INFLUENCE OF VISUAL INFORMATION ON THE INTELLIGIBILITY OF
DYSARTHRIC SPEECH

by

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ABSTRACT

Purpose: The purpose of this study was to examine the influence of visual information on the intelligibility of dysarthric speech. The two research questions posed by this study were: (1) Does the presentation mode (auditory-only versus auditory-visual) influence the intelligibility of a homogeneous group of speakers with dysarthria? and (2) Does the experience of the listener (experienced versus inexperienced with dysarthric speech) influence the intelligibility scores of these speakers?

Background: Investigations of speakers with hearing impairment and laryngectomy have indicated that intelligibility scores are higher in an auditory-visual mode compared to an auditory-only mode of presentation. Studies of speakers with dysarthria have resulted in mixed findings. Methodological issues such as heterogeneity of speaker groups and factors related to the stimuli may have contributed to these mixed findings.

Method: Eight speakers with dysarthria related to Parkinson disease were audio and video tape-recorded reading sentences. Movie files were created in which an auditory-only condition containing the speaker's voice but no visual image of the speaker and an auditory-visual condition containing the speaker's voice and a view of his/her face. Two groups of listeners (experienced and inexperienced with dysarthric speech) completed listening sessions in which they listened to (auditory-only) and watched and listened to (auditory-visual) the movies and transcribed what they heard each speaker say.

Results: Although auditory-visual scores were significantly higher than auditory-only intelligibility scores, the difference between these scores was influenced by the order in which the two conditions were presented. A speaker effect was found across presentation modes, with less intelligible speakers demonstrating greater benefit from the inclusion of visual information. No statistically significant difference was found between the two listener groups in this study.

Conclusions: These findings suggest that clinicians should include assessment of both auditory-only and auditory-visual intelligibility measures in speakers with Parkinson disease. Management of intelligibility impairment in these individuals should consider whether visual information is beneficial to listeners.

INTRODUCTION

Communication is critical to quality of life, and speech intelligibility is an important component of communication. Speech intelligibility is influenced by many factors, including cues provided to the listener by the speaker. The focus of this study is how visual information from a speaker can influence intelligibility in dysarthria.

This section begins with discussion of intelligibility as a construct and the effects of impaired intelligibility in dysarthria. The influence of non-acoustic factors on intelligibility, especially visual information provided by the speaker's movements and how that information influences intelligibility in speakers with normal speech and speech impairments will then be discussed. This is followed by examination of methodological considerations concerning speaker characteristics, listener characteristics, stimuli selection and their implications for future research. Finally, the purpose for the proposed project is presented.

Intelligibility

Intelligibility has been defined in many ways, depending upon the issues examined. For the purposes of this study, intelligibility is defined as “. . . the degree to which a speaker's message can be recovered by a listener” (Kent, Weismer, Kent, & Rosenbek, 1989, p. 483). This definition of intelligibility does not limit the message to information contained specifically within the acoustic signal, but rather allows for the

consideration of other variables, such as visual speech cues that also affect what the listener understands.

Measures of speech intelligibility reflect the interaction between a speaker and a listener under given communication conditions (Ansel, 1985). Years of research have shown that many factors can influence intelligibility measures. Factors related to the speaker include severity of the intelligibility impairment (Yorkston & Beukelman, 1978), and rate of speech (Yorkston & Beukelman, 1981a). The type of speech stimulus used can affect the intelligibility scores obtained. These can include words, sentences, or paragraphs. Use of different scoring methods, including multiple choice or transcription can also affect intelligibility measurement (Beukelman & Yorkston, 1980). Predictability levels of words within sentences can influence intelligibility scores (Duffy & Giolas, 1974). Factors related to the listener have also been shown to influence intelligibility scores, including listener familiarity with the speech sample (Beukelman & Yorkston, 1980) and listener experience with the speech disorder and/or the individual speaker (e.g., Beukelman & Yorkston, 1980; Platt, Andrews, Young, & Quinn, 1980; Yorkston & Beukelman, 1980). Some tools used in intelligibility assessment limit these factors in order to control for them. In some cases, these limitations may influence the measurement such that functional aspects of communication are not adequately represented.

Intelligibility Measurement in Dysarthria

Damage to the nervous system can result in disorders of motor speech that can affect the intelligibility of the speaker. One cluster of motor speech disorders is dysarthria, defined as “. . . a collective name for a group of related speech disorders that are due to disturbances in muscular control of the speech mechanism resulting from impairment of any of the basic motor processes involved in the execution of speech” (Darley, Aronson, & Brown, 1975, p. 2). Dysarthria can be divided into different types, with each characterized by auditory perceptual characteristics and often associated with various neuropathological conditions. These conditions include neurogenic injuries, such as stroke or traumatic brain injury, or neurogenic diseases, such as Parkinson disease or multiple sclerosis. Dysarthria can result from impairment of any or all of the systems involved in the production of normal speech, including the respiratory, laryngeal, and upper-airway articulatory systems. Changes in the function of these systems can result in “speech impairment that is characterized by slow, weak, imprecise, and/or uncoordinated movements of the speech musculature” (Yorkston, Beukelman, Strand, & Bell, 1999, p. 16).

Speakers with dysarthria often exhibit reduced intelligibility due to the impairment across the multiple systems involved in speech production. In some cases, the effects of dysarthria on intelligibility are quite severe. Speech-language pathologists often measure intelligibility during assessment and management of dysarthria.

Determining how best to measure the intelligibility of speakers with dysarthria has been an ongoing challenge due to the many variables that can affect intelligibility scores.

The early work on intelligibility in speakers with dysarthria was conducted by Tikofsky and Tikofsky (1964). Their work was the first to demonstrate that normal speakers and speakers with dysarthria could be differentiated based on measures of speech intelligibility. They developed a 160-word list designed to estimate single-word intelligibility using transcription tasks. The number of words accurately transcribed by listeners formed the measure of intelligibility. They recorded speech samples from 10 speakers with normal speech and 10 from speakers with dysarthria. The scores obtained from the speech samples made it possible to place the speakers with dysarthria into categories of intelligibility ranging from mild to severe. An experienced speech-language pathologist also qualitatively judged each speaker's severity of dysarthria across a range from mild to severe. Findings from this study led the researchers to conclude that quantitative transcription scores could be used to differentiate severity of intelligibility impairment to supplement descriptions of dysarthria severity (i.e., clinician judgment). Shorter, revised word lists were later published by Tikofsky (1970) to allow for greater clinical applicability.

Platt and colleagues (Andrews, Platt & Young, 1977; Platt, Andrews, Young, & Quinn, 1980) developed another single-word intelligibility test. This test provided an overall intelligibility score and called for the examiner to list the phonemic errors produced by the speaker. These investigators expressed caution in the analysis of single

phoneme errors within isolated words stating that this “may not reflect the respiratory and laryngeal system interactions that are necessary for connected speech” (Platt, et al., 1980, p. 54).

Kent and colleagues (1989) developed a single-word test to help identify the acoustic and phonetic bases of intelligibility impairment in dysarthria. This test targets 19 phonetic contrasts reported in the literature as vulnerable to error in motor speech disorders. The test uses a multiple-choice format, grouping the target word with minimal or near-minimal pairs. Listener responses can be used to construct phonetic error profiles showing the particular phonetic contrasts that presumably make an important contribution to the overall speech intelligibility deficit. This method of testing allows for identification of sources of the intelligibility deficit, quantitative analyses at varied levels, and sensitivity to potential speech deficits across clinical subgroups of dysarthria. The error profiles may also have some utility in guiding remediation programs. Studies published to date on this test, have demonstrated that different error profiles may underlie similar global intelligibility deficits, that certain gender effects may be prominent in some profiles, and that the relationship between disease type and the phonetic error profile may be quite complex (Bunton & Weismer, 2001, Kent, et al., 1990, 1991; J. Kent et al., 1992).

Several standardized instruments have been marketed to clinicians for assessment of intelligibility in dysarthria. Yorkston and Beukelman (1981a) constructed the most widely used test of speech intelligibility in adults, *The Assessment of Intelligibility of*

Dysarthric Speech (AIDS), following the completion of numerous studies of intelligibility measurement in speakers with dysarthria (Beukelman & Yorkston, 1979, 1980; Yorkston & Beukelman, 1980, 1981b). This test consists of measurement of both single-word and sentence-level intelligibility and involves transcription and/or multiple-choice format for listener responses. The single-word test utilizes 50 word pools, each of which contains 12 similar sounding words. One test item is randomly selected from each pool to allow for an individualized word list for each speaker. The sentence items are selected from 11 sentence lists ranging from 5 to 15 words. Two sentences from each list are randomly chosen resulting in 22 sentence items containing 220 words. Speakers are audiotape recorded while they read words and/or sentences and the samples are played for unfamiliar listeners to transcribe. A “communication effectiveness ratio” is also calculated by recording the production time for each sentence and computing an estimate of average speaking rate for the correctly transcribed words. The rate of intelligible speech (Intelligible Words per Minute, IWPM) produced by the speaker is divided by the mean rate of intelligible speech produced by a group of previously studied normal speakers (i.e., 190 IWPM). This use of this ratio is based on the idea that two speakers who produce the same number of intelligible words may not have the same effectiveness as communicators. In this assessment, a speaker who produces words at a fast rate is determined to be a better communicator. Kent and colleagues (1989) have pointed out that this may apply to severely disordered speakers for whom speech movements are very

slow, but in other speakers, faster speech does not necessarily result in more effective communication.

The *AIDS* procedures have also been adapted so that the assessment can be presented to listeners via a computer. A software program, the *Sentence Intelligibility Test* (Yorkston, Beukelman, & Tice, 1996), was developed to allow clinicians to utilize sound cards, as well as audio record and playback drivers during intelligibility measurement. The sentences from the *AIDS* are used as stimuli.

Enderby (1983) created *The Frenchay Dysarthria Assessment* which estimates intelligibility through word, sentence, and conversation. Ten words are randomly selected from a set of 50 words, which vary in syllable structure and frequency of usage. Performance on both word and sentence tasks is determined on-line, although audio recording is encouraged so that responses can be checked later. Five levels of intelligibility are utilized to grade performance: a) all 10 words are correctly and easily recognized, b) all 10 words are correctly recognized but with difficulty, c) 7 to 9 words are correctly recognized, d) 5 words are correctly recognized, e) 2 or fewer words are correctly recognized. The conversational task is based on a 5-minute conversation and is graded on five levels: a) no abnormality, b) speech is abnormal but intelligible; c) speech is severely distorted so that it can be understood half the time, d) occasional words are recognizable, and e) speech is totally unintelligible. Kent and colleagues (1989) have suggested that variability in scores on this measure can be difficult to interpret because the word items vary greatly in syllable number and shape.

Although measurement of intelligibility is considered critical in the clinical management of many communication disorders, Kent and colleagues have stated that, “. . . consensus withers when it comes to deciding how intelligibility should be measured and assessed” (Kent et al., 1994, p. 81). They suggested that each speaker has a range of potential intelligibility, depending upon many factors, such as the nature of the spoken material, context of the communication situation, and availability of visual cues. The intelligibility measurement tools developed for use in clinical and research situations do not allow for consideration of many functional communication factors that may affect intelligibility scores.

