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The Production of Emotional Prosdy in Varying Severities of Apraxia of Speech

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THE PRODUCTION OF EMOTIONAL PROSODY IN VARYING SEVERITIES OF APRAXIA OF SPEECH

By

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An Abstract of the Thesis Presented
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One mild AOS, one moderate AOS and one control speaker were asked to produce utterances with different emotional intent. In Experiment 1, the three subjects were asked to produce sentences with a happy, sad, or neutral intent through a repetition task. In Experiment 2, the three subjects were asked to produce sentences with either a happy or sad intent through a picture elicitation task. Paired t-tests comparing data from the acoustic analyses of each subject's utterances revealed significant differences between FO, duration, and intensity characteristics between the happy and sad sentences of the control speaker. There were no significant differences in the acoustic characteristics of the productions of the AOS speakers suggesting that the AOS subjects were unable to volitionally produce acoustic parameters that help convey emotion.

Two more experiments were designed to determine if naïve listeners could hear the acoustic cues to signal emotion in all three speakers. In Experiment 3, naïve listeners were asked to identify the sentences produced in Experiment 1 as happy, sad, or neutral. In Experiment 4, naïve listeners were asked to identify the sentences produced in Experiment 2 as either happy or sad. Chi-square findings revealed that

the naïve listeners were able to identify the emotional differences of the control speaker and the correct identification was not by chance. The naïve listeners could not distinguish between the emotional utterances of the mild or moderate AOS speakers. Higher percentages of correct identification in certain sentences over others were artifacts attributed to either chance (the naïve listeners were guessing) or a response strategy (when in doubt, the naïve listeners chose neutral or sad). The findings from Exp. 3 & 4 corroborate the acoustic findings from Exp. 1 & 2.

In addition to the 4 structured experiments, spontaneous samples of happy, sad, and neutral utterances were collected and compared to those sentences produced in Experiments 1 & 2. Comparisons between the elicited and spontaneous sentences indicated that the moderate AOS subject was able to produce variations of FO and duration similar to those variations that would be produced by normal speakers conveying emotion (Banse & Scherer, 1996; Lieberman & Michaels, 1962; Scherer, 1988). The mild AOS subject was unable to produce prosodic differences between happy and sad emotion.

This study found that although these AOS subjects were unable to produce acoustic parameters during elicited speech that signal emotion, they were able to produce some more variation in the acoustic properties of FO and duration, especially in the moderate AOS speaker. However, any meaningful variation pattern that would convey emotion (such as seen in the control subject) were not found. These findings suggest that the AOS subjects probably convey emotion non-verbally (e.g., facial expression, muscle tension, body language).

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INTRODUCTION

Apraxia of speech (AOS) is a motor deficit caused by a lesion to the brain that is usually located in the area of the primary or pre-motor strip of the left frontal lobe. Because of the location of the motor strip, apraxia of speech is often accompanied by a Broca's aphasia and/or dysarthria (Duffy, 1995). Apraxia of speech disturbs the volitional control of articulation and the prosody of one's speech. These disturbances do not result from a muscular weakness or slowness but rather from a problem with motor programming and sequencing of the articulators. Individuals with apraxia of speech are aware of their speaking difficulties and can appear to become easily frustrated when their verbal productions are not correct.

Depending on the severity of the AOS, individuals will demonstrate varying degrees of difficulty with articulation and prosody. Although their overall intelligibility is good, individuals with mild to moderate apraxia of speech demonstrate articulatory and prosodic deviations in their speech (Wertz, La Pointe, & Rosenbek, 1984). Research on the acoustic patterns of the prosody of several individuals with mild to moderate apraxia of speech has shown a slowed speaking rate resulting from a slowing of the articulators on mono- and poly-syllabic words (Kent & Rosenbek, 1983). This same study found a general flattening of intensity across syllabic sequences and sentence terminal fall of the fundamental frequency (FO), a pattern that is consistent with that of normal speakers. Individuals with severe to profound apraxia of speech demonstrate unintelligible speech, many times consisting of strings of nonsense-sounding syllables (Duffy, 1995). There is limited research that has addressed the acoustic patterns of suprasegmental characteristics of speech that convey emotion in individuals with severe to profound AOS (the majority of the research in this area has been done with mild-moderately severe AOS). Clinician observation and anecdotal evidence suggest that emotional content in the unintelligible utterances can be understood. These observations imply that some suprasegmental characteristics must be retained in the utterances of AOS speakers.

The purpose of this study is to determine if the acoustic characteristics of the prosodic structure that convey emotion are retained in the verbal expression of individuals with varying degrees in severity of AOS, thus enabling naive listeners to interpret this aspect of meaning.

REVIEW OF THE LITERATURE

Prosody

Vocal expression is one of several modes through which emotion is portrayed (Scherer, 1988). Research has shown that individuals produce standard configurations of acoustic attributes in expressing particular emotions (e.g., Bachorowski & Owren, 1995; Banse & Scherer, 1996; Cosmides, 1983). These acoustic dimensions, characterized by variations in frequency, duration, and intensity, are referred to as prosody or the prosodic features of speech.

Acoustic Dimensions

Frequency

Prosodic features of speech refer to variations in three acoustic properties of the speech waveform: frequency, duration, and intensity. These three variations in the speech waveform correspond to the perceptual correlates of stress, rhythm, and intonation. Frequency refers to one complete sound cycle per unit of time of a complex sound wave (Ladefoged, 1993). Frequency is measured in hertz (Hz), a term that denotes one complete cycle of vibration per second. This cycle of vibration is directly correlated to one complete opening and closing movement of the vocal folds.

The fundamental frequency is the lowest and most powerful component frequency of a complex sound found in one's voice and is often referred to as one's pitch (Fucci & Lass, 1999). The vocal tract configuration shapes the source spectrum into formant frequencies that are harmonics of the FO. These formants are determined by the resonance of the vocal tract and are a feature of the resonating cavities lying above the vocal folds. The quality of vowels in speech are dependent on the formants determined by the configuration of the vocal tract (Ladefoged, 1993). The pitch comprises the intonation contour of the prosodic structure in conveying linguistic and paralinguistic (including emotional) meaning (Bachorowski & Owren, 1995).

Duration

Duration refers to the relationships of timing of sounds resulting from discrete movements/changes of the articulators (Fucci & Lass, 1999). Duration is a measurement taken over time and is recorded in milliseconds (msec). A common term in discussions of temporal duration, voice onset time (VOT), is an acoustic index of the phase relation between the lowering gesture of the tongue or jaw during oral closure release for the consonant and the vocal fold adduction and elevation required for the production of the subsequent vowel. If the onset of voicing precedes the articulatory event, the sound is said to be prevoiced or to have a voicing lead. Onset voicing that follows the articulatory event results in a sound that is said to have a voicing lag. Voicing leads result in a negative value of VOT, while voicing lags have a positive VOT (Ingram, 1989).

Intensity

According to Fucci and Lass (1999), intensity is directly related to the degree of opening or amplitude, created between the vocal folds during phonation. The greater the distance between the vocal folds during each cycle of vibration, the greater the speaker's vocal intensity and perceived loudness. Intensity is measured by a logarithmic unit, the decibel (dB).

Perceptual Correlates of Prosody

The acoustic dimensions of FO, duration, and intensity correspond to the perceptual characteristics of stress, rhythm, and intonation.

Stress

A syllable with an increased FO, intensity, and/or duration as compared to adjacent syllables, is perceived as "stressed." A listener typically perceives a stressed syllable as being more prominent. Additionally, a stressed syllable contains a full vowel. An unstressed syllable typically contains a reduced vowel in most situations. Clark and Yallop (1990) state that the syllabic variations of suprasegmental features are the most basic level of prosody. In the English language, four degrees of stress are used: primary, secondary, tertiary, and weak. Listeners segment words on the basis of the strength of the syllables and use stress to determine the meaning of a word or sentence (Taft, 1984).

Stressed syllables within some segmentally identical words play a role in their grammatical assignment, phrase boundary, semantic interpretation, and syntactic parsing (Butterfield & Cutler, 1988; Emmorey, 1987; Nakatani & Schaffer, 1978; Streeter, 1978). Depending on whether the primary stress is placed on the first or second syllable of a disyllabic noun or verb, the perception of the stressed syllable would assign the grammatical category of a noun or verb (Emmorey, 1987). For example, primary stress placed on the first syllable would be perceived as the noun "PROduce," but stress placed on the second syllable would be perceived as the verb "proDUCE." Nakatani and Schaffer (1978) found that listeners use their perception of stress placement to determine a monosyllabic adjective and a disyllabic noun combination vs. a disyllabic adjective and a monosyllabic noun combination.

Rhythm

The rhythm of a language is defined by the strong beats occurring simultaneously as the syllables of words (Clark & Yallop, 1990). Normal rhythm is such that there is an alignment of the syllables with a tendency toward isochrony of stressed syllables and unstressed syllables. English is a normal rhythmic language (Couper-Kuhlen, 1986).

Intonation

Intonation corresponds to variations (rise/fall) in the FO of vowels within syllables conveying prominence of that individual word within a sentence (Ladefoged, 1993). A prominent syllable is accented (Bolinger, 1986). An accented syllable simultaneously signals an accent on that syllable and contributes to the intonation contour of the utterance (Bolinger, 1986). The resulting intonation contour is referred to as the "speech melody" of the utterance (Couper-Kuhlen, 1986).

The intonation contour may play a linguistic role in marking the internal organization of a sentence, e.g., syntactic constituents (Cooper, Paccia, & Lapointe, 1978). In a broader sense, the intonation contour may convey the intention of the speaker. In American English, intonation is often used to signal a declarative statement by an end-of-sentence rise-fall of the intonation contour, while questions are often characterized by an end-of-sentence pitch-rise of the intonation contour (Couper-Kuhlen, 1986).

The Role of Prosody in Pragmatics

Extensive research has found that prosody is used to convey both linguistic and nonlinguistic (paralinguistic) information within different contexts (e.g., Cooper et al., 1978; Scherer, 1986, 1988). The study of the relationships between language and the contexts in which language is used is referred to as pragmatics (Davis & Wilcox, 1985). Pragmatics includes the use of verbal and nonverbal skills in combination with one another. Nonverbal communication enhances the understanding of indirect requests, metaphors, idioms, speech acts, presupposition and inference, discourse operations, and social roles. Many nonverbal communicative acts are conveyed through prosodic features. For example, the use of a specific tone of voice for indirectly conveying negative emotion may be more socially appropriate than a blunt verbal expression of the same feelings (Mehrabian, 1972). Cues conveyed through tone of voice have been found to be more important than lexical content or word meaning for perceiving communicative intent and for interpreting meaning (Tompkins & Mateer, 1985).

Theories

Several researchers have developed different frameworks used to describe pragmatics. For example, Searle (1970) established a framework of pragmatics referred to as conversational speech acts. Speech acts are the social functions performed by sentences involving the role of both the speaker and listener. Searle believes that speech acts, not sentence form or sentence meaning, are the basic unit of communication. Speech acts are divided into two different categories of illocutionary acts (the intentions of the speaker) and perlocutionary acts (the effects the illocutionary act has on the listener).

According to Prutting and Kirchner (1983), pragmatic context refers to the physical and social situation of participants in a conversation, as well as their knowledge and point of view. Prutting and Kirchner expand pragmatic abilities into three different behaviors: utterance act, propositional act, and illocutionary and perlocutionary acts. The utterance act assesses the way the function of speech is being accomplished or presented and includes the paralinguistic, verbal, and nonverbal aspects of speech. The propositional act consists of linguistic dimensions of the meaning of the sentence and plays a role in providing information for both the speaker and the listener. The illocutionary and perlocutionary acts are the shared dyadic behaviors utilized by the discourse partners (each act as defined by Searle, 1970).

