker effectiveness higher, were more willing to interact and more

persistent when supplemental cues were provided than when no cues were provided. Attitudes were least positive with no cues and most positive when combined cues (both alphabet and topic cues) were provided. Thus, in the face of communicative challenges, listeners appeared to prefer multiple sources of information.

Listener familiarity or amount of experience is another critical variable. Studies suggest that partners familiar with the speaker with severe dysarthria understand more than do individuals with general familiarity with dysarthria (e.g. rehabilitation professionals) or inexperienced individuals (Dowden, 1992; Hunter et al., 1991). These advantages are maintained when supplemental cues are added. Familiarity effects, however, do not generalize to listeners who are initially inexperienced but then familiarized with severely dysarthric speech, such as listener participants in a research study (Dowden, 1992; Garcia & Cannito, 1996a; Hunter et al., 1991). Thus, extensive contact, such as daily interaction with speakers with severe dysarthria, results in improved ability to understand distorted speech. Thus far, attempts to provide general familiarization of dysarthric speech in experimental conditions has not resulted in important gains in listeners' abilities to understand.

In summary, listener skills, attitudes and experience contribute in important ways to the "range of intelligibility potentials" for speakers with severe dysarthria. Listeners must be viewed as an active participant in the message construction process. Therefore, information and training is critical. Clinical information might come in the form of comparisons of their performance with less familiar partners. Because familiar listeners may underestimate the problems that less experienced listeners encounter, such information should be provided as part of the clinical decision-making process that leads to the selection of speech supplementation strategies (Hustad & Beukelman, 2000). The topic of listener training will be discussed in the following section of future research directions.

Summary of Clinical Implications

Speech supplementation strategies may be useful for speakers with severe or profound dysarthria, regardless of medical diagnosis or type of dysarthria. The best candidates exhibit dysarthria that interferes with communication function in naturals settings, have adequate pragmatic and cognitive skills, and sufficient motor function to generate the cues. Selection among the various strategies must be made on an individual basis because each strategy has unique advantages and disadvantages. Strategies are best when gains are sufficiently large to move speakers into a functional range of speech intelligibility. Some strategies may have the benefit of improving speech production, especially in cases where rate reduction is an appropriate target for intervention. Listeners play a critical role in ensuring the successful use of strategies. Therefore, sound clinical practice dictates that the attitudes and skills of frequent communication partners are considered. Listener training should be included as an important element of intervention.

FUTURE DIRECTIONS

Phases of Clinical Outcome Research

In 1975, the World Health Organization (WHO) published a phased model of clinical-outcome research (World Health Organization, 1975). Although initially developed for the study of drug interventions, the phases or stages of the model have also been applied to clinical outcome research in the field of speech pathology (Robey & Schultz, 1998). Robey and Schultz describe a series of phases that move from the initial efforts to detect the possible usefulness of an intervention through phases where the efficacy (effects of treatment under ideal conditions) and effectiveness of treatment (effects of treatment under typical or average clinical conditions) are documented. See Table 7 for a summary of the objectives and focus of investigations for each phase of research.

Table 7. Standard Model of clinic outcome research (Robey & Schultz, 1998).

Phase I:

Objective

- To develop critical research hypotheses for later testing
- To establish the safety of the new treatment
- To detect the activity of treatment

Focus of investigation:

- Brief treatment
- Small number of subjects
- No control subjects
- Often other treatments have been unsuccessful for subjects

Phase II:

Objective

- To define the population for future study
- To operationally define the elements of intervention
- To make exploratory estimates of efficacy

Focus of investigation:

- Formulation and standardization of protocols and clinical methods
- Validation of measurement instruments
- Experimental observations that establish optimal duration and schedule of treatment
- Assessment the range of factors affecting activity
- Identification of optimal dosage
- Refinement of the critical research hypothesis
- Development an explanation for why the treatment works.

Phase III:

Objective

- To conduct efficacy testing (documenting outcomes under optimal conditions)

Focus of investigation:

- Large sample,
- External control

Phase IV and V:

Objectives

- To document treatment effectiveness under typical conditions
- To continue efficacy studies with follow-up test of specified subpopulations
- To compares the magnitude of outcome under usual clinical condition with the outcome of the efficacy trials

Focus of investigation:

- Large samples of the target population in a particular geographic area of service-delivery setting

- Control may be from another community

Current Status of Speech Supplementation Research

The WHO model of outcome research provides a framework for assessing the current status of research related to speech supplementation. The studies examined in this review reflect the initial phases of clinical outcome research (Phases I and II). Specifically, brief "treatments" have been provided to a small number of subjects for whom other treatments have been unsuccessful. Thus, it is now possible to describe broadly a target population. Testing protocols have been established and outcome measures are beginning to be investigated or developed. Studies have begun to examine not only speech intelligibility but also improved speech production associated with cueing strategies. Finally, explanations of why speech supplementation works have begun to appear. Considerable progress has been made, however, much work remains to be done. The following is a discussion of some potential future research directions.