Influence of Non-Acoustic Factors on Intelligibility Measurement

Two types of information are used by a listener who is attempting to understand a speaker's verbal message (Lindblom, 1990; Vogel & Miller, 1991). One is signal-dependent and one is signal-independent. Information entirely taken from the acoustic signal is described as signal-dependent. In the use of signal-dependent information, the listener uses bottom-up processing of the acoustic signal to separate acoustic information into phonetic and linguistic units. Bottom-up processing is driven by the acoustic signal with the focus on “. . . different cues or specific features of the signal that contribute to discriminable contrasts” (Garcia & Cannito, 1996, p. 90). In speakers with dysarthria, compromised signal-dependent or acoustical information contributes to a lack of intelligibility.

Signal-independent information refers to “what is in the listener’s brain” (Lindblom, 1990, p. 225). For the purposes of this study, signal-independent information refers to information that is not specifically contained within the acoustic signal, including visual information provided by the speaker. In this top-down processing, the listener uses knowledge of the language or other experience to understand the message. Hustad, Jones, and Dailey (2003) have proposed several types of signal-independent information that may affect a listener’s ability to understand a speaker’s message. They described three types of communicative knowledge that may be used by listeners to decode a spoken message. First, linguistic knowledge defines a listener’s expectations for semantics, syntax, and phonology. Second, paralinguistic knowledge includes gestures, facial expression, and speech-related movements that may also be used by a listener to help understand a message. Third, experiential knowledge refers to shared knowledge of culture and experiences between the listener and speaker. Top-down processing of these types of information can be effectively utilized when an incomplete or unclear acoustic message is presented to facilitate the understanding of a complete message.

Lindblom’s model of mutuality (1990) describes the interaction between signal-dependent and signal-independent information for listeners who communicate with individuals with impaired intelligibility. Lindblom proposed that speakers with intelligibility impairments provide listeners with reduced signal-dependent (acoustic-phonetic) information. In this case, listeners may be more reliant upon the signal-

independent (linguistic-contextual) knowledge to compensate for the information missing from the acoustic signal. In other words, signal-independent information can be used to fill in the gaps left by compromised signal-dependent information to help decode a message. Lindblom proposed that these two sources of information are negatively correlated. That is, when presented with an adequate acoustic signal, the listener does not need to rely on signal-independent information, such as context, to understand the speaker's message. On the other hand, when a listener is presented with a compromised acoustic signal he may need to rely on signal-independent information in order to understand message. Thus, the task of understanding dysarthric speech may require a different pattern of perceptual strategies than non-disordered speech.

In general, signal-independent information is not well-controlled in the intelligibility measurement tools described above. Table 1 summarizes features of the measurement tools previously described and highlights the manner in which intelligibility scores are obtained using these tools. In most dysarthria intelligibility measurement protocols, the listener has access only to acoustic information, limiting the use of some forms of signal-independent information available to the listener (i.e., visual information). The one exception is *The Frenchay Dysarthria Assessment*, which allows for listener access to visual information (but does not require its use). The protocols of the other measurement tools described above suggest the use of audio-recorded speech samples. In a discussion of the theoretical and research basis of the development of the *AIDS*, Yorkston and Beukelman (1981a) stated, "Intelligibility scores probably differ depending

on whether the judge views the dysarthric speaker via video tape recording as the speaker produces the message, or whether the judge simply listens to the message from an audio-recording. For ease of clinical administration, the decision was made to use audio-recordings as the only transmission mode” (p. 40). Intelligibility measurement protocols, which provide auditory-only information, do not allow the listener access to signal-independent information such as facial movements and expressions. Therefore, it is possible that some speakers may demonstrate clinical intelligibility scores that are not accurate estimates of their functional abilities because listeners are not given access to information that may commonly be present during a face-to-face communicative encounter, such as visual cues that are provided by the speaker.

Table 1. Characteristics of intelligibility measurement tools developed for use with speakers with dysarthria.

Measurement Tools	Speech Tasks	Listener Tasks	Presentation Modes	Outcome Measures
Tikofsky & Tikofsky(1964) Tikofsky (1970)	Single Words	Transcription	Auditory-Only	% Intelligibility
Platt & Colleagues (1977, 1978, 1980)	Single Words	Transcription	Auditory-Only	Overall % intelligibility List of phonemic errors
Kent & Colleagues (1989)	Single words – 19 phonetic contrasts	Multiple Choice	Auditory-Only	% Intelligibility Phonetic error profile
Yorkston & Beukelman (1980) – AIDS Yorkston, Beukelman, & Tice (1996) SIT	Single words Sentences	Multiple Choice OR Transcription	Auditory-Only	% Intelligibility Communica- tion effectiveness ratio
Enderby (1983) Frenchay	Words Sentences Conversation	Transcription “therapist”	On-line Audio record for reliability	% Intelligibility

Influence of Visual Information on Intelligibility Measurement

In the study of intelligibility, visual and auditory sources of information have been investigated separately and together. Studies examining the influence of visual information on intelligibility in different speaker populations are discussed in the next sections.

Speakers with Normal Speech

Visual information provided by a speaker's face can enhance speech intelligibility when the acoustic signal is degraded or when listening situations are less than ideal (Sumby & Pollack, 1954). O'Neill (1954) examined the influence of combined auditory and visual information in speech intelligibility in listeners with normal hearing. The listeners, who had no speech-reading experience, were presented with words and phrases under three conditions: 1) auditory-only, 2) visual-only, 3) auditory-visual. Stimuli were presented under several speech-to-noise ratio conditions. Results indicated that listeners identified words and phrases more accurately when visual information was included than when it was not.

Neely (1956) completed a study of one trained normal speaker and listeners with normal hearing to examine the effects of visual factors on the intelligibility of speech. These listeners transcribed the speaker's utterances on-line from 11 different test positions that varied in distance and angle to the speaker. One position involved the listener facing away from the speaker. A random noise generator was used to degrade the auditory signal. Results showed significantly higher intelligibility scores from the

listeners who saw the speaker while they heard the speech, than in those who did not see the speaker. An increase in intelligibility scores of approximately 20% was noted with the addition of visual cues in this study.

Studies of speakers with normal speech production and a degraded acoustic signal had relatively consistent findings. These studies have revealed that intelligibility is better when a degraded auditory signal is combined with visual information related to the act of speech production. When the acoustic signal is good, intelligibility is not improved with the addition of visual information. In this case, a type of ceiling effect may be noted where the acoustic signal starts at a high level that does not allow for much improvement. This supports Lindblom's (1990) claim that when the acoustic signal is degraded, signal independent information can enhance the listener's ability to understand.

Speakers with Hearing Impairment

Studies have also been conducted to determine whether inclusion of visual information could increase intelligibility of speakers with hearing impairment. The speech of individuals with congenital hearing impairment is often characterized by reduced intelligibility. Siegenthaler and Gruber (1969) recorded the speech of hearing-impaired individuals and provided normal listeners with auditory-only, visual-only and auditory-visual presentations of the speech samples. Intelligibility scores were found to be higher in the auditory-visual condition than in either of the other conditions. These results suggested that the inclusion of visual information with auditory information increase the accuracy with which listeners understand the speech of individuals with

hearing impairment. Monsen (1983) conducted a similar study in which the intelligibility of sentences spoken by hearing-impaired adolescents was assessed under various presentation modes. Listeners were presented with either an auditory-only or combined auditory-visual recording of the sentences. Intelligibility scores were significantly higher in the auditory-visual presentation than in the auditory-only presentation.

Menke, Oschner, and Testut (1983) investigated the influence of facial cues in the perception of target phonemes produced in words by prelingually deaf children. Experienced and inexperienced listeners were presented with speech samples from the children under auditory-only or auditory-visual conditions. Findings revealed that both groups perceived target phonemes in words more accurately when facial cues were provided. A lack of differences between the listener groups was attributed to the poor intelligibility of speech in the talkers. It was noted that correct target phoneme identification exceeded 50% in only one instance. Examination of individual listeners revealed that one of the three experienced listeners demonstrated significant benefit from the inclusion of visual information, suggesting that availability of visual cues in a listening task may be influenced by listener experience level.

Speakers with Laryngectomies

Research examining speakers with laryngectomies using esophageal speech has been conducted to assess whether intelligibility is influenced by the inclusion of visual information. Berry and Knight (1975) examined visual cues available during speech

production and their influence on intelligibility as judged by inexperienced listeners. Four speakers who had undergone laryngectomy were audio and video recorded reading a standardized passage. The listeners were asked to rate on a 7-point direct magnitude rating scale how well they understood the speakers. Intelligibility ratings were higher in the auditory-visual condition compared to those in the auditory-only condition. Next, these listeners were given multiple-choice questions to determine if they understood the content of the passage. No significant differences were found between auditory-visual and auditory-only conditions based on the multiple-choice scores.

Hubbard and Kushner (1980) compared intelligibility scores in auditory-only, visual-only and auditory-visual modes for speakers with laryngectomies who used esophageal speech. Eight esophageal speakers and eight normal speakers were audio and video recorded producing sentences. Three groups consisting of 10 listeners each were presented with stimuli using one of the three presentation modes. For the esophageal speakers, intelligibility scores were higher for the auditory-visual mode than for the other two presentation modes. Scores for the three presentation modes were not different for the normal speakers.

Speakers with Dysarthria

More recent studies have examined the influence of visual information on the intelligibility of individuals with dysarthria. Barkmeier (1988) examined the benefit of visual information by comparing intelligibility scores between auditory-only and auditory-visual presentations. Twelve speakers with dysarthria were videotaped while

reading sentences from the *AIDS* (Yorkston & Beukelman, 1981a). Experienced and inexperienced listeners transcribed these sentences and rated intelligibility under both auditory-visual and auditory-only conditions. These listeners completed two listening sessions, one week apart and were presented with the auditory-only and auditory-visual conditions in a randomized, counterbalanced order. Findings showed higher intelligibility scores in auditory-visual presentation of sentences versus those presented in an auditory-only manner in both experienced and inexperienced listening groups. Experienced listeners provided higher intelligibility transcription scores than inexperienced listeners. Analysis of the order of mode of presentation revealed that when the presentation order was auditory-only in the first session and auditory-visual in the second session, transcription scores were higher in the second session (auditory-visual). However, when the first session presentation mode was auditory-visual, transcription scores were not significantly different in the second session. Barkmeier suggested that, "Listeners appeared to maintain intelligibility measures during the second experimental session when the audio-visual mode of presentation was presented during the first experimental session" (p. 79). No significant differences were noted between the two presentation conditions on the intelligibility rating task.

Hunter, Pring, and Martin (1991) also examined influences of auditory-only and auditory-visual presentation in eight speakers with dysarthria related to cerebral palsy. These speakers were audio and video recorded reading sentences from the *Speech Intelligibility in Noise (SPIN) Test* (Kalikow, Stevens, & Elliot, 1977). Results showed

that the speakers with moderate dysarthria were more intelligible in the auditory-visual condition than in the auditory-only condition. By contrast, the speakers with severe dysarthria had similar intelligibility scores with the auditory-only and auditory-visual presentation modes. While the results of this study imply that severity of intelligibility may influence the effects of presentation mode, it is important to note that these groupings were based on subjective intelligibility ratings, rather than on intelligibility scores obtained through transcription.