Davis and Wilcox (1985) alternately use a framework for assessing pragmatics by dividing speech into three different contexts: linguistic, paralinguistic, and extralinguistic. These three different contexts determine the social appropriateness of language use and contribute to processing time and meaning of an utterance (Davis, 1985). Because Davis and Wilcox (1981, 1985) have focused much of their attention on the pragmatic abilities of aphasic individuals, this model's applicability in addressing the role of prosody in pragmatics in brain damaged populations has prompted a closer look. Three different levels (linguistic, paralinguistic, and extralinguistic) will be discussed.

Contexts

Linguistic

According to Davis and Wilcox (1985), linguistic context refers to the verbal behaviors that occur within and between linguistic units. This context includes the intrasentential context level (i.e., the relationship of words within a sentence) and the intersentential context level (i.e., the relationships between sentences). For example, one linguistic context frequently studied in children is that of story telling and discourse. During story telling, a child's linguistic context is assessed in his/her ability to tell a sequential story, demonstrate cohesiveness, and correctly use different parts of a story (e.g., characters, setting, event) correctly. Prosody assists in the semantic interpretation of sentences by denoting lexical stress (Cooper et al., 1978), emphatic stress (Scherer, 1986), and syntactic constituents (Nakatani & Schaffer, 1978).

Paralinguistic

The paralinguistic context accompanies an utterance and its linguistic context (Davis, 1985). Characteristics of the paralinguistic context include the suprasegmental features of stress, rhythm, and intonation along with the rate of speech. These paralinguistic conventions may express the speaker's emotional state, identify new information, and signal word or phrase meaning that focuses the listener on the information being presented, and help the listener form judgments about personality traits, such as emotional stability, introversion, and extroversion. Murray and Arnott (1999) suggest that the primary function of emotion in communication is the encoding and decoding of intentions. An individual's emotional state may be conveyed intentionally or unintentionally through the three levels of speech abstraction: suprasegmental, segmental, and intrasegmental (Murray & Arnott, 1999). The suprasegmental level, where the prosodic features of speech are contained, is an area of interest for many researchers (e.g., Davis, 1985; Hess, Scherer & Kappas, 1988; Scherer, 1986). Prosodic features may alter the meaning of an utterance by revealing the speaker's feelings or attitudes in a manner that phonetic features alone cannot achieve (Fucci & Lass, 1999). The acoustic properties of speech provide external cues about the internal emotional processes that are trying to be conveyed. This phenomenon is called "vocal expression of emotion." This correlation between prosodic characteristics and the expression of emotional content has enabled researchers to be quite accurate when decoding emotional meaning from vocal cues (Scherer, 1986; 1988).

Many studies have shown a direct relationship between prosodic features of FO, duration, and intensity, and the perception/production of emotion (e.g., Bachorowski & Owen, 1995; Banse & Scherer, 1996; Hess et al., 1988; Lieberman & Michaels, 1962; Scherer, 1986, 1988). In one study, Lieberman and Michaels (1962) addressed the contributions of the FO and amplitude to the paralinguistic intent of the utterance, including emotion. Six male speakers were given semantically neutral sentences and told to say each of the sentences with a vocal modification belonging to one of the following categories: a bored statement, a confidential communication, a question expressing disbelief or doubt, a message expressing fear, a message expressing happiness, an objective question, an objective statement, and a pompous statement. Each sentence was produced three times in each category. The sentences were recorded and the FO contour and intensity variability information was then extracted from each of the sentences. A fixed-vowel POVO–type synthesizer was used to extract the pitch information. The pitch perturbations were then smoothed out and the amplitude information was extracted. The sentences were made into 5 different tapes with varying acoustic information: original speech, perfect pitch with no amplitude modulation, perfect pitch with amplitude modulation, smoothed pitch with amplitude modulation, and amplitude modulation with constant pitch. Ten naïve listeners were asked to judge the correct intended category of each of the sentences. Results showed that when the original speech was presented, the naïve listeners identified the correct category with 85% accuracy. When the perfect pitch with no amplitude modulation tape was presented, the naïve listeners identified the correct category with 44% accuracy, and 47% accuracy when the perfect pitch with amplitude modulation was presented. However, there was little correct identification of emotion when only the FO contour was presented. In addition, intensity plays a small role (difference of 3%) in the interpretation of emotion. These findings suggest that the FO and intensity characteristics of prosodic structures must play a role in conveying paralinguistic intent.

Scherer (1986, 1988) has reviewed the literature and studied the acoustic parameters of mean FO and intensity that interact to produce a speaker's overall vocal quality (determined by the pattern of energy distribution in the spectrum). This interaction between the mean FO and intensity may be predictive of a specific emotional expression. For example, a downward intonation contour is often characteristic of the emotions of boredom or sadness (Scherer, 1988). In addition, a decrease in mean FO, standard deviation of FO, mean intensity, and increase in duration also signals sadness. An increased mean FO, standard deviation of FO, mean intensity, and a decreased duration often signals happiness.

Bachorowski and Owen (1995) conducted a study using male and female subjects with the intent to elicit positive and negative emotional responses to success ("Good job," with a schematic smiling face) and failure feedback ("Try Harder," with a corresponding picture of a frowning face) to decisions of whether two auditory signals presented in a pair were actual words. They then took a measure of the vocal expression of emotion of the subject's responses. An acoustic analysis of the FO, jitter, and shimmer perturbation of each speaker was obtained. Results showed that both positive and negative emotional states can be associated with an increase in FO and intensity variability. Females demonstrated greater variability in FO and intensity for positive feedback, whereas males demonstrated greatest variability for negative feedback.

Another study (Banse & Scherer, 1996) looked at emotions produced by actors portraying scenarios containing 12 different emotions. Portrayals were recorded, the sound recordings were digitized, and different parameters of frequency, intensity, and duration were analyzed. Twelve university students were presented with only an audio recording of each emotional portrayal and asked to identify which of the 12 emotions they perceived. Similar to the findings of Bachorowski and Owen (1995), results from the recognition experiment and acoustic analyses suggest that the mean and variability of the FO, duration, and intensity provide important information in differentiating different emotions. For example an increased mean FO, standard deviation of FO, mean energy, and decreased duration signal happiness. A decrease in mean FO, standard deviation of FO, and mean energy signal sadness. Banse and Scherer (1996) cautiously interpret these results as due to the possibility that the observed values may be more extreme than the predicted values because actors may have exaggerated the difference between the low- and high-intensity as a result of acting sympathetically aroused.

In addition to prosodic features, emotional information can also be conveyed through facial expression, gestures, and body positions within different situational contexts (Hess et al., 1988; Scherer, 1988). Visual cues, such as facial expressions, may play a more important role than vocal cues in encoding and decoding certain emotions (shame and disgust) based on a higher recognition rate in the audio-visual condition (Banse & Scherer, 1996), although not all emotions can be recognized equally well from facial expression (Hess et al., 1988). Hess et al. (1988) found that facial expression is an important source of information in a social context, and that both vocal and facial expressions affect the perception of emotions. Facial expressions that portray friendly or unfriendly expressions are often identified by one's smile or lack of smile (Hess et al., 1988). How much gestural information, such as facial and limb movements, contributes to the perception of emotional expression is an area that needs further research (Goldthwaite, 1997; Grant & Walden, 1996; Massaro, 1986).

Extralinguistic

Conversational participants, both speaker and listener, are very important aspects of pragmatics. Conversation is a cooperative endeavor in which each participant recognizes a common purpose or shares the direction of the conversation. Prior knowledge of the basic rules of speech and language, attitudes toward the topic being discussed and toward the speaker, and knowledge about the subject shared by either participant play major roles in the successful understanding of the conversation.

Extralinguistic contexts include the situation, conversational participants' status and roles, their world knowledge, and the participants themselves (Davis & Wilcox, 1985). Extralinguistic contexts exist outside of, or separate from, each utterance, and they are generally referred to as the "context." These contexts include the purpose, setting (or situation), and other aspects about the participants in the conversation.

The purpose and setting of an utterance varies from person to person and context to context. The purpose engages the listener's attention through avenues such as instructing, requesting information, and expressing feelings. The setting may influence a listener's interpretation of an utterance. For example, in the setting of one's home the phrase, "I need help" may mean something different than if one were inquiring directions in an airport. The phrase "I need help" contains more urgency in the latter situation because the person may be late or lost, instead of needing assistance carrying in groceries (as at home).

There are five different contexts that pertain to each participant (speaker and listener), and each must be taken into consideration in order to fully understand a given conversation: (a) the conceptual knowledge possessed by each participant, (b) the emotional state of each participant, (c) the role of each participant, (d) the physical orientation of participants to each other, and (e) the movements produced by each participant (Davis & Wilcox, 1986). As a result, some of the affective force of an utterance can be seen as a parallel channel of nonverbal cues that convey affect in a direct and independent way.

Prosodic Deficits in Brain-Damaged populations

As mentioned previously, prosody is an important aspect of pragmatics used to help convey linguistic and paralinguistic information in a communicative interaction. Brain damage may interfere with an individual's ability to convey linguistic or nonlinguistic information through prosody. Some research has proposed that right hemisphere damaged (RHD) individuals have more difficulty producing emotional prosody due to the structures responsible for emotion being located in the right hemisphere (e.g., Lalande, Braun, Charlebois, & Whitaker, 1992). Similarly, left hemisphere damaged (LHD) individuals should not have as much difficulty with emotional prosody as with linguistic prosody, due to the structures responsible for language being located in the left hemisphere (e.g., Perkins, Baran, & Gandour, 1996). However, other research indicates that the notion of hemispheric specialization for processing both linguistic and emotional prosodic structures continues to be a controversial subject (e.g., Pell & Baum, 1997a; Tompkins & Flowers, 1985). Research in the hemispheric specialization for producing linguistic and emotional prosodic structures produce more consistent results (e.g., Shapiro & Danley, 1985).

Left Hemisphere Damage vs. Right Hemisphere Damage

Left hemisphere damage usually results in an acquired language disorder, known as aphasia. Aphasia is a disturbance of the complex process of comprehending and formulating verbal messages and results from a newly acquired disease of the central nervous system (Damasio, 1998). Aphasia is a language disorder, not a speech disorder. A language disorder affects the process of formulating the message and the use of language (e.g., words, signs), whereas a speech disorder affects the act of executing an already formed verbal message (Damasio, 1998).

According to the Boston classification system (Goodglass & Kaplan, 1972), different types of aphasia are identified by the degree of impairment in three areas: verbal expression, repetition, and auditory comprehension. The area(s) of difficulty for an individual varies from person to person. For example, a patient with aphasia may have difficulty selecting the lexical and syntactic items necessary to convey meaning as well as using the selected items in a way that a listener can perceive the intended meaning.

Some researchers believe that hemispheric specialization is contingent upon the linguistic or paralinguistic functions of a prosodic structure. According to this view, left hemisphere damage may interfere with the ability to process and/or produce linguistic prosody (e.g., Perkins et al., 1996). Damage to the right hemisphere has many consequences including difficulties with processing and producing nonverbal information, understanding holistic representations of language (Grela & Gandour, 1999), and expressing emotional prosody (Gandour, Larsen, Dechongkit, Ponglorpisit, & Khunadorn, 1995; Pell & Baum, 1997a; Ross, Thompson, & Yenkosky, 1997; Tompkins & Flowers, 1985). Fischer, Alexander, Gabriel, Gould, and Milione (1991) remind researchers that there is ample evidence that the right hemisphere plays a specialized role in processing higher-order emotional information, integrating the overall perceptual configuration of visuo-spatial material, and maintaining and sustaining appropriate attention and concentration.