Future Research Directions

Speech Supplementation in Natural Communication Settings

The majority of studies reviewed in this report were experimental investigations conducted under controlled conditions. Speakers with dysarthria were typically audio- or video- recorded as they produced prepared utterances, which later were presented to the listeners. There is an urgent need to investigate speech supplementation strategies in more natural communication situations. The following are examples of this type of research:

- Use of strategies in a dynamic interaction paradigm where an interchange occurs between the speaker with dysarthria and a listener. This paradigm may more closely predict performance in natural settings than the transcription tasks used in the majority of studies to date.
- Qualitative studies of the experiences of speakers with dysarthria and their communication partners as various cueing strategies are introduced.
- Measurement of patterns of strategy use in natural setting with ratings of acceptability from both speakers and their frequent communication partners.
- Studies that develop and evaluate methods of measuring success of strategy use in natural settings.

Better Understanding of the Mechanisms of Effect

Hypotheses have been formulated that speculate why various supplementation strategies work. More well-controlled experimental investigations are needed to confirm these hypotheses or develop new ones. The following are examples of this line of research:

- Studies of change in speech production associated with the supplementation strategies.
- Studies that attempt to parcel out the benefit to the listener of various "top-down" versus "bottom up" cues.

- Variability exists both among speakers and listeners. What accounts for the greater impact for some speakers than others? What accounts for better performance of some listeners?

Clear Guidelines About How the Strategies Can Best be Applied

Because little effort has been focused on use of the strategies in settings other than the experimental conditions, research is needed to explore various applications of the strategies. The following are potential questions for this line of inquiry:

- Can alphabet supplementation be used as an exercise to practice better speech production? For example, would it help speakers learn to reduce their speaking rate?
- In what natural communication situations do speakers with severe dysarthria find speech supplementation most useful?
- In what natural communication situations do speakers with moderate dysarthria find speech supplementation most useful?
- How can supplementation strategies be integrated into augmentative communication systems?
- How can the strategies be modified across the age span from children through elderly speakers?

Better Guidelines for Assessment and Training

Results of the current review suggest some general guidelines for candidacy involving primarily the severity of dysarthria. Better descriptions of procedures for assessment and training are need.

- What cognitive demands are inherent in various supplementation strategies? How can these demands be assessed? How can training programs help meet these demands?
- Does communication improve with speaker and/or listener training in use of the strategies?
- What is the most effective way to teach the use of multiple strategies or strategy shifting in response to various communication situations?
- How can unfamiliar listeners be trained so that their performance approximates more closely the performance of familiar listeners?

Better Outcome Measures

The studies reviewed in this report relied heavily on a small number of outcome measures, most commonly speech intelligibility. Clearly, other outcome measures are needed, especially as investigations begin to focus on communication in natural settings where transcription of speech intelligibility is not a practical outcome measure. The following are examples of possible research questions:

- What is the relationship between severity of dysarthria as measured by speech intelligibility and perceived function in natural settings?
- How do speakers' estimates of their own communication effectiveness relate to speech intelligibility measures?

- How much gain in intelligibility is needed before listeners perceive a benefit?
- What is the relationship between intelligibility (listeners' ability to understand words produced by the speaker with dysarthria) and comprehension (listeners' ability to draw meaning from the communicative exchange)?
- Is comprehension a better predictor of performance in natural settings than intelligibility?
- What measures best reflect the speaker's experience in natural communication settings?
- How can changes in the level of participation be assessed?

Focus on Listeners

Because listeners play an active role in the construction of messages when interacting with speakers with severe or profound dysarthria, more information is needed about them.

- Are listeners used in the current studies (often college students) typical of the frequent communication partners of speakers with severe dysarthria?
- What are the attitudes of listeners to various supplementation strategies?
- Are there important differences among listeners? If so, what variables are associated with better listeners? With poorer listeners?
- How do listener estimates of communication effectiveness compare to those of the speakers with dysarthria?
- Do listeners for whom English is not a first language do more poorly than native speaker in understanding severe dysarthria?

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