Hustad and Cahill (2003) reported mixed findings in a study of auditory-only versus auditory-visual modes of presentation for a group of five speakers with dysarthria related to cerebral palsy. Two of the speakers were described as having a mild intelligibility deficit and three were described as having a severe intelligibility deficit based on the *Sentence Intelligibility Test (SIT)* (Yorkston et al., 1996). Clinical descriptions of the dysarthria were spastic (three speakers), hyperkinetic (one), or mixed (one). The authors reported minimal differences ($< 4\%$, not significant) in intelligibility scores for four of the five speakers between presentation modes, with higher scores occurring in the auditory-visual mode for three of these four speakers. For the remaining speaker, auditory-visual scores were found to be 10% higher than those in auditory-only, a difference that was statistically significant. This speaker demonstrated the most severely impaired intelligibility and was judged to have a mixed dysarthria. Overall, results of this study suggest that speakers characterized by different dysarthria types,

severity levels, and degree of motor impairment do not demonstrate similar benefit on intelligibility measurement from the inclusion of visual information.

In a set of two studies, Garcia and colleagues (1996, 1998) investigated effects of auditory-only and auditory-visual presentation modes in conjunction with contextual factors, such as message predictability and the use of concurrent production of gestures with utterances. Garcia and Cannito (1996) audio and video recorded a speaker with severe flaccid dysarthria. Resultant stimuli were presented to listeners in three modes: auditory-visual, auditory-only, and visual-only. When mode of presentation was examined with the data collapsed across the other factors (such as predictability and inclusion of gestures), auditory-visual presentation resulted in significantly higher intelligibility scores than auditory-only or visual-only presentations. Based on the three-way interaction of presentation mode, gestures, and predictability, the authors suggested that multiple sources of information are available to listeners and how much is understood may be a function of the interaction of these sources. It is important to note that the investigation of auditory-visual and auditory-only influences in this study was considered in the context of gestures. Although auditory-visual and auditory-only modes were presented in both gestured and non-gestured conditions, the differences between auditory-only and auditory-visual modes were not analyzed for statistical significance in the non-gestured condition. Therefore, effects of visual information in this study were determined by both gestures and other visual information such as speech movements.

In a similar study, Garcia and Dagenais (1998) investigated the use of gestures paired with speech, while varying mode of presentation and predictability. Two types of predictability were studied: verbal, in which predictability occurred through the spoken message, and nonverbal, in which predictability was established through the gesture. These factors were examined in auditory-visual and auditory-only modes of presentation. Speakers in this study were four individuals with dysarthria related to different types of cerebral palsy. These speakers were reported to vary in level of impairment, gestural abilities, and overall level of motor functioning. Listeners transcribed sentences of low or high predictability (verbal and nonverbal) produced by these speakers in auditory-visual or auditory-only conditions. Findings indicated that inclusion of the visual information enhanced intelligibility for all speakers, although there were complex interactions with the other variables. All speakers demonstrated higher intelligibility scores with highly predictable sentences, both in auditory-only and auditory-visual modes. However, the benefits varied among speakers based on whether the gestures were included. Overall, results of this study demonstrated that while various combinations of factors independent of the acoustic signal can affect intelligibility scores, effects of these factors and combinations varied in the heterogeneous speakers examined in this study.

Methodological Considerations of Intelligibility Measurement in Dysarthria

Studies of normal speakers and speakers with hearing impairments and laryngectomies have demonstrated clear benefits of visual information on speech intelligibility. By contrast, researchers examining the influence of visual information on

intelligibility scores for speakers with dysarthria have reported mixed results. Several factors may have contributed to these mixed results, including those related to characteristics of the speakers, listeners, and stimuli.

Speaker Characteristics

Previous studies of the influence of visual information on the intelligibility of dysarthric speech have examined heterogeneous populations of speakers (Table 2). These groups of speakers evidenced heterogeneous characteristics in etiology, dysarthria type, severity of dysarthria, and level of intelligibility. For example, the 12 speakers in Barkmeier's (1988) study were described as having 7 different etiologies, including Parkinson disease, amyotrophic lateral sclerosis, cerebral palsy, cerebellar degeneration, intracranial hematoma, spino-cerebellar degeneration with episodic brainstem dysfunction, and Hodgkin's disease. These different etiologies would likely result in speakers with perceptually different speech characteristics. In addition, the underlying neuropathophysiology responsible for the movement disorders in these cases could result in quite different movement characteristics. As another example, the four speakers in the Garcia and Dagenais study (1998) were dissimilar in terms of etiology, sentence intelligibility skills, gestural skills, and overall motor functioning. The speech intelligibility of Speaker 3 (etiology of amyotrophic lateral sclerosis) was 28% on sentences and he demonstrated moderate deficits in upper extremity function bilaterally. In contrast, Speaker 2 (etiology of multiple strokes) was described as having a speech intelligibility of 62% and no observable upper extremity impairment. As suggested by

the authors, the variability of the effects of visual information, predictability, and gestures was likely due to the heterogeneity of the speakers.

Table 2.

Note. AO = Auditory-only; AV = Auditory-visual; CP = cerebral palsy; CVA = cerebral vascular accident; *AIDS* = *Assessment of Intelligibility of Dysarthric Speech*; *HINT* = *Hearing in Noise Test*; *Predict* = *predictability*; *SIT* = *Sentence Intelligibility Test*; *SPIN* = *Speech Intelligibility in Noise Test*

Table 2. Methodological issues and findings from 4 studies examining influence of visual information on the intelligibility of speakers with dysarthria.

Studies	Speakers	Stimuli Characteristics Visually and Predictability Balanced	General Findings AV versus AO
Barkmeier (1988)	<ul style="list-style-type: none"> • 12 speakers • ages from 25 – 75 • Varied etiologies with no indication of dysarthria types or severity levels • No intelligibility data 	<ul style="list-style-type: none"> • 10 different <i>AIDS</i> sentences per speaker • Visual- No • Predict- Unknown (semantics) Yes (syntax) 	Mean intelligibility scores were higher in AV than in AO on transcription tasks.
Hunter, Martin, & Pring (1991)	<ul style="list-style-type: none"> • 8 speakers • ages not provided • Types of CP and dysarthria not indicated, • 4 severe, 4 moderate dysarthria • No intelligibility data 	<ul style="list-style-type: none"> • 50 <i>SPIN</i> sentences • Visual – No • Predict – Yes 	AV intelligibility scores were higher than AO in moderate; no difference between AV and AO in severe.
Garcia & Dagenias (1998)	<ul style="list-style-type: none"> • 4 speakers • ages 37 – 76 • various etiologies, 3 with spastic dysarthria, 1 mixed (spastic/flaccid) • Sentence Intelligibility - 10% to 79% 	<ul style="list-style-type: none"> • 16 sentences sounds • Visual – No • Predict – Yes 	For all speakers, intelligibility scores were higher in AV than in AO. The effects of visual information, gestures, and predictability varied highly between the speakers.
Hustad & Cahill (2003)	<ul style="list-style-type: none"> • 5 speakers • ages 24 – 50 • CP; hyperkinetic, mixed (spastic-hyperkinetic) or spastic dysarthria • Sentence Intelligibility - 16% - 80% 	<ul style="list-style-type: none"> • 40 <i>HINT</i> sentences • Visual – No • Predict – Yes (semantics) No (syntax) 	No difference between AV and AO for 4 speakers AV intelligibility scores were 10% higher than in AO for 1 speaker.

Even in studies where a single etiology was reported for the speakers, other variables contributed to their heterogeneity. Two studies described a common etiology for all speakers (i.e., cerebral palsy); however, different types of dysarthria were reported among the speakers (Garcia & Dagenais, 1998; Hustad & Cahill, 2003). In the Garcia and Dagenais study, speakers with the same type of dysarthria were described as having perceptually different speech characteristics. Although Speakers 2 and 4 were described as having the same type of dysarthria (spastic), the characteristics of their speech also varied considerably. For example, the speech of Speaker 2 was characterized by “harsh voice quality, low pitch, and imprecise articulation” (p. 1285), whereas the speech of Speaker 4 was characterized by “strained-strangled voice, hypernasal resonance, slow rate, and imprecise articulation” (p. 1285).

Examination of a group of speakers with different dysarthria types may lead to mixed findings between speakers simply as a consequence of the lack of homogeneity among the group members. Studies involving such diversity among speakers examined as a group have not provided meaningful information regarding the influence of visual information on the intelligibility of speakers with dysarthria.

Listener Characteristics

Listener characteristics have been shown to influence intelligibility scores of speakers with dysarthria. This section focuses on how listener experience with disordered speakers, listener familiarity with the speaker, and listener familiarity with the stimuli can influence intelligibility scores.

Listener experience with disordered speakers.

Intelligibility scores can be influenced by the listener's experiential knowledge.

Yorkston and Beukelman (1980) found that experienced clinicians obtained higher intelligibility transcription scores for speakers with dysarthria than inexperienced listeners. They suggested that “. . . speech pathologists may overestimate intelligibility scores because they are more familiar with the speech patterns of dysarthric speakers than unfamiliar listeners” (p. 37). Barkmeier (1988) compared experience levels of listeners and found that experienced listeners scored speakers with dysarthria higher on both transcription and intelligibility rating tasks.

Klimacka et al. (2001) suggested that experienced listeners might have learned patterns and strategies to decode speech of the hearing impaired. Experienced listeners may make better use of cues from these speakers, whereas inexperienced listeners may be too distracted by the disordered quality of speech to exploit the cues.

The intelligibility tools used to measure dysarthria do not consistently address the question of listener experience because they do not specify who the listener is. It is important to consider whether there are differences in how experienced and inexperienced listeners use visual information to understand dysarthric speech. This information could assist clinicians in making decisions regarding who is best suited to judge intelligibility in a given situation.

Listener familiarity with the speaker.

Studies have examined the effects of listener familiarity on intelligibility scores following repeated exposure to a particular speaker or voice. Studies that have examined familiarization in speakers with dysarthria had mixed results. Some studies have demonstrated that prior familiarization with a specific speaker led to increased intelligibility scores (Hustad & Cahill, 2003; Spitzer, Liss, Caviness, & Adler, 2000; Tjaden & Liss, 1995), while others found no differences between pre- and post-familiarization scores in listeners (Garcia & Cannito, 1996; Yorkston & Beukelman, 1983). The discrepancy between these findings is likely related to the different types of familiarization procedures used in these studies. While questions regarding level of listener familiarity with speakers with dysarthria remain, it is apparent that this could be a factor affecting intelligibility scores. Thus, listener familiarity should be controlled in studies that examine the influence of visual information on the intelligibility of dysarthric speech.

Listener familiarity with the stimuli.

Listener familiarity with the speech stimuli has also been demonstrated to influence intelligibility scores in studies of dysarthric speech. Yorkston and Beukelman (1980) found that listeners who were familiar with the speech stimuli produced higher intelligibility percentage scores than those who were unfamiliar with the stimuli prior to the transcription task. This factor should be considered in the design of a study of the influence of visual information on intelligibility, ensuring that listeners do not hear the

same speaker produce the same stimuli in auditory-visual and auditory-only conditions that will be compared.