Another theory supports an interhemispheric relationship view based on the assumption that an interrelationship exists among cognitive functions, handedness, and the intrahemisphere localization of the function (Balan & Gandour, 1999; Fischer et al., 1991; Foldi, 1987; Gandour et al., 1995; and Van Lancker & Sidtis, 1992). According to this view, both cerebral hemispheres are somehow responsible, or integrated, for the control of different elements of speech (e.g., linguistic and emotional prosody).

Perceptual Deficits

Lexical Stress

Researchers have found that LHD patients have difficulty processing lexical stress differences, whereas RHD patients do not have the same difficulty (Behrens, 1987; Emmorey, 1987; Pell & Baum, 1997a). For example, Emmorey (1987) examined the ability of 15 LHD, 7 RHD, and 22 normal subjects to comprehend stress contrasts between noun compounds and noun phrases (e.g., greenhouse vs. green house). The subjects were presented with a stimulus word and were told to listen to how the word was said. The subjects were then asked to point to the correct picture of a picture pair representing a noun compound/adjective (e.g., darkroom/dark room) or noun/verb (e.g., CONvict/conVICT). Results revealed that the LHD subjects performed worse than their normal matches, but there was no significant difference between the RHD subjects and their normal matches. The researchers of this study conclude that comprehension of lexical/phrasal stress contrasts is preserved with damage to the right hemisphere but impaired with damage to the left hemisphere, implying a possible left hemisphere specialization for the perception of lexical stress.

Intonation

Intonation conveys both linguistic (e.g., syntactic constituents) and paralinguistic (e.g., emotion) information. Research addressing hemispheric specialization in processing and producing intonation contours is controversial. Baum, Pell, Leonard, and Gordon (1997) studied 10 LHD, 10 RHD, and 10 normal control subjects. Each subject was presented with a recording of the stimulus phrase "pink and black and green." After being presented with the stimulus phrase, each subject responded by pointing to a picture arrangement that matched the auditory stimuli. In one picture arrangement, the pink, black, and green squares were equally spaced. In the second arrangement, the pink and black squares were close together with the green one being further apart. The third arrangement displayed the pink square further apart from the black and green ones. The findings from this study revealed that both the LHD and RHD subjects performed significantly worse than the normal control subjects in the identification of phrasal groupings supporting the hypothesis of an interhemispheric relationship in the perception of intonation. These results are contradictory to other research findings (Perkins et al., 1996) that demonstrate impairments in the processing of intonation boundaries that correspond to syntactic constituents by LHD, but not RHD subjects.

As with perception of linguistic prosody, research findings about the perception of emotional prosody in LHD and RHD subjects as a localized function of one hemisphere continue to be controversial. Some research supports the hypothesis that RHD individuals have greater difficulty perceiving affective prosody than LHD individuals, therefore implying a right hemisphere function for the perception of emotion (Barrett, Crucian, Raymer, & Heilman, 1999; Bowers, Coslett, Bauer, Speedie, & Heilman, 1987; Lalande et al., 1992; Ross et al., 1997; Tompkins & Flowers, 1985). Other research findings suggest that there is no difference in the ability of LHD and RHD individuals to perceive emotional prosody, thus implying an interhemispheric relationship of function (Pell & Baum, 1997a; Schlanger, Schlanger, & Gerstman, 1976; VanLancker & Sidtis, 1992).

In a study by Tompkins and Flowers (1985), 33 subjects (11 each in LHD, RHD, and normal groups) were examined. The subjects participated in five different identification tasks: prosodic pattern discrimination, mood selection I, mood selection II, and two emotional concepts tasks. For the prosodic pattern discrimination task, each subject heard 50 pairs of low-pass filtered phrases. The subjects were asked to identify whether the two phrases were the "same" or "different" (as written on the index cards) by pointing to index cards. In the mood selection I task, each subject was presented with 40 unfiltered, semantically neutral phrases conveying one of four moods (happy, angry, afraid, and no emotion). Subjects were asked to identify the appropriate emotion, disregarding semantic content, by selecting the appropriate emotional label for each phrase. The subject was given two choices for each phrase. In the second task (mood selection II), the researchers presented the same 40 emotionally toned phrases from the previous task to each of the subjects. Each subject then was given the option of four alternative selections for each stimulus phrase instead of two selections as they were in mood selection I. Once again, the subjects were asked to identify the appropriate emotion based on tone, thus ignoring the sentence content. The final two tasks of emotional concepts were designed to rule out impaired access to emotional concepts and representations through having the subjects select emotion-word synonyms and match emotional labels to corresponding tape-recorded descriptions of situations. Results support the authors' hypotheses regarding differential hemispheric participation in processing emotional intonation: RHD subjects were more impaired than either LHD or normal subjects in all of the experiments.

Conversely, Van Lanker and Sidtis (1992) claim that prosodic processes are made up of multiple skills and functions distributed across cerebral systems. In their study, 24 LHD, 13 RHD, and 37 non-brain damaged control subjects listened to five sentence types containing emotionally neutral meaning, spoken by a professional actress using different prosodic variations to convey sad, angry, happy, or surprised emotional content. The subjects were presented with the written word for each emotion below the pictured face, and instructed to point to a line drawing of a happy, sad, angry, or surprised face. Results revealed that both the LHD and RHD groups performed at comparable levels on each of the tasks. Additional analyses were conducted to determine the principal acoustic cue used by each of the brain damaged groups used for identification of affective prosody. These additional analyses revealed that FO variability was the most significant cue. Researchers have yet to determine if it is the function of prosody (linguistic vs. paralinguistic) or the perception of individual acoustic cues (frequency, intensity, or duration) that determines hemispheric specialization in processing prosodic structures.

Production Deficits

Lexical Stress

Research addressing the production of linguistic prosody produced by brain damaged adults is as inconclusive as research on the perception of linguistic prosody in this population. Research has shown that RHD individuals do not demonstrate as much difficulty producing linguistic prosody at the lexical level as LHD individuals (Balan & Gandour, 1999; Behrens, 1988; Emmorey, 1987; Gandour, et al., 1988). In a previously mentioned study (Emmorey, 1988), the ability of 15 LHD (8 nonfluent, 7 fluent), 7 RHD, and 22 control subjects to produce stress contrasts between noun compounds and noun phrases (e.g., GREENhouse vs. greenHOUSE) was addressed. Each subject was asked to produce a noun compound and adjective noun sequence when presented with a picture with words written in large print identifying the carrier phrase to be used. Each subject's productions were then judged by 14 normal listeners to identify between compound nouns and noun phrases. Acoustic analyses were performed on both the FO and duration parameters of each subject's productions. Results indicated that the 14 normal listeners had more difficulty correctly identifying the productions of the LHD than the RHD group. Furthermore, the non-fluent LHD subjects never used pitch to distinguish noun compounds from phrases, and only two LHD subjects used duration. Results of the acoustic analysis of RHD subjects' productions revealed that all but one of the RHD subjects produced pitch and/or duration cues, a pattern similar to that of the control group. These results indicated that LHD subjects' ability to produce pitch and duration cues may be impaired at the lexical level.

Balan and Gandour (1999) found similar results when looking at the production of phonemic stress pairs produced by 8 LHD (non-fluent and fluent) and 8 RHD subjects. During the testing, subjects were presented with pictures and asked to produce the names of the pictured objects in either compound noun or noun phrase forms contained within a sentence. Each subject's productions were recorded and presented to listeners who were then asked to identify the productions as either a compound noun or noun phrase. Acoustic analyses of the mean FO, mean amplitude, vowel duration, and intersyllable pause duration were performed. Results indicated that the non-fluent LHD subjects performed at the lowest level of accuracy in signaling phonemic stress as compared to the fluent LHD and RHD subjects. Moreover, both experimental groups performed at a lower level than that of the normal group. Acoustic analyses of FO, duration, and intensity parameters revealed that pause duration between noun phrases was the strongest cue used to signal phonemic stress for all brain damaged subjects. The normal subjects used vowel duration and FO as the strongest and secondary cues when signaling phonemic stress. Emmory (1988) showed that only two out of 15 LHD subjects used duration to distinguish noun compounds from phrases; thus Balan and Gandour's findings that pause duration was the strongest cue used by fluent LHD subjects to signal phonemic stress is not necessarily consistent with other research.

Balan and Gandour found that RHD subjects preserve the ability to produce phonemic stress. Emmorey (1988) found that RHD subjects are able to signal phonemic stress when elicited in isolation, whereas Balan and Gandour (1999) found that RHD subjects demonstrated difficulty producing phonemic stress when elicited in a sentence. These contradictory findings may be related to the context in which the productions were elicited.

Intonation

The research of the production of intonation by brain damaged subjects also has revealed conflicting results. For example, Cooper, Soares, Nicol, Michelow & Goloski (1984) compared the abilities of nine subjects with brain damage (5 LHD, 4 RHD) and four normal control subjects to produce FO (peak) and duration cues (of the utterance-final word and of the entire utterance) in sentences influenced by clause and utterance length. They elicited sentences varying in length. In the first technique, sentence length was varied by manipulating the length of the clause by increasing the number of syllables within the clause but not increasing the number of words or by lengthening the sentence by increasing both the number of syllables and words. For example, (1a) Al wants peaches. (1b) Al wants to buy some peaches. (1c) Al wants to buy a three-pound box of peaches. The second technique clause sentences of varying length with the ordering of the clauses reversed. For example: (1) Mike typed and Bob talked. (2) Mike liked to type and Bob liked to talk. (3) Mike had just sat down to type and Bob was beginning to talk. All sentences were read aloud by each subject using each technique. Each subject's productions were recorded and analyzed for peak FO within the first and last stressed syllable of each sentence, and for the duration of both the entire sentence and final word of the sentence. Results indicate that LHD subjects produce greater abnormality when compared to the normal subjects' productions in both speech duration parameters and peak FO than RHD subjects. These findings indicate that the left hemisphere plays a greater role in the production of linguistic prosody that conveys emphatic stress at the intonational phrase level than the right hemisphere.

Other researchers have shown that both RHD and LHD individuals demonstrate difficulty producing prosody at the phrase and sentence level implying an interhemispheric relationship for the production of intonation (Baum et al., 1997; Behrens, 1989). Baum et al. (1997) studied the ability of 10 LHD, 10 RHD, and 10 control subjects to produce acoustic correlates of phrase boundaries. The stimulus phrase "pink and black and green" was elicited in three different conditions corresponding to three pictures of colored squares in particular groupings (e.g., "pink and black, and green" and "pink, and black and green"). Each production was recorded and digitized, word and pause durations were computed, and the FO contour was extracted from each utterance. In addition to the acoustic analysis, a perceptual analysis involving non-brain damaged listeners was conducted. The non-brain damaged individuals were asked to identify the different conditions of the stimulus phrase produced by the brain damaged individual by selecting the corresponding pictures of color groupings. Results indicated that LHD and RHD subjects provided fewer acoustic cues to phrase boundary distinctions as compared to the control subjects, thereby leading to a substantial reduction in the ability of listeners to perceive their intended meaning. These results support the hypothesis that both RHD and LHD subjects have difficulty producing linguistic prosody that denotes syntactic constituents.

Prosodic structures also convey emotion. Compared to research addressing linguistic prosody, research on hemispheric specialization for the production of paralinguistic prosody related to emotion is less controversial. In general, researchers have agreed that the right hemisphere is the primary location of the structures responsible for the production of affective prosody (e.g., Ross et al., 1997; Shapiro & Danly, 1985).