Stimuli Characteristics

Another important consideration in creating a study designed to compare conditions of auditory-only versus auditory-visual presentation modes using transcription intelligibility tasks is the selection of speech stimuli. The two key issues relating to stimuli are the influence of visual information provided by the stimuli and the influence of word predictability within sentence stimuli.

Influence of visual information provided by the stimuli.

The stimuli must be selected to ensure that differences between the two presentation modes are not due to the fact that some words and/or sentences contain sounds that carry more visual information than others. Listeners receive many cues for place of articulation, such as that for bilabial sound production of /p/, /b/, or /m/ when labial approximation is observed. According to Summerfield (1987), “The visual information specifying the more forward places of articulation is distinctive, while that specifying nasality and voicing is hard to see” (p. 15). Some researchers have used a written phonemic inventory (Nilsson, Soli, & Sullivan, 1994) or phonetic inventory (Kalikow et al., 1977) to attempt to balance lists for content of visual information. This approach controls the frequency of specific speech sounds, however it does not account for usefulness of visual information for a listener. For example, in a written inventory of phonemes, the effects of coarticulation cannot be taken into account. In addition,

segmental and prosodic information (e.g., primary sentence stress) is provided by visual speech perception (Lansing & McConkie, 1999) but would not be available through analysis of a written inventory.

Protocols have been developed to equalize sentence lists for the ease of speech reading (MacLeod & Summerfield, 1990; Rosen & Corcoran, 1982; Rosenblum, Johnson, & Saldana, 1996). These protocols use a Loose Key-word Scoring method (Bench & Bamford, 1979) to assign a score based on the number of key words that can be transcribed using visual-only information. Lists equalized by this method allow for the comparison of auditory-only and auditory-visual conditions without concern that visual factors present in one list provided information in one condition but not in the other.

None of the studies examining the influence of visual information on intelligibility in dysarthric speech used stimuli that took into account the effects of speech reading cues (Table 2). Furthermore, lists previously employed have not been equalized in terms of quantity or quality of speech reading information available. For example, Hunter, et al. (1991) used stimuli from the *SPIN* (Kalikow et al., 1997) which controlled for phonetic content through means of a written inventory. When examining the influence of visual information on intelligibility, the design must allow for the assurance that stimuli to be presented in auditory-only and auditory-visual conditions are equalized for the influence of phonemes that may carry more visual information.

Influence of semantic predictability.

The predictability of words (i.e., semantic predictability) in sentences for a transcription task is another important consideration in intelligibility measurement. Duffy and Giolas (1974) defined predictability as “the property of the sentence which permits the prediction of a missing word(s) in that sentence” (p. 632). Predictability can be influenced by semantic context, when the words in sentences provide information about words that may be missing. In addition, syntactic context provided by a language user’s knowledge of grammatical structure of sentences could add to the predictability of words in sentences.

Some effort has been made to create lists of sentences in which the level of predictability of the words is known. Kalikow et al. (1977) investigated the influence of semantic predictability of words in sentences. Sentences of high predictability (e.g. “She cooked him a hearty meal.”) and low predictability (e.g. “Bob would consider the pole.”) were presented under conditions of various signal-to-noise ratios and normal-hearing listeners transcribed the key (final) word. Results indicated that sentences with high predictability were transcribed correctly significantly more often than were those with low predictability, with a trend toward more benefit from high predictability as the signal-to-noise ratio increased.

Duffy and Giolas (1974) investigated the relationship between word predictability and sentence intelligibility and concluded that “. . . word predictability is a factor influencing sentence intelligibility and that careful selection of key words, based on

their predictability status, is a method of controlling or influencing the intelligibility of sentences” (p. 631). This consideration is particularly critical in the population of speakers with dysarthria, where listeners may be relying more heavily on signal-independent cues, such as semantic predictability, when presented with a compromised acoustic signal.

Information in Table 2 describes differences for the control of predictability in stimuli used in the studies examining influences of visual information on the intelligibility of dysarthric speech. While some of these studies controlled for stimuli predictability (Garcia & Dagenais, 1998; Hunter et al, 1991), others did not. For example, Hustad and Cahill (2003) used sentence lists from the *HINT* (Nilsson et al., 1994). These lists are reported to follow a predictable syntactic structure, subject-verb-object. The sentences were not, however, rated on semantic predictability. A quasi-counterbalancing approach was used to “assure that predictability was approximately uniformly distributed across listeners and other independent variables” (p. 200). Examination of the sentences from these lists suggests that many are highly predictable based on semantic content. For example, “The wife helped her husband” and “She’s drinking from her own cup.” One possible explanation for the lack of differences found between auditory-only and auditory-visual conditions in this study is that listeners were able to use the semantic context to accurately complete the transcription task regardless of whether auditory-visual or auditory-only information was provided to the listeners.

The examination of intelligibility is genuinely representative of what the listener understands only when the predictability of words in sentences are low enough to ensure that the listener is not using semantic or syntactic context to guess correctly on any unintelligible words. Stimuli chosen for this type of study should be of low predictability, based on both semantic and syntactic context.

Statement of Purpose

Many speakers with dysarthria exhibit reduced intelligibility. For this reason, assessment of intelligibility is an important component of an evaluation of dysarthric speech. Past research has focused on constructing tools to measure intelligibility in speakers with dysarthria (Beukelman & Yorkston, 1980; Tikofsky & Tikofsky, 1964; Yorkston & Beukelman, 1980). These measurement tools consistently use audio-only speech samples that do not allow listeners access to visual information from the speakers. Research examining the influence of visual information using hearing impaired and laryngectomee populations have shown that higher intelligibility scores are obtained when visual information is presented than when it is not (Berry and Knight, 1975; Hubbard and Kushner, 1980; Monsen, 1983; Siegenthaler & Gruber, 1969). Studies examining the influence of visual information on the intelligibility of dysarthric speech have had mixed results (Barkmeier, 1988; Hunter et al, 1991; Hustad & Cahill, 2003). Several factors may have contributed to these mixed results, including heterogeneity of speakers, amount of visual information inherent in the stimuli, and semantic predictability of the stimuli.

The purpose of this study was to examine the influence of visual information in the measurement of intelligibility for a homogeneous group of speakers with dysarthria. Homogeneity was based on medical diagnosis of Parkinson disease and on perceptually similar speech characteristics. The proposed study also controlled for visual information provided by the speech stimuli, predictability of stimuli, and listener experience.

The specific questions related to this purpose were:

(a) Does the presentation mode (auditory-only versus auditory-visual) influence the intelligibility of a homogeneous group of speakers with dysarthria? It was hypothesized that listeners would benefit from the inclusion of visual information, as demonstrated by higher intelligibility scores in the auditory-visual versus the auditory-only condition.

(b) Does experience of the listener (experienced versus inexperienced with dysarthric speech) influence the intelligibility scores of these speakers? It was hypothesized that experienced listeners would have higher intelligibility scores than the inexperienced listeners.

(c) Is there an interaction between listener experience level and presentation mode? It was hypothesized that inexperienced listeners would demonstrate greater performance improvement with visual cues than experienced listeners.

METHOD

Subjects

Three types of subjects participated in this project: speakers, inexperienced listeners, and experienced listeners. All subjects signed consent forms that had been approved by the Institutional Review Board at the University of Arizona.

Speakers

Eight speakers, ranging in age from 57 to 82 years, participated in this study. They all had a medical diagnosis of Parkinson disease and were recruited from local support groups. They all had English as a first language, reported normal to corrected-to-normal vision, and did not have a beard, moustache, or facial deformity which may have impeded visualization of their lip movements. Each speaker passed a pure-tone hearing screening in at least one ear, with tones presented at a level of 40 dBHL at frequencies of 500, 1000, and 2,000 Hz (GSI 17 audiometer). All of the speakers demonstrated intelligibility impairment as measured by the sentence subtest of the *Sentence Intelligibility Test (SIT)* (Yorkston et al, 1996) as judged by an unfamiliar listener. The intelligibility of these speakers ranged from 38 to 92%. Perceptual characteristics of their dysarthrias were similar. This similarity was determined by descriptive information provided by five master clinicians who each reported more than 20 years of clinical experience working with patients with dysarthria. These clinicians were asked to describe the perceptual characteristics of each subject's speech based on the Darley, Aronson, and Brown (1969a, 1969b) taxonomy given samples of vowel prolongation,

rapid alternating movements, and paragraph reading. Table 3 provides speaker information, including age, gender, intelligibility at sentence level, and speech characteristics that were noted by at least four of the five master clinicians. Appendix A contains a summary of the criteria and rationale for the selection of speakers.

Table 3. Demographic and descriptive information for the eight speakers.

Speaker	Sex	Age	Intelligibility on <i>SIT</i>	Perceptual Speech Characteristics
A	M	73	82%	Irregular voice quality Imprecise consonants
B	M	82	92%	Irregular voice quality Imprecise consonants Irregular rate
C	M	74	75%	Irregular voice quality Imprecise consonants Irregular rate
D	M	81	38%	Irregular voice quality Imprecise consonants Irregular rate
E	M	72	80%	Irregular voice quality Imprecise consonants
F	F	57	86%	Irregular voice quality Imprecise consonants Irregular rate
G	F	79	70%	Irregular voice quality
H	M	60	42%	Irregular voice quality Imprecise consonants Irregular rate

Inexperienced Listeners

Ten inexperienced listeners were recruited from the university student community. Listeners selected for the “inexperienced” group ranged in age from 19 to 24 years, had no prior experience evaluating and/or treating speakers with dysarthria, and had no coursework in motor speech disorders. These listeners reported no regular (daily or weekly) contact with a speaker with dysarthria and no prior communication with the speakers in the study. Inexperienced listeners had English as their primary language, normal or corrected-to-normal self-reported vision, and demonstrated normal hearing on a screening with tones presented at a level of 25 dBHL at octave frequencies from 500 through 6000 Hz (GSI 17 audiometer) (American Speech-Language-Hearing Association, 1997). See Appendix B for inexperienced listener selection criteria and rationale.

Experienced Listeners

Ten experienced listeners were selected from a pool of local speech-language pathologists. Listeners selected for the “experienced” group ranged in age from 27 to 54 years, were certified by the American Speech-Language-Hearing Association as speech-language pathologists, and were currently working with adults with dysarthria and had more than 6 months of professional experience with this population. These listeners reported no prior communication with the speakers in the study and no specific knowledge of the study. The experienced listeners had English as their primary language, normal or corrected-to-normal self-reported vision, and demonstrated normal hearing on a screening with tones presented at a level of 25 dBHL at octave frequencies from 500

through 6000 Hz (GSI 17 audiometer) (American Speech-Language-Hearing Association, 1997). See Appendix B for experienced listener selection criteria and rationale.

Stimulus Recording Procedures

A recording session was scheduled if speakers met the initial criteria for study participation (i.e., interest in participation, reduced intelligibility). When possible, this session was conducted in an IAC sound-treated room. Three of the eight speakers were not able to complete recording in this room due to transportation issues. These speakers were recorded in a quiet environment with background and lighting similar to that used in the sound-treated room. The sessions were scheduled according to when the speaker felt his/her intelligibility would demonstrate the greatest impairment, with medication cycle and fatigue considered as factors. Notes from these sessions were recorded on the speaker information form (Appendix C). Described below is the equipment set-up, the process used for the selection of stimuli, and the tasks that each speaker was asked to perform.

Equipment Set-up

Each speaker was seated comfortably in a chair and encouraged to place his/her arms on the chair's arms for stability. Two of the eight speakers sat in their wheelchairs. Each speaker was positioned in front of a neutral-colored background and wore a black cloak to minimize visual distractions.

Microphone audio signals were recorded simultaneously onto a digital audiotape (DAT) recorder (Tascam Digital Audio Tape Recorder, Model DA-P1) and videotape

recorder using a lapel microphone (Audiotechnica AT 8533) attached to the speaker's collar. The microphone did not obscure the speaker's face or mouth. The mouth-to-microphone distance varied between speakers due to differences in physical size and ranged from 9 to 13 cm. The mouth-to-microphone distance was kept constant for each speaker throughout the recording session.

Video and audio samples were recorded with a video recorder (Sony Video Camera Recorder - CCD-TR101) positioned directly in front of each speaker. The camera was set to capture each speaker's face centered in view from the shoulders up. A constant distance (approximately 6 feet) between speaker and camera was maintained across speakers, with the camera set on auto-focus. The angle of the camera was maintained parallel to the floor and a vertical movement of the tripod platform adjusted for height differences in speakers.

A pure-tone (Korg Auto Chromatic Tuner, AT-12) was used as a calibration signal on DAT and the audio channel of the videotape. The tone generator was placed at mouth level for each speaker. A sound pressure level meter (Bruel & Kjaer, 2236) held just above the microphone was used to record in decibels the sound pressure level of the tone. This level was read aloud by the investigator onto the recording tapes and also written down in the notes from the recording session. See Appendix D for the recording session protocol.

Stimuli Selection

The stimuli that were read by each speaker consisted of eight lists of fifteen sentences each (Appendix E) taken from *the Institute of Hearing Research (IHR) Audio-Visual Sentence Lists* (MacLeod & Summerfield, 1990). Sentences were derived from lists developed for speech-in-noise tests based on Bench and Bamford's (1979) British sentences. These sentences were adapted by MacLeod and Summerfield into 10 sets of 15 sentences equalized for lip reading using procedures described by Rosen and Corcoran (1982) to determine difficulty of lip reading. The 10 lists were balanced for syntactic predictability, with each list containing an equal number of sentences with the same structure (e.g., subject-verb-object).

A study was conducted to determine semantic predictability of the sentence lists. Three forms of each sentence were typed as a pencil and paper fill-in-the-blank task. A different key word was left as a blank on each form of each sentence. Each sentence contained three key words. For example, "____ moved the furniture." (Form 1), "They ____ the furniture." (Form 2), and "They moved the ____." (Form 3). Each form was presented to undergraduate participants who were asked to write the word most likely to fill in the blank. A total of 90 participants each completed 5 different forms of different sentences.

Results of statistical analysis (t-tests) indicated that eight of the ten lists were statistically similar for semantic predictability when all three forms were considered for each sentence (see Table 4). Lists 9 and 10 were found to be significantly different from

the other lists, with List 9 being characterized by higher predictability and List 10 being characterized by lower predictability. Closer inspection of List 10 indicated that one sentence (“The bath taps are dripping”) resulted in this lower predictability score, as 0/15 respondents completed the sentence form missing the word “taps.” This sentence was felt to represent a nonstandard American English phrase, and it was determined that use of the word “tubs” would preserve the visual contribution of sounds in the sentence while allowing for a more familiar use of words. Reanalysis of this list was conducted using the word “tubs” which 7/15 respondents had indicated and the list was then found to be significantly similar to the other lists. Based on this change, only List 9 was eliminated from the set of 10 because of its higher predictability score, this left the other 9 lists equal for semantic predictability.

The results of this study indicated that all lists could be described as “low predictability,” with the percentages ranging from 19 to 28%. A total of only eight sentence lists was needed for the study, based on the targeted number of speakers. Therefore, one additional list was eliminated. List 1 was chosen for elimination based on finding in the MacLeod and Summerfield (1990) study that indicated a correction factor was necessary for this particular list in order to ensure that the lists were equalized for ease of speech reading. In summary, Lists 2 through 8 and List 10 taken from the MacLeod and Summerfield study were selected for the current study as they were determined to be balanced for the visual contribution of sounds, syntactic structure and semantic predictability. Table 4 contains the predictability scores for each list.

Table 4. Predictability scores for the IHR lists.

List	Semantic Predictability %	Special considerations
1 <i>eliminated</i>	28.1	Speech reading correction factor
2	22.8	
3	23.1	
4	24.4	
5	21.4	
6	22.8	
7	24.2	
8	28.5	
9 <i>eliminated</i>	35.4	Speech reading correction factor; p-value significant on all t-tests
10	15.1 (taps) 19.9 (tubs)	p-value significant on eight t-tests Change “taps” to “tubs” no significant t-tests

Speech Tasks

The speech tasks included sentence reading [*SIT* sentences (Yorkston et al., 1996)], paragraph reading [*My Grandfather* (Gray, 1936)], spontaneous conversation prompted by the investigator, rapid alternating speech movements (i.e., syllable repeats), and prolonged vowels. The latter four samples were gathered for the master clinician descriptions. Following a short break, speakers were asked to read the *IHR* stimuli to be used in the transcription portion of the study.

Orthographic representations of stimulus sentences were printed on neutral-colored paper with typed lettering (Times New Roman, 74 point) and positioned on a music stand placed directly above the video camera lens. This placement ensured that the speaker's gaze was just above the camera lens so that the speaker appeared on tape to be looking at the camera. The speaker read the sentences aloud from the cards without cues. If a speaker made a reading error, that sentence was set aside by the investigator and presented again at the end of that sentence block. Delaying a repetition of the sentence was felt to minimize performance effects that may have occurred as the speaker attempted to correct the sentence. The speaker was instructed to speak naturally as though having a conversation with the investigator in the room. Planned 2-minute breaks were taken after each sentence block (15 sentences). Additional breaks were allowed at any time during the recording session when requested by the speaker.

Pilot recordings from four speakers with Parkinson disease who had reduced intelligibility (as judged by the investigator) in conversational speech exhibited performance effects when asked to read the sentence stimuli in front of the camera. The investigator noted that intelligibility improved noticeably during the recording session compared to the speaker's spontaneous speech. These performance effects have been observed in both speech and motor tasks where impairment can be noticeably improved by simple cues, such as the presence of recording equipment (Aronson, 1990). In order to obtain a speech sample of the *IHR* sentences that represented the speaker's usual speech performance, a dual-task paradigm was utilized (Dromey & Benson, 2003; Ho, Iansek, &

Bradshaw, 2002). Pilot data indicated that selected motor tasks reduced intelligibility to a level more representative of the speaker's spontaneous speech skills. These motor tasks included holding a nut in one hand and screwing a bolt with the other or moving small plastic beads along a looped wire. These tasks were performed under the black cloak so that the speaker was not looking at the objects and so that his/her movements during the task could not be seen on the videotape.

Listening Procedures

Movies created from the recordings were played for listeners who transcribed the sentences in both auditory-only (AO) and auditory-visual (AV) conditions. These transcription scores were averaged and analyzed statistically to answer the proposed study questions.

Stimulus Set Preparation

Video recordings were transferred to a personal computer via Firewire (IEEE 1394). Digital video software (Adobe Premiere Pro) was used to edit the video recordings of each speaker. It was found that an automatic gain control device on the videorecorder amplified extraneous background noise. To eliminate this noise, audio files from the digital audio tape (DAT) recordings were matched with the digital audio files from the videorecording. A computer software program (MatLab 7.0) was used to align the two audio signals. A cross correlation was computed between the audio signal from the DAT and videotaped samples using the first 200,000 sample points to determine the time difference between them. The DAT audio signal was then shifted to match the

sample from the videotape. To accomplish this, points were either taken away or the beginning of the audiofile was padded with extra samples of zero amplitude. The amplitude of the signal was also normalized during this process to 80% full scale. Following the alignment of the two audio signals, the higher quality DAT audio files were imported into the Premiere Pro software program. The original audio sample was then deleted, leaving the video file aligned with the DAT audio file.

Each sentence produced by each speaker was dubbed into an AV movie file and an AO movie file. For each AV movie file, the image of the speaker appeared for approximately 1 second prior to the sentence being produced in order to allow listeners a chance to view each speaker at rest. For each AO movie file, a black screen with a small blue square was presented while the audio portion of the movie was played. A 12-second pause was inserted between each sentence to allow for listeners to transcribe the sentence. A randomized sentence order was used for each speaker and each list. Edited movie files were recorded onto digital video disk (DVD) format for presentation.

Each of the 20 listeners (10 experienced and 10 inexperienced) was assigned to a random presentation order for the 8 speakers and a random sentence list order. A listener was also randomly assigned the order of presentation mode (AV or AO first). Listeners were presented with all eight speakers in a blocked presentation mode during each listening session. Listeners completed two listening sessions, with the second session occurring within 7 to 10 days of the first. Following is an example listener session that illustrates these random assignments:

Example Listener Session

Session 1:

AV	Speaker B/ List 8
AV	Speaker G/List 1
AV	Speaker C/List 3
AV	Speaker F/List 5
AV	Speaker A/List4
AV	Speaker E/List 6
AV	Speaker D/List 2
AV	Speaker H/List 7

Session 2:

AO	Speaker A/List 3
AO	Speaker D/List 6
AO	Speaker G/List 4
AO	Speaker B/List 1
AO	Speaker E/List 2
AO	Speaker H/List 5
AO	Speaker C/List 8
AO	Speaker F/List 7

Equipment Set-up

All listening sessions were conducted in a quiet listening environment with dimmed lighting to allow optimal visualization of the video screen. Listeners were seated individually at a table approximately 2 feet in front of a 17-inch digital video monitor wearing headphones (AKG, K 240 DF). The monitor was positioned at listeners' eye level. The output level of stimulus material was set by the investigator to a comfortable listening level prior to the start of the experimental session and was maintained throughout the session. Listeners were instructed to look at the monitor during all trials.

Listening Tasks

Written and oral directions were given to each listener (Appendix F). The listener was given the instructions for only the presentation mode they were assigned to during that session, i.e., “You will see and hear a speaker” or “You will hear a speaker.” For both presentation modes, listeners were instructed to write down what they heard each speaker say as accurately as possible. Following delivery of specific instructions, listeners were given the opportunity to ask questions. Prior to the set of test sentences for a speaker, the listener was presented with two practice sentences in the mode to be presented for that speaker. These sentences were taken from the two eliminated *IHR* lists. In total, each listener transcribed 20 sentences for each speaker in a session, including 2 practice sentences, 3 reliability items, and 15 sentence items for analysis. Notes from these sessions were recorded on an inexperienced listener screening form (Appendix G) and an experienced listener screening form (Appendix H).