For example, Ross et al. (1997) studied the abilities of 10 LHD and 12 RHD subjects to repeat and comprehend affective prosody when the verbal-articulatory load of the stimulus sentences was gradually reduced. In the production experiments, subjects were asked to repeat words, syllables (e.g., BABA), and vocalizations (e.g., ah), using affective prosody (e.g., neutral, angry, happy, sad, surprised, and disinterested). Results indicated that when the verbal-articulatory load was reduced, the LHD group's ability in conveying affective prosody improved. The RHD group had difficulty conveying affective prosody regardless of condition. When asked to comprehend the affective prosody of stimuli when the verbal-articulatory load was reduced, the same pattern of results was revealed for both groups. These findings suggest that affective prosody is lateralized to the right hemisphere.

Weniger (1984) also found that the verbal complexities of sentences influence LHD subjects' abilities to produce emotional prosody. Weniger found that Broca's aphasics (anterior site of lesion) demonstrated a normal FO declination in the production of emotionally influenced phrases. However, when sentence complexity increased, little FO declination was observed. In addition, the more complex the syntactic structure, the more properties of emotional prosody that were impaired. Wernicke's aphasics (posterior lesion), however, were able to produce the emotional intonation contour under the condition of a more complex syntactic structure, although the sentences might be filled with neologisms and semantic and phonemic paraphasias.

Apraxia of Speech

Anatomy and Physiology of Speech Production

The production of speech involves an interactive participation between the motor programming system and higher level activities related to conceptualization and language. The motor programming system is often referred to as the motor speech programmer (MSP) (Darley, Arnson, & Brown, 1975). The MSP receives information from many structures in the brain including those responsible for sensory feedback and the right hemisphere. The highest level of speech programming (which includes the patterning and sequencing of movements) is located in the left hemisphere. LHD resulting in aphasia may co-occur with a motor speech disorder. To fully understand the capacities of LHD individuals with motor speech impairment formulation. The supplementary motor area and premotor areas are connected to the primary motor cortex, which is the focal point of the pyramidal tract for speech.

Damage to the structures of the motor system can result in a motor speech impairment due to weakness and poor coordination of the muscles themselves (dysarthria), or to the ability to select, program and move the speech musculature (apraxia of speech). Clinical evidence has indicated that it is possible to have impairment of the programming of motor speech (apraxia of speech) with no impairment of the functions of language (Aten, Johns, & Darley, 1972).

Definition

Apraxia of speech (AOS) is often defined as a neurogenic speech disorder resulting from impairment of the capacity of the MSP in positioning and movement of muscles for the volitional production of speech. Apraxia of speech can occur without significant weakness, or neuromuscular slowness, and in the absence of disturbances of conscious thought or language (Duffy, 1995). Apraxia of speech frequently results from middle cerebral artery infarcts of the left hemisphere and is often present with a Broca's aphasia (Rogers & Storkel, 1999, Ziegler & vonCramon, 1986). A middle cerebral artery infarct encompasses the location of the MSP and is frequently the common etiology of AOS. Damage to the MSP may result in planning and programming disorders that are not consistent with disorders of tone or reflexes. However, disorders at the planning or programming level of motor control could indicate strength, speed, range, accuracy, steadiness, and kinematic abnormalities if these discrete movement parameters were involved in the planning or programming deficit (McNeil, Robin, & Schmidt, 1997). In AOS, the access to, and/or storage of, motor patterns for speech are disrupted (Whiteside & Varley, 1998). Although the exact level of breakdown causing AOS is still unclear, the speech disturbances/ characteristics that result are very clear. Individuals with AOS have problems retrieving and developing an internal model or plan of the intended movement patterns of their articulators. Some researchers have even speculated that AOS is a disruption of the ability to access and encode both the grammatical and phonological information (Rogers, Redmond, & Alarcon, 1999). Other researchers have speculated that AOS is related to a reduced capacity to plan more than one syllable at a time (Rogers & Storkel, 1999). Volitional speech is more difficult than automatic speech for individuals with AOS (Odell, McNeil, Rosenbek, & Hunter, 1991). In addition, individuals with AOS are often aware of and able to predict their errors (Deal & Darley, 1972). One way to describe the difficulties demonstrated by AOS is to understand that due to the location of the brain damage, the once automatic functions of the speech articulators (moving while simultaneously thinking of the next thing to say) is no longer automatic; individuals with AOS must program their articulators for each aspect of speech production (Whiteside & Varley, 1998).

Segmental Characteristics

Darley et al. (1975) argue that the segmental characteristic features of AOS distinguish it from other communication problems and justify its being considered a separate entity, although AOS may co-exist with aphasia. General characteristics of AOS include: lexical stress level errors (Odell, McNeil, Rosenbek, & Hunter, 1991), articulatory difficulties (Deal & Darley, 1972; Rosenbek & LaPointe, 1981; Ziegler & vonCramon, 1986), greater difficulty with initiating speech than with continual speech (Rosenbek & LaPointe, 1981), poorer performance with an increase in complexity of word length than with simple word length (Deal & Darley, 1972), increased difficulty with initial phonemes (Aten et al., 1972), decreased vowel durations (Collins, Rosenbek, & Wertz, 1983), and poor co-articulation (Zielger & von Cramon, 1986).

During spontaneous speech, individuals with mild to moderate apraxia of speech demonstrate some articulatory and prosodic deviations, and verbal modifications in their speech, although their overall intelligibility is good. This overall good intelligibility allows the average naïve listener to understand them (Wertz, et al., 1991). Individuals with severe to profound apraxia of speech demonstrate greater degrees of difficulty with errors (evidenced by their high occurrence and predictability rate). These difficulties, often resulting in unintelligible speech, frequently consist of strings of nonsense syllables, possible mutism, and frequently accompanying oral and/or limb apraxia (Duffy, 1995).

In one study, Ziegler and von Cramon (1986) examined the timing of lingual movements relative to laryngeal, velar, and labial gestures in the speech production of apraxic individuals. Eight AOS and 12 non-brain damaged individuals participated as the subjects in three experiments. Each AOS subject had a co-existing aphasia. The first experiment addressed the temporal control of laryngeal and lingual gestures required in the production of voiceless lingual plosives (e.g., /t/ and /k/) in plosive-vowel sequences. Each subject was given a phonetic test consisting of tri-syllabic nonsense words with a specified vowel embedded within a sentence. Several repetitions were elicited from each subject. The subjects were also asked to produce a voiced/voiceless pair of words to assess the distinction between the alveolar stop cognates in the context of a high front and a high back vowel. The utterances were recorded and digitized. With the apraxic subjects, VOT (an acoustic index of the phase relation between the lowering gesture of the tongue during oral closure release for the consonant and the vocal fold adduction required for the production of the subsequent vowel) occurred later than in the normal group indicating a laryngeal delay in the AOS subjects.

The second experiment focused on difficulties of velar timing, more specifically on the inter-articulatory phasing (e.g., the relationship between the lowering of the tongue and closure of the velar port that is required in a transition from a lingual-nasal sound to a non-nasal sound). The six tri-syllabic nonsense words and carrier phrases from experiment one were used in the context of additional alveolar and velar nasals after both high and low vowels. Subjects repeated each test word twice. Results indicated that velar mistiming was a problem for the AOS subjects and that this mistiming may have caused the occurrence of both substitutions and additions.

The final experiment studied the interaction of lingual and labial movements with respect to the temporal aspects of speech. A co-articulation paradigm was used to assess the degree to which lip rounding gestures were anticipated. The tri-syllables of experiment one and two were used as test materials for this final experiment. Each subject was given two attempts to produce the stimulus through repetition of the examiner's model. Each subject's productions were recorded, digitized, and then analyzed phonetically. Analyses were performed on the burst release of the plosive

/t/ preceding the target vowels. Results indicated that anticipatory lip rounding of the AOS subjects failed to occur at the appropriate time for release of the plosive burst implying that disturbed co-articulation is a general problem in apraxia of speech.

Ziegler and von Cramon (1986) found premature elevation of the velum in the speech production of apraxic subjects. This velar mistiming may cause the occurrence of both substitutions and additions of phonemes through intended nasal consonants being perceived as an addition (e.g., /n/ as /nd/), or by substituting nasal sounds as oral sounds. Co-articulation errors may result in groping-like behavior that is characteristic of apraxic individuals when their attempts to find the correct articulatory posture and sequences are not successful at first (Kent & Rosenbek, 1982, 1983; McNeil et al., 1997; Odell et al., 1991; Ziegler & von Cramon, 1986). Darley et al. (1975) explained that the errors of speech recur but not always in the same manner; the errors on different trials prove to be highly variable. Some researchers believe that the characteristics of AOS are symptomatic of secondary compensatory strategies and not of the disorder itself (Kent & McNeil, 1987; Kent & Rosenbek, 1982; Whiteside & Varley, 1998). Individuals with AOS often recognize their articulatory errors. As mentioned in the definition of AOS, a prominent characteristic is increased difficulty with producing volitional-purposeful speech.

Suprasegmental Characteristics

Much of the research on AOS has addressed acoustic dimensions of speech production at the segmental level. Although less research has been done that addresses suprasegmental deficits of AOS, deficits associated with AOS that may negatively impact the stress, rhythm, and intonation of a sentence include increased word and vowel duration patterns (Collins et al., 1983); a general slowed rate of speaking with resulting prolongations of transitions and intersyllable pauses (Kent & Rosenbek, 1983); a limited variation in relative peak intensity across syllables resulting in abnormal stress and rhythm patterns (Kent & Rosenbek, 1983; Odell et al., 1991); and longer/shorter VOT errors depending on the length of the word (Collins et al., 1983).

Lexical stress was addressed by Odell et al. (1991) who studied 4 AOS subjects, 4 subjects with conduction aphasia, and 4 subjects with ataxic dysarthria in their ability to produce normal prosodic parameters of single-word imitation. Stimuli consisted of 30 mono-, di-, and trisyllabic words (e.g., please-pleasing-pleasingly). Subjects were asked to repeat each word once after the examiner. All speech samples were recorded. Perceptual judgments and phonetic transcriptions were performed on each utterance. Three categories of prosodic deviation were used to identify and evaluate each subject's prosody: abnormalities in syllabic stress (equal or abnormal stress), deviations in intraword temporal parameters (lack of a continuous, sufficiently rapid transition between syllables resulting in a brief silent interval between syllables, or a lack of smooth appropriately rapid and unobtrusive transition from one consonant to another), and repeated production difficulties (initial struggle, non-initial struggle, or repetition). Comparison of phonetic transcriptions and perceptual analyses results revealed that the apraxic group had the highest rate of errors of syllabic stress (43% and 46% for two- and three-syllable words, respectively), followed by the dysarthric group (23% and 25%), and then the aphasic group (3% and 5%). Within the group of AOS subjects, 71% of the disyllabic and 74% of the trisyllabic words with stress errors were perceived as containing vowel distortions (such as inappropriate lengthening of the schwa, or a change in the schwa vowel to a more qualitatively distinct vowel of a normally unstressed syllable, or an increase in duration in unstressed syllables). Odell et al. inferred that these errors may have been dependent on speaking rate. In addition, Odell et al. found that the apraxic subjects demonstrated more difficulty in smooth sound-to-sound movements resulting from initial word position struggles. These findings indicated that the majority (93%) of the misarticulated vowels were in the context of a vowel and consonant (VC) combination, implying additional co-articulatory difficulties demonstrated by the AOS subjects.