Data Analysis

Scoring

Intelligibility for each speaker was determined by counting the number of words correctly identified and dividing by the total number of words possible for each trial (total words per sentence ranges from 4 to 7). A mean score was computed for each of the 10 listeners in each listening group (experienced and inexperienced). Synonyms or responses reflecting morphological variations, such as *cat* for *cats*, were considered incorrect. Misspellings (e.g., theif for thief) and homonyms (e.g., their for they’re or rode

for rowed) were accepted as correct. Two raters scored the number of correct words per sentence and these scores were compared. Less than 5% of these scores were not in agreement and in these cases, the raters discussed the scores and came to a consensus before a final score was assigned.

Experimental Design and Analysis

Ten experienced and ten inexperienced listeners transcribed eight speakers in both AV and AO presentation modes. A total of 15 sentences were completed for each speaker in each mode. A total of 2400 transcriptions were collected (10 listeners x 15 speakers x 2 modes x 8 speakers).

Descriptive Statistical Analysis

Mean intelligibility scores and standard deviations were computed for each speaker and sentence list in each presentation mode (see Appendix I). These mean scores were used as data points in the statistical analyses.

Inferential Statistical Analysis

A four-way analysis of variance (ANOVA) was used to examine four main effects: mode (AO vs. AV), speaker, and listener experience (experienced vs. inexperienced), and order of presentation (i.e., which mode was by completed by the subject in the first session). Speaker and mode were examined as within-subject variables and listener experience and order as between-subject variables. This ANOVA used an interaction model, with the alpha level set at .05.

Two post-hoc analyses were conducted using Tukey's Honestly Significant Difference (HSD) Test with Bonferroni adjustment to control alpha level of .05. The first analysis was used to determine significance of interactions between speakers (.05 alpha divided by 8 speakers = .00625). The second analysis examined differences within and across mode based on the order the modes were presented to the listener (.05 alpha divided by 4 scores = .0125).

Reliability Measures

To measure intra-listener reliability, 20% (3 sentences) were randomly repeated during the transcription of each sentence list in each condition. Presentation 1 and presentation 2 transcriptions for these target sentences were compared to determine consistency of listener performance. A Pearson product-moment correlation coefficient was obtained between these transcriptions in both modes. Mean difference percentage scores and standard error of measurement (SEM) were computed for each speaker by determining the differences in scores on the reliability sentences for presentation 1 and presentation 2.

RESULTS

Reliability

As a measure of intra-listener reliability, Pearson product-moment correlation coefficients were calculated. Correlations were .93 for both AO and AV modes. Mean difference percentage of change was 4.3% (SEM = 1.44) in the AO mode and 3.2% (SEM = 1.32) in the AV mode.

Mode

Group mean intelligibility scores were higher in the AV mode [80.61% (SD = 6.19)] than in the AO mode [70.88% (SD = 4.69)]. Analysis of variance (ANOVA) revealed a significant interaction between order and mode and between speaker and mode (see Table 5).

Table 5. ANOVA analysis across all variables and interactions between variables
(* indicates significant results).

Variables	df	F	Pr > F	γ
		Within subjects		
Mode	1	7575.78	< .001*	.670
Speaker	7	147.45	< .001*	.902
Error	126			
		Between subjects		
Listener experience	1	1535.6	.133	.136
Order	1	193.7	.581	.019
Error	18			
		Interaction		
Speaker x Listener experience	7	1.724	.110	.097
Mode x Listener experience	1	.038	.848	.002
Speaker x Mode	7	4.697	< .001*	.227
Order x Mode	1	7.528	.014*	.320

Regarding the interaction between order and mode, the difference between AO and AV modes was greater for listeners who had the AO mode in the first session than for those who had the AV mode first. This is shown in Figure 1 which illustrates the mean AV scores minus the mean AO scores across speakers. Listeners who had the AO mode in Session 1 demonstrated a larger increase in transcription scores in the AV mode presented in session 2 (mean increase of 13%). Listeners who had the AV mode in session 1 and AO in session 2 had a mean difference of 7%, with AV scores higher than AO scores. There were two exceptions within this order of listeners who had greater or equal scores for AO compared to AV; Listener 7 (AV = 70%, AO = 75%) and Listener 11 (AV = 84%, AO = 84%). Regardless of the order, scores obtained through 18 of the 20 listeners were higher in the AV mode compared to the AO mode.

Figure 1. Mean intelligibility differences between modes across all speakers for all listeners.
Left side of figure illustrates listeners with AO (Session 1) - AV (Session 2) order.
Right side illustrates listeners with AV (Session 1) - AO (Session2) order.

Figure 2 shows mean intelligibility scores collapsed across all listeners and speakers with standard errors represented by bars. Post hoc contrast analysis revealed that the amount of change between the two scores of listeners who completed an AO (session 1) – AV (session 2) order was significant [$t(16) = 4.68; p < .001$], with the AV scores higher than AO. Similarly, the amount of change between the two scores of listeners who completed an AV (session 1) – AO (session 2) order was also significant [t

(16) = 3.39; $p = .004$], with AV scores higher than AO. Post hoc analysis using Tukey HSD revealed that the difference between the two mean AO intelligibility scores (68% and 74%) was not significantly different ($p = .084$), nor was the difference between the two mean AV intelligibility scores (79% and 82%) ($p = .579$).

Figure 2. Mean intelligibility scores based on session order.

Listener Experience

Mean intelligibility scores for the AV and AO mode were slightly higher for the experienced listeners compared to the inexperienced listeners. The mean intelligibility scores were as follows: AO/Inexperienced = 69% (SD = 26%), AV/Inexperienced = 79% (SD = 19%), AO/Experienced = 74% (SD = 21%), AV/Experienced = 83% (SD = 17%). However, ANOVA indicated that these scores were not significantly different and there were no significant interactions.

Speaker

Mean intelligibility scores and standard deviations for speakers in both presentations modes are displayed in Figure 3. Mean intelligibility for speakers ranged from 96.7% (Speaker B in AV) to 40.4% (Speaker D in AO). The mean AV intelligibility scores were higher for all of the speakers than the mean AO scores. Post hoc contrast analysis revealed a significant mode by speaker effect (Table 5). Specifically, intelligibility scores were significantly higher in AV than AO for three speakers [Speaker D = $t(126) = 4.42$; $p < .001$; Speaker G = $t(126) = 6.68$; $p < .001$; Speaker H = $t(126) = 4.87$; $p < .001$].

Figure 3. Intelligibility scores for individual speakers for AO and AV modes
(* indicates significant results).

DISCUSSION

The purpose of this study was to examine the influence of visual information on the intelligibility of dysarthric speech. The inclusion of visual information resulted in higher intelligibility scores for all speakers in this study, although the amount of benefit depended upon the individual speaker and the order in which the AO and AV modes were presented to listeners. The following discussion focuses on a critique of the method, implications of the present findings, clinical implications, and directions for future research.

Critique of the Method

The method used in this study had several strengths that related to the speakers and stimuli. Specifically, these included the use of a homogeneous speaker group and stimuli that were balanced for predictability and visual information.

A homogeneous speaker group was an important feature of the design of the present study. All of the present speakers were diagnosed with Parkinson disease, and perceptual analysis of their speech by expert clinicians indicated that they exhibited generally similar speech characteristics (see Table 3). The fact that the present speakers represented a relatively homogeneous group probably contributed to the consistent results obtained in this study. By contrast, the use of heterogeneous subjects was believed to account, in part, for the mixed results reported for previous investigations of speech intelligibility in dysarthria (Barkmeier, 1988; Hunter et al., 1991; Hustad & Cahill, 2003).

The speech stimuli were selected so that the lists used in the AO and AV conditions were balanced for both syntactic structure and semantic predictability. Balanced syntactic structure was ensured in this study by selecting the Institute of Hearing Research (IHR) sentence lists that had been balanced by MacLeod and Summerfield (1990). That is, the lists contained an equal number of sentences of the same structure (e.g., subject-verb-object). Semantic balance ensures that the sentence lists have similar predictability based on word meaning within a sentence. A feasibility study was conducted prior to the selection of these lists to examine semantic predictability of the IHR lists. Results from this study revealed that the eight lists chosen each had a semantic predictability of less than 30% for key words. Although sentence lists from other studies have considered either syntactic (Barkmeier, 1988) or semantic (Hustad & Cahill, 2003) predictability, only the present study and the study by Hunter and colleagues (1999) used stimuli that were balanced for both semantic predictiveness and syntactic structure.

This is the first study of dysarthric speech intelligibility that has taken into account the visual information provided by the stimuli. The stimuli sentences used in this study were balanced for visual information in that the lists were equalized for lip-reading cues available to listeners. Again, this was accomplished by the selection of the IHR sentence lists that had been balanced by MacLeod and Summerfield (1990) for use in lip-reading tasks.

Implications of the Findings

The following section will address the influence of selected variables on intelligibility scores obtained in this study. These variables include visual information, order (familiarity), listener experience, and individual speaker performance.

Influence of Visual Information on Intelligibility

Intelligibility scores were higher when visual information was available to listeners than when it was not. This finding was similar to those of previous studies where visual information was beneficial to listeners in populations of speakers with laryngectomies (Berry & Knight, 1975; Hubbard & Kushner, 1980) and hearing impairment (Siegenthaler & Gruber, 1969; Monsen, 1983).

Most listeners appeared to be aware of the advantage of being able to see the speaker's face during the transcription task. After both listening sessions were completed, listeners were asked, "What was your experience completing this task over both of these sessions?" Fourteen of the twenty listeners indicated that the task was "easier" or "less frustrating" in the AV mode and all but one of these listeners had higher transcription scores in the AV mode than in the AO mode. Half of these 14 listeners had the AO mode first and half had the AV mode first; thus, order of presentation mode did not appear to influence the nature of these post-experimental comments. One listener reported that during the AO condition, she "missed articles, like *the* or *an* at the beginning of sentences" but during the AV condition, she was able to detect them when the speaker's mouth was visible. Another listener stated that, "the sound was more like

a back-up when the visual information was there.” Six listeners reported that they focused on the speakers’ lips and mouth during the AV condition and one reported that he also benefited from seeing the speaker’s expressions.

Four of the twenty listeners reported that the inclusion of visual information helped with some speakers, but not with others. These listeners all had higher transcription scores in the AV mode than they did in the AO mode for all speakers. One listener indicated that the AV condition was “more tiring” and that it was easier to tune into the speaker’s voice when not watching the speaker. Contrary to her perception, this listener had higher scores for the AV than the AO condition.

Influence of Order (Familiarity) on Intelligibility

Mean intelligibility scores were higher when visual information was provided (AV mode) than when it was not (AO mode), regardless of the order of presentation. Nevertheless, the significant interaction between mode and order suggests that familiarity with the task, the speakers, and/or the stimuli influenced performance.

Barkmeier (1988) found an interaction between order and mode. In that study, intelligibility scores were significantly higher for AV than for AO, but only if the AV mode was presented after the AO mode. Hustad and Cahill (2003) also reported descriptive findings that higher intelligibility scores occurred in the AV mode compared to the AO mode when listeners began in the AO mode. The somewhat more robust statistical advantage of AV over AO found in the present study may be attributed to the

use of more stringent controls on the speakers (i.e., more homogeneous) and stimuli (i.e., balanced for predictability and visual information).