The production of temporal duration in 11 subjects with AOS and 11 non-brain damaged subjects was studied by Collins et al. (1983). Each subject repeated three sets of words that increased in length (e.g., please, pleasing, pleasingly). All productions were recorded and digitized. Word durations, vowel durations, and VOTs were analyzed. Results of the word and vowel duration analyses revealed that the AOS subjects used greater vowel duration and standard deviations of vowel duration for all words except one (please). Word duration increased as the length of the word increased; however, vowel duration did not vary (increase or decrease) as the word increased. Additional analyses between the two groups revealed that although vowel and word duration did vary, the degree of variance was not significant. These findings demonstrate that the AOS subjects have a preserved ability to effectively use duration at the syllable level even though they require greater overall production time when compared to the normal subjects.

One of the prosodic parameters that Kent and Rosenbek (1983) studied was the ability of 7 male AOS subjects to produce intonation similar to that of a control group of 7 non-brain damaged subjects. Speech elicitation tasks consisted of conversing, describing a picture, reading a paragraph, and imitating single words. Each subject's productions were recorded and digitized. In addition to identifying the acoustic characteristics of duration, the researchers extracted intensity and FO from each of the utterances. Analyses of prosodic disturbances revealed that the AOS subjects retained the ability to produce the terminal fall FO contour of the utterances, but demonstrated a flattening of overall intensity across syllables within the utterance, slow speaking rate with prolongations of transitions, and intersyllable pauses.

Although research in the area of production of emotional prosody in the general RHD and LHD populations has been well documented (Lorch et al., 1998; Ross et al., 1997; Shapiro & Danly, 1985; Weinger, 1984), research in the ability of AOS subjects to produce emotional prosody is limited.

Statement of the Problem

In summary, the findings from the aforementioned studies indicate that normal speakers conveyed emotion through the production of FO variations, duration cues, and intensity differences (Bachorowski & Owen, 1995: Bane & Scherer, 1996; Hess et. al, 1988; Lieberman & Michaels, 1962; Scherer, 1986, 1988). More specifically, happiness was signaled by an increased mean FO, standard deviation of FO, mean energy, and a decrease in duration (Bachorowski & Owen, 1995; Banse & Scherer, 1996; Scherer, 1986). Sadness was signaled by a decrease in mean FO, standard deviation of FO, mean energy, and increase in duration (Bachorowski & Owen, 1995; Banse & Scherer, 1996; Scherer, 1986).

Subjects with LHD have shown deficits in perceiving and producing linguistic prosody which conveys lexical stress differences (e.g., Damasio, 1998; Emmorey, 1987), and denotes syntactic constituents (Perkins et al., 1996). Alternately, RHD subjects have shown deficits in perceiving and producing emotional prosody (e.g., Baum et al., 1997; Grela & Gandour, 1999; Lalande et al., 1992; Tompkins & Flowers, 1985). Studies have shown that AOS speakers have difficulty with the production of correct articulation and prosody (e.g., Collins et al., 1983; Deal & Darley, 1972; Kent & Rosenbek, 1983; Odell et al., 1991; Rosenbek & LaPointe, 1981; Ziegler & vonCramon, 1986). How AOS impacts the production of prosody that conveys emotion has not yet been determined.

The purpose of this study was to examine the ability of subjects with varying severities of AOS to volitionally produce specific prosodic features that perform the paralinguistic function of portraying happy and sad emotions. Analyses were performed to determine if the acoustic characteristics of the prosodic structures that convey emotion were retained in the verbal expression of patients with varying severities of AOS, enabling naïve listeners to understand this aspect of meaning.

Hypothesis one: Subjects with varying severity of AOS (mild, moderate) are able to produce acoustic properties of prosodic structures that convey emotional content.

Hypothesis two: Naïve listeners are able to hear the appropriate acoustic properties, produced by subjects with AOS, and to perceive the correct emotional content of utterances.

Results of this study will provide for further understanding of the brain's mechanisms and interhemispheric relationship in the area of verbal production of emotion and AOS. Research findings may provide information for future clinical application.

METHOD

Four experiments were designed to assess the abilities of individuals with mild to moderate AOS to produce emotional prosody and to identify the acoustic features that naïve listeners use to perceive emotion in utterances produced by AOS speakers. One experiment involved the acoustic analysis of the production of emotional phrases by AOS subjects elicited through verbatim repetition of semantically neutral sentences. In a second experiment, subjects were asked to read a short story (4 sentences) that portrayed either a happy or sad emotion. The final two experiments involved naïve listeners who were asked to judge the productions of the AOS and normal speakers from the previous experiments in terms of which emotion was being expressed.

Experiment 1

Experiment 1 was designed to examine the acoustic features of emotional prosodic structures produced by subjects with mild and moderate AOS through repetition of target sentences.

Subjects

Two subjects with AOS were recruited for this study from the University of Maine Conley Speech and Hearing Center's Neurogenics Clinic and a local stroke support group. One subject had a mild AOS and another had a moderate AOS. One non-brain damaged subject was recruited as a control subject to participate in the speech production experiments.

Screening and Pre-Tests

Screening tests were administered to the AOS subjects to determine if the prospective subjects met criteria for participation in the experiment. The screening tests are as follows:

1. Oral-peripheral exam: An oral-peripheral exam was conducted to assess the integrity of oral and laryngeal structures and their movements to rule out the presence of dysarthria and identify AOS. Criterion for inclusion was no muscle weakness of oral structures disrupting speech, and irregular diadochokinetic rates due to apraxia of speech. (total time 10-15 minutes)
2. Hearing screening: A puretone hearing screening was performed from 250-8000 Hz to verify that the subjects' hearing was within normal limits for their age. Criterion for inclusion was normal hearing for their age groups (Lebo & Reddell, 1972). (total time 10-15 minutes)
3. Language Assessment: The Western Aphasia Battery (WAB) (Kertesz, 1982) was administered to assess language abilities. Each subject's reading ability was assessed at the sentence level. Criterion for inclusion

was an aphasia quotient greater than 20 and the ability to read at the sentence level (total time 45-60 minutes)

4. Apraxia Battery : The Apraxia Battery for Adults- Second Edition (ABA-2) (Dabul, 2000) was administered to determine the presence of AOS. The severity of the AOS was determined by the subject's scores on the ABA-2. Criterion for inclusion was the presence of AOS with accompanying severity rating (as identified in ABA-2 examiner's manual). An accompanying nonverbal-oral and/or limb apraxia may be present. (total time 20-30 minutes)

5. Depression Testing: The Beck Depression Inventory (BDI) (Beck, 1996) was administered to rule out the presence of depression. Criterion for inclusion was a score between 0-9. (total time 20 minutes)

Mild Subject

The mild AOS subject was a 68 year old, right handed female. She had sustained a single left hemisphere cerebral vascular accident (CVA) that was a result of an occlusion of the left internal carotid artery as identified by a carotid sonogram. CT results were unremarkable. The mild AOS subject was three years nine months post onset, a native American English speaker from Maine. She had no previous history of neurological damage, alcoholism, or mental illness, and had corrected visual acuity. Her oral-peripheral exam was unremarkable with the exception of a mild right sided lip weakness and poor dentition. Her hearing was within normal limits. Her scores on the WAB were as follows: Spontaneous speech- 14/20; Auditory verbal comprehension Yes/No questions- 60/60; Auditory word recognition-

60/60; Sequential commands- 58/80; Repetition- 30/100; Naming-25/60; Word fluency- 8/20; Sentence completion- 7/10; Responsive speech- 10/10; Reading- 32/40; Reading commands- 11/20; Aphasia quotient- 52.5/100. Her individual scores reflected stronger auditory comprehension and automatic expressions within sentence completion and responsive speech. However, her AOS contributed to impairments in spontaneous speech and repetition making her aphasia difficult to classify according to the Boston classification system. Her scores on the ABA were as follows: Diadochokinetic rate- 24 (mild); Increasing word length- 15 (severe); Limb apraxia- 50 (normal); Oral apraxia- 47 (normal); Utterance time for polysyllabic words- 47 (normal); and Repeated trials- 33 (mild). Considering the subject's automatic speech and scores on the ABA, she was classified as having mild AOS involvement. Her score on the BDI was 5, which was within normal limits.

Moderate Subject

The moderate AOS subject was a 54 year old, right handed female. She had sustained a single left hemisphere cerebral vascular accident (CVA) in the area of left middle cerebral artery distribution, as identified by a CT scan. The moderate AOS subject was 15 months post onset and was a native American English speaker from Maine. She had no previous history of neurological damage, alcoholism or mental illness, and had corrected visual acuity. The subject's oral-peripheral exam was unremarkable with the exception of impaired diadochokinetic rates. Her hearing was within normal limits for both ears with borderline mild difficulties in the higher frequencies. Her scores on the WAB were as follows: Spontaneous speech-11/20; Auditory verbal comprehension Yes/No questions- 60/60; Auditory word recognition-

39/60; Sequential commands- 44/80; Repetition- 7/100; Naming- 27/60; Word fluency- 1/20; Sentence completion- 2/10; Responsive speech- 9/10; Reading- 24/40; Reading commands- 10/20; Aphasia quotient- 45.2/100. Her individual scores reflected stronger auditory comprehension and automatic expressions within responsive speech. However, her AOS contributed to impairments in her spontaneous speech and to making her aphasia difficult to classify according to the Boston classification system. Her scores on the ABA were as follows: Diadochokinetic rate- 17 (mild); Increasing word length- 1(normal for maintaining the number of syllables); Limb apraxia- 46 (normal); Oral apraxia- 48 (normal); Utterance time for polysyllabic words- 106 (severe); and Repeated trials- 4 (severe). The moderate subject demonstrated limited spontaneous utterances consisting mostly of single words and yes/no responses. The subject was classified as having moderate AOS involvement. Her score on the BDI was 8, which was within normal limits.

Normal Subject

One non-brain damaged control subject was recruited to represent normal speech production. The control subject was a 40 year old, right handed female. She was a native American English speaker from Maine. She had no previous history of neurological damage, alcoholism, or mental illness, and had corrected visual acuity. A hearing screening indicated her hearing was within normal limits. She was administered the BDI and received a score of 3, which was within normal limits.

Materials

Ten sets of semantically neutral sentences were created that could be produced with either a happy, sad, or neutral voice (e.g., "The house is white!

(happy), "The house is white." (sad), and "The house is white." (neutral)). Each sentence contained five-six high frequency content words. None of the words was more than two syllables long. Each sentence was phonetically balanced to control for articulatory difficulty (e.g., no more than a combined total of eight plosives, fricatives, and affricates). (see Table A.1.) The practice and stimulus sentences were pre-recorded using a native speaker of Maine in a sound proof room with a Marantz PMD 222 audio recorder and head worn microphone. The final set of stimuli were selected from a pilot study using normal listeners who scored between 85-100% accuracy correctly identifying the intended emotion.

Procedure

Recording Procedure

The subjects were seated at a table in a quiet room. Two tape recorders were in the room: one was used to present the instructions and practice sentences and another to record each subject's productions. All subjects were given pre-recorded verbal instructions and two practice items prior to administration of the stimulus sentences played at a comfortable hearing level, through a Marantz PMD 222 audio recorder and speakers. The instructions for Experiment 1 were, "You will hear a sentence that conveys either a happy, sad, or neutral emotion. Repeat the sentence exactly as you hear it." If the subject did not understand the instructions, they were repeated and/or explained orally. If the subject did not understand the instructions after two practice items and an oral explanation, she was dismissed from the study.