Influence of Listener Experience on Intelligibility

There were no significant differences in intelligibility scores between experienced and inexperienced listeners in this study. By contrast, Barkmeier (1988) found that experienced listeners achieved higher intelligibility scores for speakers with dysarthria than inexperienced listeners. Although it is not clear why the findings of these two studies disagreed with respect to listener experience, it can be speculated that differences in the speaker group may have influenced listeners' performances. Specifically, the homogeneity of the speaker group in the current study may have made the transcription task easier for the inexperienced listeners, in contrast to a listening task involving speakers with a variety of etiologies. It may be easier for listeners who are experienced with motor speech disorders to transcribe a variety of different types of speech than it is for listeners without this type of experience.

Influence of Individual Speakers on Intelligibility

Although all speakers earned higher mean intelligibility scores when visual information was provided than when it was not, the difference between AV and AO scores ranged among speakers. In fact, only three speakers demonstrated significantly higher AV scores. It is relevant to note that these same three speakers demonstrated the lowest AO intelligibility scores. This finding is similar to that of Hustad and Cahill (2003) where only one of five dysarthric speakers showed a significant increase in the AV

mode compared to the AO mode, with that speaker being described as the most severely impaired and having the lowest AO intelligibility score. Listeners appeared to rely more on visual cues to help them identify a speaker's message when the acoustic signal was less clear. This finding supports Lindblom's model of mutuality (1990) where he proposed that a listener presented with a compromised acoustic signal may understand more of the speaker's message if signal-independent information can be utilized.

Although all speakers had higher mean intelligibility scores in the AV mode than in the AO mode, the more intelligible speakers (i.e., those whose AO intelligibility scores ranged from 88% to 92%) did not demonstrate significant benefit from listeners being able to see their faces. This finding was similar to Hustad and Cahill (2003) who also observed that their more intelligible speakers' scores did not increase with the inclusion of visual information. These results suggest a ceiling effect for the more intelligible speakers in which the inclusion of visual information does not appear to provide further cues to listeners that were not already available in the acoustic signal. Nevertheless, the possibility that visual cues could provide clinical benefit should not be discounted. For example, Speaker B demonstrated an overall increase in intelligibility from AO to AV mode of 7%, (from 90% in AO to 97%). While not statistically significant, it is possible that a 7% improvement could benefit the speaker's functional communication.

The speaker who benefited least from the inclusion of visual information was described by listeners as not providing as much visual information. Speaker C demonstrated the least amount of change between the modes of all of the speakers (3%).

Several listeners commented that this speaker was difficult to understand due to a “lack of expression” or “masked face”.

Clinical Implications

The present findings have implications for clinical practice, including assessment and management of intelligibility impairment in speakers with Parkinson disease. As suggested by Kent (1994), each speaker has a range of potential intelligibility that is influenced by factors related to the speaker, listener, and conditions in which the communication takes place. In everyday communication situations, visual cues are commonly available to listeners; therefore, in order to assess a client’s functional intelligibility, it is relevant to include visual information. This study strongly suggests that clinicians should consider assessing intelligibility in speakers with Parkinson disease both with and without visual information. This type of assessment would allow clinicians to obtain an accurate view of the speaker’s real-life communication abilities.

Assessment of intelligibility in both AO and AV modes can allow clinicians to determine management strategies to most effectively assist dysarthric speakers in being understood. If it is determined that visual information is beneficial to a particular speaker, management could be planned to ensure that listeners are provided with visual cues associated with speech production. On the other hand, if visual information is found to hinder speech intelligibility, management strategies might be implemented to provide a focus on the auditory information, without allowing for interference from visual cues.

Future Directions

This study demonstrated that visual information benefits the intelligibility of speakers with Parkinson disease. However, these results cannot be generalized to all dysarthric speakers. Although the speakers in this study were judged to have similar perceptual characteristics, the level of intelligibility impairment varied. Each speaker has individual speech patterns which are affected by their motor speech disorder, their personal speech style prior to the onset of Parkinson disease, as well as the compensations they might be making in order to be better understood. The influence of visual information on intelligibility in other types of dysarthria and varying severity levels are important areas for future investigation. Specifically, investigation aimed at clearly defining different levels of intelligibility impairment will be beneficial in determining whether all speakers with dysarthria benefit from the inclusion of visual information.

Given the finding in the present study that the intelligibility scores of some speakers increased when visual information was included, it is relevant to examine what visual cues are being attended to by listeners. The comments regarding individual speakers obtained from listeners in this study were limited but did indicate that listeners focused on both facial expressions and movements directly related to speech production. In contrast to the present study, there may be speakers with dysarthria whose visual movements negatively affect AV intelligibility scores. For example, studies conducted with speakers with bilateral facial paralysis secondary to Moebius Syndrome have demonstrated that listeners identify bilabial sounds with greater accuracy in AO modes

than in AV modes of presentation (DeFeo & Schaefer, 1983; Nelson & Hodge, 2000). In these speakers, it appears that the inclusion of visual information distracts listeners from the acoustic signal and may have a negative effect on their speech intelligibility.

Therefore, questions concerning what aspects of a speaker's movements and/or expressions may contribute to a listener's perception will be useful in determining the influence of visual cues with dysarthric speech and has implications for both assessment and management.

Perhaps there is no single intelligibility assessment that can be used across the spectrum of ages, abilities, and assessment needs in speakers with dysarthria, however factors present in real-life communication situations should be considered. Future development of clinical evaluation tools to assess intelligibility should include the option to utilize visual information provided by the speaker in addition to the acoustic information. This type of assessment would allow clinicians to capture the true nature of the intelligibility impairment as well as provide useful strategies for listeners.

APPENDIX A
Speaker Criteria

Speaker Criterion	Determinant	Rationale
Parkinson disease (PD) with associated dysarthria	Medical diagnosis (self report)	<p>Reduced vocal intensity affects the intelligibility of PD (Ramig, 1992)</p> <p>Inclusion of visual information was found to be beneficial to intelligibility, with more benefit as the signal was more compromised (Sumbly & Pollack, 1954; O'Neill, 1954)</p> <p>6 of 12 speakers with dysarthria who demonstrated benefit with the inclusion of visual information had PD (Barkmeier, 1988)</p> <p>Speech movements and their timing is accurate, although limited range of movement is noted (Duffy, 1995)</p>
	Self report	85% of PD diagnoses are made after the age of 50 (National Parkinson Foundation, 2003)
Impaired intelligibility at sentence level	Sentence Intelligibility Test score (Yorkston, et al, 1996)	Reduce the ceiling effects for speakers with high intelligibility
Perceptually similar speech characteristics	Descriptions made by master clinical listeners	Ensure homogeneity of perceptual characteristics of speakers
English as a primary language	Self report	Reduce the influence of language differences between both speakers and listeners
Normal to corrected-to normal vision	Self report	Speaker task involves reading word and sentence stimuli
Adequate hearing for speaking task (in at least one ear)	Hearing screening 40 dBHL at 500, 1,000 & 2,000 Hz	This threshold is considered normal for individuals over the age of 50 (Morrell, Gordon-Salant, Pearson, Brant, & Fozard, 1996)
No facial deformities No facial hair judged by the experimenter to inhibit the availability of visual speech cues	Experimenter observation	Reduce interference with listeners' ability to perceive the visual aspects of speech

APPENDIX B
Listener Selection Criteria

Listener Criterion	Determinant	Rationale
Inexperienced Listener	Self report	Inexperienced Listener - 1) have no prior experience evaluating and/or treating speakers with dysarthria, 2) have no coursework in motor speech disorders, 3) have not had regular (daily or weekly) communication with a speaker with dysarthria, 4) have no prior communication with the speakers in the study
Experienced Listener		Experienced Listener – 1) ASHA certified SLPs who 2) report currently working with speakers with dysarthria with more than 6 months experience with this population, and 3) have no prior communication with the speakers in the study, and 4) no specific knowledge of the study
Over 18 years of age	Self report	Human subject consent – age of adult participants
English as the primary language	Self report	Reduce the influence of language differences between both speakers and listeners
Normal or corrected-to-normal vision	Self report	Ability to read directions and complete transcription task
Adequate hearing for listening task (in both ears)	Hearing screening 25 dBHL at 500, 1,000, 2,000, 4,000 & 6,000Hz	ASHA Guidelines The frequencies of 500 and 6,000 Hz were added to provide more strict criteria as listeners will rely heavily on auditory perception during the listening task. American-Speech-Language-Hearing Association Panel on Audiologic Assessment (1997). Guidelines for Audiological Screening. Rockville, MD

APPENDIX C
Speaker Information Form

Date _____

Age _____

Subject number _____

1. Has a physician diagnosed you with Parkinson disease?
2. Do you have normal or corrected to normal vision?
3. What is the primary language that you speak?
4. Do you have any other major health problems?
5. Do you have or have you ever had any speech problems other than those associated with your Parkinson disease?
6. Are you able to read large print?
7. What is your medication schedule?

General availability and optimal recording times

	M	T	W	Th	F	S	S
Morning							
Afternoon							
Evening							

Right Ear

Freq (Hz)	500	1,000	2,000
40 dB			

Left Ear

Freq (Hz)	500	1,000	2,000
40 dB			

SIT – Single Word Intelligibility Score: _____%

APPENDIX D
Recording Session Protocol

RECORDING SESSION PROTOCOL

Speaker Code: _____

Date of Recording: _____

Time of Day: _____

Last Medication: _____

Next Medication: _____

Human Subjects Form: _____

Set-up:

_____ Sound level meter

_____ SLM extension cord

_____ DAT recorder

_____ DAT microphone - lapel mic – measure mouth to mic distance
keep constant distance

_____ DAT tapes

_____ Video camera

_____ Video tripod

_____ Videotapes

Place tripod on tape marks on floor. Adjust for height of speaker only by raising tripod platform.

APPENDIX D (continued)

Video camera – set on camera, auto focus Video lapel mic/extension from camera to speaker. Placement: _____

Video cam connected to TV for monitoring of picture – TURN OFF when recording.

_____ Video mic/extension

_____ TV

_____ Tape measure

_____ Black cape and clip

_____ Taupe sheet/clips

_____ Power strip

_____ Lamps – place on sides of, shades on, with both poles facing away from speaker

_____ Music Stand

_____ Speech stimuli (words/sentences from SPIN)

Calibration: _____ dB SPL

Recording:

In the booth:

Lapel mic – on with correct placement _____

Video camera – on _____

(record – be sure numbers are counting and red light is on

be sure that camera is grounded with wire connected to camera into 3rd hole of outlet

Monitor TV screen for speaker position, mic placements

Always start by stating out loud on all tapes – 1. date, 2. time, and 3. subject code

APPENDIX E
IHR Sentence Stimuli for Speaker Recording Task
(MacLeod, A, & Summerfield, Q., 1990)

List 2

1. He tore his shirt.
2. They finished the jigsaw.
3. She brought her camera.
4. The lady watered her plants.
5. The salt cellar's full.
6. The boy hit his thumb.
7. The mother shook her head.
8. The snow lay on the hills.
9. The father used a towel.
10. The tree was in the back garden.
11. The yacht sailed past.
12. The lady pushed the pram.
13. They're leaving today.
14. The picture hung on the wall.
15. The children sit under the tree.

List 4

1. The old clothes were dirty.
2. He carried a stick.
3. She read her book.
4. The new house was empty.
5. The thief brought a ladder.
6. The horse stands by the gate.
7. They're heading for the park.
8. The gardener trimmed the hedge.
9. They're standing up.
10. Someone's hiding in the bushes.
11. The waiter lit the candles.
12. The baker iced the cake.
13. The woman slipped on the ice.
14. The small puppy was scared.
15. The lady changed her mind.

List 3

1. The lunch was very early.
2. The dirty boy is washing.
3. He hid his money.
4. The curtains were too short.
5. The knife cut the cake.
6. They emptied their pockets.
7. The new shoes were tight.
8. The coat hangs in the cupboard.
9. The sun shone through the clouds.
10. She took her purse.
11. The team lost the match.
12. The shirt caught on a nail.
13. They picked some raspberries.
14. The man climbed the mountain.
15. The lady hurt her arm.

List 5

1. The daughter closed the box.
2. They broke into the safe.
3. The doctor carries a bag.
4. The new game was silly.
5. The little boy was tired.
6. They saw the sign.
7. She's wrapping the parcel.
8. The children laughed at the clown.
9. The apple pie was hot.
10. The ship sailed up the river.
11. The house has a lovely garden.
12. The noisy dog is barking.
13. They bought some tickets.
14. The man goes to the bank.
15. The nurse helped the child.

APPENDIX E (continued)
IHR Sentence Stimuli for Speaker Recording Task
(MacLeod, A, & Summerfield, Q., 1990)

List 6

1. The girl knew the story.
2. He reached for a cup.
3. The lady was quite cross.
4. The rope was too short.
5. She's listening to the radio.
6. The husband cleaned the car.
7. The postman leaned on the fence.
8. The china vase was broken.
9. The other team won.
10. They locked the safe.
11. The leaves dropped from the trees.
12. The men watched the race.
13. The bird's building a nest.
14. The woman called her dog.
15. They're waving at the train.

List 7

1. The cat scratched the chair.
2. She tapped at the window.
3. The man painted the gate.
4. He slid on the floor.
5. They're lifting the box.
6. The woman listened to her friend.
7. The driver hooted his horn.
8. The cake tasted nice.
9. The sailor stood on the deck.
10. The young girls were pretty.
11. They painted the ceiling.
12. The back door was shut.
13. The tree lost its leaves.
14. The boy eats with his fork.
15. The young mother's shopping.

List 8

1. The girl sharpened her pencil.
2. She closed her eyes.
3. The plant grows on the wall.
4. The puppy licked his master.
5. The family's having a picnic.
6. The train arrived on time.
7. They won the game.
8. The lady waited for her husband.
9. The post office was near.
10. They rowed the boat.
11. The old fox was sly.
12. The baby lost his rattle.
13. He dug with his spade.
14. The boiled egg was soft.
15. The two ladies were watching.

List 10

1. She sings in the bath.
2. The meat was too tough.
3. The child ate some jam.
4. They're stealing the apples.
5. The children dried the dishes.
6. The paper boy was cheeky.
7. The little car was slow.
8. The bath tubs are dripping.
9. They came at Easter.
10. He's wearing a tie.
11. The new towel was clean.
12. The water poured from a jug.
13. The red apples were in a bowl.
14. The bus stopped at the shops.
15. The man drew with a pencil.

APPENDIX F

Instructions for listening trials

AO listener instructions:

You are going to hear speakers saying sentences. You are to listen carefully and then write down what you think the person said. Please watch the screen while you are listening to the speaker's voice. After each sentence, you will have time to write down what you thought the person said as accurately as possible. You can take as much time as you need to write it down. If you do not understand what the speaker says, please take your best guess and write down whatever you think you understood. The sentences the speakers say may not make sense to you but please write down exactly what you hear each speaker say.

AV listener instructions:

You are going to see and hear speakers saying sentences. You are to watch and listen carefully and then write down what you think the person said. Please watch the speaker while you are listening to his or her voice. After each sentence, you will have time to write down what you thought the person said as accurately as possible. You can take as much time as you need to write it down. If you do not understand what the speaker says, please take your best guess and write down whatever you think you understood. The sentences the speakers say may not make sense to you but please write down exactly what you hear each speaker say.

APPENDIX G
Inexperienced Listener Screening Form

Date: _____

Subject Number: _____

Age: _____

1. Do you have normal or corrected to normal vision?

2. What is the primary language that you speak?

3. Do you have experience evaluating or treating speakers with speech disorders?

4. Have you had coursework in motor speech disorders?

5. Have you spent much time communicating with someone with a speech disorder?
Describe.

6. Do you know anyone with Parkinson disease, Lou Gehrig's disease, multiple sclerosis, cerebral palsy?

Right Ear

Freq (Hz)	500	1,000	2,000	4,000	6,000
25 dB					

Left Ear

Freq (Hz)	500	1,000	2,000	4,000	6,000
25dB					

Comments:

APPENDIX H

Experienced Listener Screening Form

Date: _____
 Subject Number: _____
 Age: _____

1. Do you have normal or corrected to normal vision?

2. What is the primary language that you speak?

3. Do you have current ASHA certification in speech-language pathology?

3. Do you have more than 6 months of current experience evaluating or treating speakers with dysarthria?

Right Ear

Freq (Hz)	500	1,000	2,000	4,000	6,000
25 dB					

Left Ear

Freq (Hz)	500	1,000	2,000	4,000	6,000
25dB					

Comments:

APPENDIX I

Raw Data

Week1	Listener Group	Listener Number	Speaker Code	% Intell AO	% Intell AV
AO	I	1	A	96	97
AO	I	1	B	92	99
AO	I	1	C	73	77
AO	I	1	D	26	49
AO	I	1	E	99	96
AO	I	1	F	95	97
AO	I	1	G	51	84
AO	I	1	H	36	85
AO	I	2	A	93	93
AO	I	2	B	72	99
AO	I	2	C	56	57
AO	I	2	D	12	55
AO	I	2	E	86	89
AO	I	2	F	82	100
AO	I	2	G	40	76
AO	I	2	H	34	68
AV	I	3	A	97	97
AV	I	3	B	95	100
AV	I	3	C	82	73
AV	I	3	D	52	64
AV	I	3	E	89	93
AV	I	3	F	91	95
AV	I	3	G	56	64
AV	I	3	H	89	66
AV	I	4	A	94	96
AV	I	4	B	100	85
AV	I	4	C	77	50
AV	I	4	D	43	46
AV	I	4	E	95	88
AV	I	4	F	86	91
AV	I	4	G	34	57
AV	I	4	H	39	67
AO	I	5	A	78	97
AO	I	5	B	92	100
AO	I	5	C	66	60
AO	I	5	D	15	57
AO	I	5	E	92	97
AO	I	5	F	86	93
AO	I	5	G	61	62
AO	I	5	H	31	65

APPENDIX I (continued)

Week1	Listener Group	Raw Data		% Intell AO	% Intell AV
		Listener Number	Speaker Code		
AO	I	6	A	82	92
AO	I	6	B	85	97
AO	I	6	C	34	71
AO	I	6	D	35	53
AO	I	6	E	76	78
AO	I	6	F	81	91
AO	I	6	G	58	55
AO	I	6	H	26	65
AV	I	7	A	95	90
AV	I	7	B	88	93
AV	I	7	C	66	78
AV	I	7	D	33	30
AV	I	7	E	90	82
AV	I	7	F	86	88
AV	I	7	G	72	64
AV	I	7	H	70	35
AO	I	8	A	100	99
AO	I	8	B	95	97
AO	I	8	C	74	57
AO	I	8	D	22	50
AO	I	8	E	77	96
AO	I	8	F	92	89
AO	I	8	G	44	70
AO	I	8	H	28	73
AV	I	9	A	99	100
AV	I	9	B	97	100
AV	I	9	C	36	55
AV	I	9	D	29	57
AV	I	9	E	73	95
AV	I	9	F	85	96
AV	I	9	G	26	74
AV	I	9	H	49	81
AV	I	10	A	83	93
AV	I	10	B	92	95
AV	I	10	C	86	69
AV	I	10	D	62	40
AV	I	10	E	93	100
AV	I	10	F	95	97
AV	I	10	G	59	88
AV	I	10	H	62	70

APPENDIX I (continued)

Raw Data

Week1	Listener Group	Listener Number	Speaker Code	% Intell AO	% Intell AV
AV	E	11	A	100	97
AV	E	11	B	100	100
AV	E	11	C	65	81
AV	E	11	D	51	68
AV	E	11	E	97	97
AV	E	11	F	95	98
AV	E	11	G	82	66
AV	E	11	H	80	66
AV	E	12	A	90	94
AV	E	12	B	86	88
AV	E	12	C	73	55
AV	E	12	D	38	30
AV	E	12	E	81	95
AV	E	12	F	97	99
AV	E	12	G	29	54
AV	E	12	H	32	35
AO	E	13	A	99	96
AO	E	13	B	96	100
AO	E	13	C	77	80
AO	E	13	D	68	75
AO	E	13	E	88	99
AO	E	13	F	92	91
AO	E	13	G	84	73
AO	E	13	H	84	84
AV	E	14	A	100	100
AV	E	14	B	99	97
AV	E	14	C	68	88
AV	E	14	D	64	66
AV	E	14	E	94	95
AV	E	14	F	92	99
AV	E	14	G	70	85
AV	E	14	H	62	76
AV	E	15	A	96	100
AV	E	15	B	91	96
AV	E	15	C	68	45
AV	E	15	D	28	75
AV	E	15	E	76	92
AV	E	15	F	93	99
AV	E	15	G	15	76
AV	E	15	H	47	57

APPENDIX I (continued)

Raw Data

Week1	Listener Group	Listener Number	Speaker Code	% Intell AO	% Intell AV
AO	E	16	A	77	95
AO	E	16	B	70	99
AO	E	16	C	47	83
AO	E	16	D	42	74
AO	E	16	E	89	97
AO	E	16	F	74	96
AO	E	16	G	57	82
AO	E	16	H	38	60
AO	E	17	A	85	95
AO	E	17	B	80	97
AO	E	17	C	36	74
AO	E	17	D	33	37
AO	E	17	E	92	92
AO	E	17	F	78	86
AO	E	17	G	45	64
AO	E	17	H	27	79
AV	E	18	A	99	97
AV	E	18	B	99	92
AV	E	18	C	79	73
AV	E	18	D	45	59
AV	E	18	E	77	88
AV	E	18	F	88	93
AV	E	18	G	61	79
AV	E	18	H	68	72
AO	E	19	A	91	99
AO	E	19	B	96	100
AO	E	19	C	83	84
AO	E	19	D	49	59
AO	E	19	E	95	95
AO	E	19	F	97	100
AO	E	19	G	74	93
AO	E	19	H	49	65
AO	E	20	A	94	100
AO	E	20	B	92	100
AO	E	20	C	76	77
AO	E	20	D	60	58
AO	E	20	E	93	95
AO	E	20	F	85	95
AO	E	20	G	30	92
AO	E	20	H	62	69

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