The stimulus sentences were presented to the subjects one at a time in a random order. The order of presentation of the utterances between subjects remained the same. The presentation rate of materials was controlled by the examiner using the pause button on the audio recorder. Each subject's productions were recorded using a Marantz PMD 222 audio recorder and head worn microphone. The microphone remained in place on the subject throughout the duration of the experiments. A volume unit (VU) meter was used to monitor each subject's intensity level. (total administration time 10-20 minutes)

Measurement Procedure

All sentences produced by the AOS and control subjects were digitized using the Kay CSL (Computerized Speech Lab) unit Model 4300 installed on a Gateway computer. Using a procedure similar to Pell and Baum (1997b), seven acoustic parameters were measured for these experiments: mean FO, SD, and progressive inclination or declination of FO across the sentence, mean syllable duration, total sentence duration, mean amplitude of sentence, and SD of amplitude across the sentence. An additional five acoustic parameters were also measured: inclination/declination of final syllable, SD of duration of syllables, adjusted SD amplitude (SD/mean), adjusted SD of duration (SD/FO), and adjusted SD of FO (SD/FO). Each stimulus sentence, produced by the mild and moderate apraxic subjects, was transcribed. From the transcribed utterances, the number of apraxic errors and aphasic errors was totaled (classification of errors was based on characteristic apraxic speech patterns and characteristic aphasic speech patterns, already cited in the literature review). Overall percentages of apraxic and aphasic errors were calculated for all stimulus sentences produced. One apraxic characteristic frequently encountered is that of long pauses (silent groping). These long pauses were not included when counting the percentage of apraxic errors, due to the difficulty distinguishing an apraxic pause, a long pause, and a typical pause (and identifying which one was intended).

Fundamental Frequency

The average FO of each sentence was calculated by isolating the vowels within each syllable on a spectrogram and using the pitch extraction function on the CSL unit. The mean FOs of all the syllables in each sentence were then averaged, yielding the average FO of each sentence. The SD of the FO of syllables across each sentence was calculated the same way as the average FO, except that after the FO of each syllable was determined, it was used to calculate the SD of FO of syllables across each sentence. The progressive inclination or declination of the FO across each sentence was calculated by subtracting the initial syllable mean FO from the final syllable mean FO. Two additional measurements (progressive inclination or declination of the FO across the final syllable and adjusted SD of FO) were also calculated. The progressive inclination or declination of the FO across the final syllable was calculated by subtracting the initial FO at the beginning of the syllable from the last pitch period at the end of the syllable. The adjusted SD of FO was calculated by dividing the SD of the FO by the mean FO.

Duration

The average duration of syllables across each sentence was calculated by marking each syllable with cursors on a spectrogram and obtaining the duration between the cursors. Significant groping was not included as part of the syllable when calculating syllable duration. All of the syllable durations were averaged to calculate the average duration of syllables for each sentence. The total sentence duration was calculated by subtracting the time of the start of the first syllable in the sentence, from the end of the last syllable in the sentence (apraxic errors were not accounted for). Two additional measurements (SD of duration of syllables and adjusted SD of duration) were also calculated. The SD of the duration of syllables was calculated the same way as the average duration, except that after the duration of each syllable was determined, it was used to calculate the SD of duration of syllables across each sentence. The adjusted SD of duration was calculated by dividing the SD of the duration of the syllables by the mean duration.

Amplitude

The average amplitude and SD across each sentence was automatically calculated using the energy extraction function on the CSL unit. SD of mean amplitude across the sentence was automatically calculated using the energy extraction function on the CSL unit. An additional measurement of adjusted SD of amplitude was calculated by dividing the SD of amplitude by the mean amplitude.

Results

Normal Subject

The normal subject produced all 30 of the stimulus sentences. The acoustic measurements for the 30 stimulus sentences can be seen in Appendix A, Table 2. Paired t-tests comparing the measurements between happy and sad sentences revealed significant differences in the mean FO ($t=7.28$, $p<.01$), SD of FO ($t=3.06$, $p<.01$), total sentence duration ($t=-2.67$, $p<.01$), and mean amplitude ($t=2.47$, $p<.05$). Paired t-tests comparing the mean measurements between happy and neutral sentences revealed significant differences between the mean FO (t=5.32 , p<.01), SD of FO (t=3.06, p<.01) and the progressive declination of the FO across the sentences (t=2.24, p<.05). There were no significant findings between the acoustic parameters of the happy and sad sentences on progressive inclination or declination of the FO across the sentence, mean syllable duration, and SD of amplitude. There were no significant findings between the acoustic parameters of the happy and neutral sentences on mean amplitude, mean duration, SD of amplitude, SD of FO, and total sentence duration. There were no significant differences on any of the acoustic parameters between the sad and neutral sentences.

An analysis of the additional acoustic parameters revealed significant differences between the happy and neutral sentences for adjusted SD of FO (t=2.23, p<.05). No significant differences were found between any of the remaining additional acoustic parameters (inclination/declination of the FO across the final syllable, SD of duration, adjusted SD of amplitude, and adjusted SD of duration).

The significant differences between the acoustic parameters of happy and sad sentences suggest that happy sentences were produced faster, louder, and with higher pitch and greater pitch variability than the sad sentences. The significant differences between the acoustic parameters of happy and neutral sentences suggest that happy sentences were produced with a rising pitch over the sentences and overall higher pitch than the neutral sentences. The lack of significant differences between the acoustic parameters of sad and neutral suggest that these sentences were produced with similar pitch, loudness or rate characteristics.

Mild Apraxia of Speech Subject

The mild apraxic subject produced 23 of the 30 stimulus sentences. Of the 23 sentences produced by the mild apraxic subject, 40/73 (55%) of the total errors produced within the sentences were due to apraxia (versus aphasia).

The acoustic measurements for the 23 stimulus sentences can be seen in Appendix A, Table 3. Paired t-tests comparing the measurements between each of the emotions (happy and sad, happy and neutral, and sad and neutral) revealed no significant differences for mean, SD, and progressive inclination/declination of the FO, mean duration, total sentence duration, mean amplitude, or SD of amplitude. No significant differences were found on any of the additional acoustic parameters (inclination/ declination of the FO across the final syllable, SD of duration, adjusted SD of amplitude, adjusted SD of duration, and adjusted SD of FO) by any emotion. The lack of significant differences between the acoustic parameters of any of the emotions suggest that the mild AOS subject was unable to effectively produce acoustic cues to distinguish between the different emotions.

Moderate Apraxia of Speech Subject

The moderate apraxic subject produced 8 of the 30 stimulus sentences. Of the eight sentences produced by the moderate apraxic subject, 11/16 (69%) of the total errors produced within the sentences were due to apraxia (versus aphasia).

The acoustic measurements for the eight stimulus sentences can be seen in Appendix A, Table 4. Paired t-tests comparing the measurements between each of the emotions (happy and sad, happy and neutral, and sad and neutral) revealed no significant differences for mean FO, SD, progressive inclination/declination of the

FO, mean duration, total sentence duration, mean amplitude, or SD of amplitude. No significant differences were found between any of the additional acoustic parameters (inclination/ declination of the FO across the final syllable, SD of duration, adjusted SD of amplitude, adjusted SD of duration, and adjusted SD of FO) of happy, sad, and neutral sentences. The lack of significant differences between the acoustic parameters suggests that the moderate AOS subject was unable to effectively produce acoustic cues to distinguish between the different emotions.

Discussion

Experiment 1 examined the abilities of a normal, a mild AOS, and a moderate AOS subject to repeat semantically neutral sentences with different emotional intent. The results for the normal subject were consistent with previous findings that indicated that happy emotions are conveyed with a higher and more variable FO (Bachorowski & Owen, 1995; Banse & Scherer, 1996; Lieberman & Michaels, 1962), faster syllable durations (Banse & Scherer, 1996), and greater intensity (Banse & Scherer, 1996) relative to sad and neutral sentences. Furthermore, the FO inclination for happy versus neutral was greater.

Neither the mild nor moderate AOS subjects was able to produce acoustic variations to signal emotion during this imitation task. One factor related to this finding is the contribution of AOS in disrupting prosodic patterns (e.g., Collins et al., 1983; Kent & Rosenbek, 1983; Odell et al., 1991). When looking at each AOS subject's repetition abilities as identified by the WAB, the researcher found both subjects demonstrated low scores. Therefore, it is not surprising that the AOS subjects had difficulty with the task of repeating sentences. In addition this task was volitional, making it difficult for any apraxic subject (Odell et al., 1991). Although the stimuli were developed with consideration towards minimizing potential aphasic and apraxic errors, both AOS subjects still had difficulty in producing the stimulus items. All the words selected for the stimulus sentences were frequently occurring words in the English language. The articulatory load of the stimulus sentences was carefully controlled so that no sentence would have more than a combination of eight plosives, fricatives, and affricates. The number of words per sentence did not exceed 6, with no word greater than two syllables.

In spite of the careful development of the stimulus sentences, the AOS subjects still produced apraxic and aphasic errors. Apraxic errors produced were characterized by groping, pauses, word initiation difficulties and vowel variations. For example, both AOS subjects demonstrated apraxic involvement evident by groping (e.g., "Her name is Er- Er- Erris."), increased use of pauses (e.g., "Loves *pause* um takes a pict-ture.") and increased durations in syllables (e.g., "He calls my naame"). This observed groping and increased pauses within the sentence and syllable may have interfered with variation in duration that are acoustic cues to signal emotion. The groping may also have impacted the SD of FO comprising the intonation contour by increasing syllable durations thereby decreasing the SD of FO.

Experiment 2

Experiment 2 elicited happy and sad emotional meaning using a picture description task that was considered to be a more natural elicitation procedure than the procedure used in Experiment 1.

Subjects

The two AOS subjects and normal subject that participated in Experiment 1, participated in this experiment.

Materials

A picture sequence description task was designed to elicit happy and sad emotional utterances. Ten pairs of pictured sequences containing four individual pictures per sequence were created. Ten of the pictured sequence pairs were designed to elicit happy sentences and 10 elicited sad sentences. Each picture was accompanied by a sentence written below the picture. Each sentence contained five-six high frequency content words. None of the words was more than two syllables long. Each sentence was phonetically balanced to control for articulatory difficulty where the total number of plosives, fricatives, and affricates was no greater than eight (see Appendix B, Table B.1).

Each sequence elicited either a happy or sad sentence, depending on the context of the first three pictures of the sequence. The happy or sad production of the target fourth sentence of the sequence was determined by the content of the first, second, and third pictures. The target fourth sentence was identical in both the happy and sad sequences, and was used in the acoustic analyses. For example, a sequence that elicited a happy target utterance was: (1) John was failing math. (2) He got all Ds. (3) Friday, John took his final exam. (4) He got a B! A sequence that elicited a sad target utterance was: (1) John was a straight A student. (2) He was first in his class. (3) He studied hard for his final. (4) He got a B. The final selection was determined through a pilot study using normal speakers who produced the appropriate emotions 85-100% of the time.

Procedure

Recording Procedure

The recording procedure was the same as in Experiment 1. Nevertheless, in this experiment, each subject was presented with two practice sequence set of pictures. The subject viewed each pictured sequence prior to hearing the instructions. The instructions for Experiment 2 were, "You will see a series of pictures that tell either a happy or sad story. Describe the series using the sentence at the bottom of each of the pictures. Feel free to take a moment to read the sentences to yourself before you read them aloud."

One tape recorder was used to present the instructions and practice sentences and the other tape recorder recorded each subject's productions. If the subject did not understand the instructions, the instructions were repeated and/or explained verbally. If the subject did not understand the instructions after two practice items and a verbal explanation, she was dismissed from the study.

The sets of picture sequences were presented to each subject in a random order. The order of presentation between subjects remained the same. The procedural format for Experiment 2 required the subject to produce 80 sentences, presented in 20 sequences (10 happy and 10 sad) of four pictures each. The target sentence (#4) was extracted and used for the acoustic analysis. Administration of practice and test items took 30-60 minutes.

Measurement Procedure

All target sentences produced by the AOS and normal subjects were digitized using the Kay CSL (Computerized Speech Lab) unit Model 4300 installed on a Gateway. The measurement procedures were the same as for Experiment 1.

Results

Normal Subject

The normal subject produced 20 of the 20 target sentences. The acoustic measurements for the 20 sentences can be seen in Appendix B, Table 2. Paired t-tests comparing the measurements between happy and sad sentences revealed significant differences in the mean FO ($t= 4.494$, $p<.01$), and mean amplitude ($t= 2.252$, $p<.05$). There were no significant findings between the acoustic parameters of the happy and sad sentences on SD of FO, progressive inclination or declination of FO across the sentence, mean duration, total duration, and SD of amplitude. No significant differences were found between any of the additional acoustic parameters (inclination/declination of final syllable, SD of duration, adjusted SD of amplitude, adjusted SD of duration, and adjusted SD of FO). The significant differences between the acoustic parameters of happy and sad sentences suggest that happy sentences were produced louder and with a higher pitch than the sad sentences.

Mild Apraxia of Speech Subject

The mild AOS subject produced 18 of the 20 target sentences. Of the 18 sentences produced by the mild apraxic subject, 27/52 (52%) of the total errors produced within the sentences were due to apraxia (versus aphasia).

The acoustic measurements for the 18 stimulus sentences can be seen in Appendix B, Table 3. Paired t-tests comparing the measurements between happy and sad sentences revealed no significant differences for mean FO, SD of FO, progressive inclination/declination of the FO, mean duration, total sentence duration, mean amplitude, or SD of amplitude. No significant differences were found between any of the additional acoustic parameters (inclination/declination of the FO across the final syllable, SD of duration, adjusted SD of amplitude, adjusted SD of duration, and adjusted SD of FO). The lack of significant differences between the acoustic parameters suggests that the mild AOS subject was unable to effectively produce acoustic cues to distinguish between different intended emotions.

Moderate Apraxia of Speech Subject

The moderate AOS subject produced 17 of the 20 stimulus sentences. Of the 17 sentences produced by the moderate apraxic subject, 23/40 (58%) of the total errors produced within the sentences were due to apraxia (versus aphasia).

The acoustic measurements for the 17 stimulus sentences can be seen in Appendix B, Table B.4. Paired t-tests comparing the measurements of happy and sad sentences revealed no significant differences between any of the acoustic parameters (mean FO, SD of FO, progressive inclination/declination of the FO, mean duration, total sentence duration, mean amplitude, or SD of amplitude). No significant differences were found on any of the additional acoustic parameters (inclination/declination of the FO across the final syllable, SD of duration, adjusted SD of amplitude, adjusted SD of duration, and adjusted SD of FO). The lack of significant differences between the acoustic parameters suggests that the moderate

AOS subject was unable to effectively produce acoustic cues to distinguish between different intended emotions.

Discussion

Experiment 2 elicited happy and sad emotional meaning by a picture description task that was considered to be a more natural elicitation procedure than used in Experiment 1. The findings for the control subject in this experiment are similar to those findings from Experiment 1. However, fewer acoustic cues were present in Experiment 2, compared to Experiment 1. In Experiment 1, the normal subject produced the following acoustic cues to signal emotion: mean FO, SD of FO, mean amplitude, and progressive inclination/declination of the FO. In this experiment, the normal subject produced differences between the mean FO and mean amplitude to signal emotional intent. Due to the consistency between the two experiments for data collection and measurements, it is the elicitation procedure that is the difference between the two experiments, and may be the reason for the similar but not exact results as in Experiment 1. For example, in Experiment 1 the normal subject was repeating what she heard (e.g., progressive inclination of FO across the happy sentences). During Experiment 2, she was relying on her personal tendencies to express emotion in this lab circumstance (e.g., lacking the use of progressive inclination of FO across the happy sentences).

As seen in Experiment 1, neither the mild or moderate AOS subject was able to produce acoustic cues to signal emotion in this experiment. The presence of AOS most likely contributed to the lack of differences in the production of the acoustic cues. Although this experiment was more natural than Experiment 1 and the stimulus sentences were designed to control for articulatory load and word frequency, volitional utterances were still required. Furthermore, this experiment also placed increased demands on the subjects relative to Experiment 1. Subjects were required to read 88 sentences (20 test sequences of four sentences each and two practice sequences of four sentences each).

On a few occasions, the AOS subjects produced words within the stimulus sentences with little or no difficulty. At other times, they struggled with their productions and showed apraxic errors similar to those described in Experiment 1. Both of the subjects were aware of their speech disturbances and became increasingly frustrated when their attempts at corrections yielded no improvement in their speech (e.g., “Darn, I just said that word!!”). The total number of apraxic errors interfered with the ability of the AOS subjects to produce all of the stimulus sentences, contributing to a small data set and possibly the lack of significant differences in acoustic cues to signal emotion. The sentences that were produced contained similar groping, pauses, word initiation difficulties and vowel variations, that is, the types of apraxic errors present in Experiment 1. It is likely that these errors interfered with the production of differences between the FO and amplitude within the prosodic structures produced by the normal speaker to convey happy and sad emotions.

<u>Experiment 3</u>

Experiment 3 addressed whether naïve listeners could identify differences in the prosodic structures that convey emotional meaning, produced by the AOS and normal subjects in Experiment 1.

Subjects

A group of naïve listeners, recruited from the local community, consisted of 8 right-handed adults (four female and four male) between the age of 40 and 70 years old. The naïve listeners were native American English speakers from Maine with no previous history of neurological damage, alcoholism, or mental illness. A hearing screening revealed that hearing was within normal limits.

Materials

The stimulus sentences produced by each of the subjects in Experiment 1 were combined, randomized, and dubbed onto another tape using a Tascam audio recorder. A total of 61 sentences (30 produced by the control subject, 23 by the mild AOS subject, and eight by the moderate AOS subject) was used. An answer sheet was numbered 1-61 with three columns (happy, sad, and neutral).

Procedure

Each of the naïve listeners was seated in a quiet room with a tape recorder set in front of each person. Pre-recorded oral instructions and two practice items were given prior to the administration of the test sentences. Instructions for Experiment 3 were, "You will hear a series of sentences. Some of the sentences may be difficult to understand and some may be easy. I want you to judge which emotion is being expressed: happy, sad, or neutral. On your rating sheet, check the emotion corresponding to the sentence that you hear." If the subject did not understand the instructions after two practice sequences, he/she was dismissed from the study. None of the qualifying naïve listeners was dismissed due to difficulty understanding directions. All materials were presented to the subjects from a tape recorder and speakers at a comfortable hearing level as indicated by the subject. The subjects were presented with the stimulus sentences in a random order and asked to judge the intended emotional content of each sentence as happy, sad or neutral (as indicated by a check mark in a happy, sad or neutral column). Administration of practice and test items took 10-20 minutes.

Results

Normal Subject's Productions

The normal subject produced all 10 of the happy sentences, all 10 of the sad sentences, and all 10 of the neutral sentences from Experiment 1. The naïve listeners correctly identified 75/80 (94%) of the happy sentences, 43/80 (54%) of the sad sentences, and 62/80 (78 %) of the neutral sentences (Appendix C, Table 1). A Chi square analysis of collapsed data across all sentence types indicated that the judgments of naïve listeners were more accurate than would be expected by chance (X^2 (1)=187.5, p<.001).

A Chi square analysis of the data according to sentence type revealed that the judgments of naïve listeners were more accurate than would be expected by chance for happy (X^2 (1)=131.85, p<.001), sad (X^2 (1)=14.99, p<.001) and neutral (X^2 (1)=70.207, p<.001). These results suggest that naïve listeners were able to identify the correct emotion in the normal subject based on acoustic information. The lack of significant differences between the acoustic cues of sad and neutral may have contributed to apparent difficulty that the naïve listeners experienced in identifying the sad sentences.

Analyses of the errors the subjects made were also completed (Appendix C, Table 2). Of the five misidentifications on the happy sentences, one was identified as sad and four were identified as neutral sentences. Of the 37 misidentifications on the sad sentences, 30 were identified as neutral and seven were identified as happy sentences. Of the 18 misidentifications on the neutral sentences, 16 were identified as sad and two were identified as happy sentences. These patterns of errors indicate that the naïve listeners most often misjudged happy and sad sentences to be neutral, thus reflecting a default response strategy reported by many of the subjects. When in doubt, the naïve listeners chose neutral. The neutral sentences were misjudged as sad in most instances.

<u>Mild Apraxia of Speech Subject's Productions</u>

The mild subject produced nine happy sentences, six sad sentences, and eight neutral sentences from Experiment 1. The naïve listeners correctly identified 22/72 (31%) of the happy sentences, 17/48 (23 %) of the sad sentences, and 45/64 (70%) of the neutral sentences (Appendix C, Table 1).

A Chi square analysis of collapsed data across all sentences types was not significant indicating that subjects may have been guessing. Subjects reported that when they had difficulty discerning happy and sad sentences, they simply picked neutral as a default. Therefore, the high percentage in identifying neutral sentences most probably reflected this default response strategy rather than the perception of acoustic information.

Analyses of the judgment errors of the mild AOS subject's productions were also completed (Appendix C, Table 2). Of the 50 misidentifications on the happy sentences, 14 were identified as sad and 36 were identified as neutral sentences. Of the 36 misidentifications on the sad sentences, 31 were identified as neutral sentences and five were identified as happy sentences. Of the 19 misidentifications on the neutral sentences, 12 were identified sad and seven were identified as happy sentences. These patterns of errors are the same as those found in the identification of the normal subject's productions. Naïve listeners most often misjudged sentences to be neutral when they were happy or sad sentences, and misjudged the neutral sentences to be sad.

Moderate Apraxia of Speech Subject's Productions

The moderate apraxic subject produced three of the happy sentences, one of the sad sentences, and four of the neutral sentences. The naïve listeners correctly identified the correct emotion in 5/24 (21%) of the happy sentences, 3/8 (38%) of the sad emotions, and 14/32 (44%) of the neutral emotions (Appendix C, Table 1). These percentages appear to follow a similar pattern than those of the mild AOS speaker. A Chi square analysis of collapsed data across all sentence types was not significant indicating that subjects may have been guessing.

An error analysis was also completed (Appendix C, Table 2). Of the 19 misidentifications on the happy sentences, seven were identified as sad and 12 were identified as neutral sentences. Of the five misidentifications on the sad sentences, four were identified as neutral and one was identified as a happy sentence. Of the 18 misidentified neutral sentences, 15 were identified as sad and three were identified as happy sentences. These patterns of errors are similar to those of the normal and mild AOS subject's productions. Naïve listeners most often misjudged sentences to be neutral when they were happy or sad sentences, and misjudged the neutral sentences to be sad.

Discussion

Experiment 3 was designed to test whether naïve listeners were able to identify emotional meanings conveyed through differences in prosodic structures that were produced by the normal, mild and moderate AOS subjects in Experiment 1. In Experiment 1, the normal subject produced acoustic cues to signal differences between the happy versus sad and neutral sentences. Therefore, it was expected that the naïve listeners in Experiment 3 would be able to identify happy sentences more often than sad or neutral sentences. As expected, the highest percentage (94%) was seen in the identification of the happy sentences presumably because those sentences had the greatest amount of acoustic significance. The poorer percentage (54%) was seen in the identification of the sad sentences, this may have reflected the lack of acoustic differences between sad and happy. The naïve listeners said that when they were not sure which emotion they were hearing, they picked neutral (corroborated in error analysis). Therefore, the identification of neutral sentences had a higher percentage but may have been an artifact of a default response strategy rather than perception of acoustic cues.

In Experiment 1, no significant differences in acoustic measurements were found between the happy, sad and neutral sentences that were produced by the mild AOS subject. Therefore, the naïve listeners were expected to have difficulty identifying the intended emotion of the utterances that were produced by the mild AOS subject. The listeners did have difficulty in identifying the happy and sad sentences as seen in poor percentages of correct responses. Unexpectedly, the naïve listeners identified the neutral sentences with a 70% accuracy. However, an error analysis revealed that the percentages of correct responses in identifying the neutral sentences may have been an artifact of the same default response strategy used when identifying the utterances produced by the control subject (i.e.., when in doubt, pick neutral).

In Experiment 1, the moderate AOS subject was unable to produce any acoustic cues to differentiate between the happy, sad, and neutral sentences. Therefore it would be expected that the naïve listeners in Experiment 3 would have difficulty identifying the intended emotion of the moderate AOS subject's productions. As expected, the naïve listeners had difficulty in identifying the intended emotions of the moderate AOS subject's productions. The same trend of an increased number of misidentified sentences being identified as neutral (or sad), found with the normal subject and mild AOS subject's sentences, was also noted on misidentification of the moderate AOS subject's sentences. The majority of the misidentified emotions for the sad and happy sentences were identified as neutral (and the misidentified emotion for the neutral sentences was sad.)

An explanation of the percentage of correctly identified sentences across these three subjects show the normal subject's sentences were identified with the greatest accuracy, and the mild and moderate AOS subjects' productions were identified with poor accuracy. These findings suggest that naïve listeners could not discern differences in emotion in sentences that were produced by the AOS subjects.

Experiment 4

Experiment 4 addressed whether naïve listeners could identify differences in the prosodic structures that convey emotional meaning, when produced by the normal, mild, and moderate AOS subjects in Experiment 2.

Subjects

The same eight naïve listeners who participated in Experiment 3 participated in Experiment 4.

Materials

The stimulus sentences produced by each of the subjects in Experiment 2 were combined, randomized, and dubbed onto another tape using a Tascam audio recorder. A total of 55 stimulus sentences (20 produced by the control subject, 18 by the mild AOS subject, and 17 by the moderate AOS subject) was used. An answer sheet was numbered 1-55 with two columns (happy and sad).

Procedure

The listening procedure was the same as in Experiment 3. Eight naïve listeners were given the pre-recorded oral instructions and two practice items prior to administration of the test sentences. Instructions for Experiment 4 were, "You will hear a series of sentences. Some of the sentences may be difficult to understand, and some may be easy. I want you to judge which emotion is being expressed: happy or sad. On your rating sheet, check the emotion corresponding to the sentence that you hear." If the subject did not understand the instructions after two practice sequences, he/she was dismissed from the study. The subjects were presented with the stimulus sentences in a random order and asked to judge the intended emotional content of each sentence as happy or sad (as indicated by a check mark in a happy or sad column). Administration of practice and test items took 10-20 minutes.

Results

Normal Subject's Productions

The normal subject produced 10 happy and 10 sad sentences, during Experiment 2. The naïve listeners correctly identified 71/80 (89%) of the happy sentences and 56/80 (70%) of the sad sentences (Appendix D, Table 1).

A Chi square analysis of collapsed data across all sentences types indicated that the judgments of naïve listeners were more accurate than would be expected by chance (X^2 (1)=55.225, p<.001). A Chi square analysis of the data according to sentence type revealed that the judgments of naïve listeners were more accurate than would be expected by chance for happy (X^2 (1)=48.05, p<.001) and sad (X^2 (1)=12.8, p<.001).

An analyses of errors on misidentified sentences was completed (Appendix D, table 2). Nine misidentifications were made on happy sentences and 24 misidentifications were made on sad sentences.

Mild Apraxia of Speech Subject's Productions

The Mild AOS subject produced nine of the happy sentences and nine of the sad sentences. Naïve listeners were able to correctly identify 76% (55/72) of the happy sentences and 45% (32/72) of the sad sentences (Appendix D, Table 1).

A Chi square analysis of collapsed data across all sentence types was not significant indicating that subjects may have been guessing.

An analysis of the misidentified emotions was completed (Appendix D, Table 2). Seventeen misidentifications were made on happy sentences and 40 misidentifications were made on sad sentences.

Moderate Apraxia of Speech Subject's Productions

The moderate AOS subject produced eight of the happy sentences and nine of the sad sentences. Naïve listeners were able to correctly identify 20/64 (31%) of the happy sentences and 57/72 (79%) of the sad sentences (Appendix D, Table 1).

A Chi square analysis of collapsed data across all sentence types was not significant indicating that subjects may have been guessing. Subjects reported that when they had difficulty discerning sentences, they simply picked sad as a default. Therefore the high percentage in identifying sad sentences may have reflected this default guessing strategy rather than the perception of acoustic information.

An analysis of the misidentified emotions was completed (Appendix D, Table 2). Forty-four misidentifications were made on happy sentences and 15 misidentifications were made on sad sentences.

Discussion

Experiment 4 addressed whether naïve listeners could identify differences in prosodic structures that convey emotional meaning, as produced by the normal, mild and moderate AOS subjects in Experiment 2. In Experiment 2, the normal subject produced differences in the mean FO and mean amplitude to distinguish between happy and sad sentences. However, the normal subject produced fewer acoustic cues in Experiment 2 than in Experiment 1 to signal emotion. Therefore, it was unclear if the limited acoustic cues produced in Experiment 2 were sufficient to expect that naïve listeners would be able to correctly identify the happy and sad sentences. The results of Experiment 4 indicated that naïve listeners were able to identify the intended emotion of the normal subject's productions.

Because the mild and moderate AOS subjects did not produce acoustic cues to differentiate between emotions, it was expected that naïve listeners would have trouble perceiving the differences in the productions of the AOS speakers. The findings indicate that the naïve listeners were guessing. However, the guessing strategy used for the mild AOS subject did not follow the aforementioned default guessing strategy as a higher percentage of guesses for happy (76%) rather than sad (45%) sentences was revealed. It is unlikely that the percentage was artificially inflated through a default guessing strategy, as listeners reported that when in doubt, they picked sad. Naïve listeners did report that when they perceived fewer instances of errors that were present (interpreted to be aphasic and apraxic errors), they identified the sentences as happy, versus sad sentences. Happy sentences may have been associated with "more fluent" productions relative to "less fluent" productions of sad sentences. However, the total number of aphasic and apraxic errors in the happy versus sad sentences in Experiment 2 was similar. The happy sentences had an average of 2.71 errors per sentence (46 errors across 17 sentences) and the sad sentences had an average of 2.56 errors per sentence (46 errors across 18 sentences). Therefore, although the naïve listeners reported "more fluent" speech associated with happy identification, average number of errors per sentence type (happy versus sad) does not reflect this strategy.

During Experiment 2, the moderate AOS subject was unable to produce the previously identified acoustic cues commonly associated with happy or sad emotion. Therefore, it would be expected that the naïve listeners would have difficulty correctly identifying the intended emotion of the moderate AOS subject's productions. As expected, in Experiment 4, the naïve listeners had difficulty in identifying the happy and sad sentences. An error analysis confirmed that the naïve listeners were using a default guessing strategy. It was reported by several of the naïve listeners that when they were unable to determine if a sentence was happy or sad, they just marked the sad column. Therefore, the higher percentages in identifying sad sentences is most probably an artifact of this default guessing strategy.

Supplementary Analyses

Supplementary analyses were performed to determine if spontaneous utterances contained emotional prosodic content absent in the elicited utterances of Experiments 1 and 2. Several spontaneous utterances present during conversation and between pre-screening protocols, were recorded and digitized. The mild AOS subject produced two happy, four sad, and two neutral spontaneous utterances. The moderate AOS subject produced four happy, three sad, and two neutral spontaneous utterances. Emotional intent of the spontaneous utterances was determined by the context of the conversation. Four of the seven acoustic parameters analyzed in Experiments 1 and 2 (average FO across the sentence, SD of mean FO across the sentence, progressive inclination or declination of FO across the sentence, average duration of all syllables across the sentence) were also analyzed in the spontaneous utterances. These additional analyses were motivated by the assumption that spontaneous speech does contain some acoustic parameters which convey an intended emotion that may not have been present in the elicited samples.

Fundamental Frequency

Comparisons of the mean FO between the spontaneous and elicited sentences for each AOS subject can be seen in Figure 1. For the mild AOS subject, there was little difference between the mean FO of the elicited and spontaneous happy and sad utterances. However, the mild AOS subject produced a higher mean FO during the spontaneous neutral utterances as compared to the elicited neutral utterances.

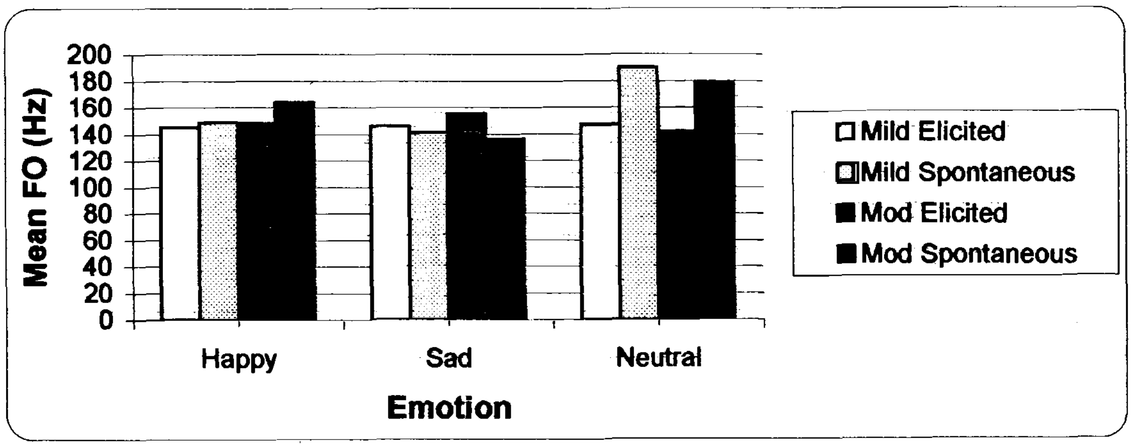

Figure 1. Mean FO for elicited and spontaneous sentences.

For the moderate AOS subject, there was a slight differences between the mean FO of elicited and spontaneous sad utterances. There were greater differences in higher mean FO for the spontaneous happy and neutral utterances versus the elicited utterances.

The findings between the mild and moderate AOS subjects were not similar to each other. The mild AOS subject only produced an increased mean FO on the spontaneous neutral sentences as compared to the elicited sentences. Surprisingly, the moderate AOS was able to produce a higher mean FO for the happy and neutral spontaneous sentences, and lower mean FO for the spontaneous sad sentences.

The findings of the moderate AOS subject's use of mean FO during spontaneous sentences when producing happy, sad, and neutral emotional intent, is consistent with the literature on the non-brain damaged populations use of mean FO to signal happy and sad emotion. Research in the non-brain damaged population has found that mean FO is greater for sentences with happy intent versus mean FO for sentences with sad intent (e.g., Bachorowski & Owen, 1995; Ganse & Scherer, 1996). These findings imply that the moderate AOS subject was able to produce differences in the mean FO when signaling happy and sad emotional intent, similar to individuals without brain damage.

Standard Deviation of the Fundamental Frequency

The comparisons of the SD of FO between the spontaneous and elicited sentences for each AOS subject can be seen in Figure 2. The mild AOS subject produced an unusual inverse pattern when comparing spontaneous to elicited sentences. The mild AOS subject's SD of FO decreased for the spontaneous happy sentences and increased for the spontaneous sad and neutral sentences compared to the elicited sentences. Within the spontaneous utterances, the mild AOS subject produced the greatest SD of FO on the sad, neutral, and happy sentences (respectively).

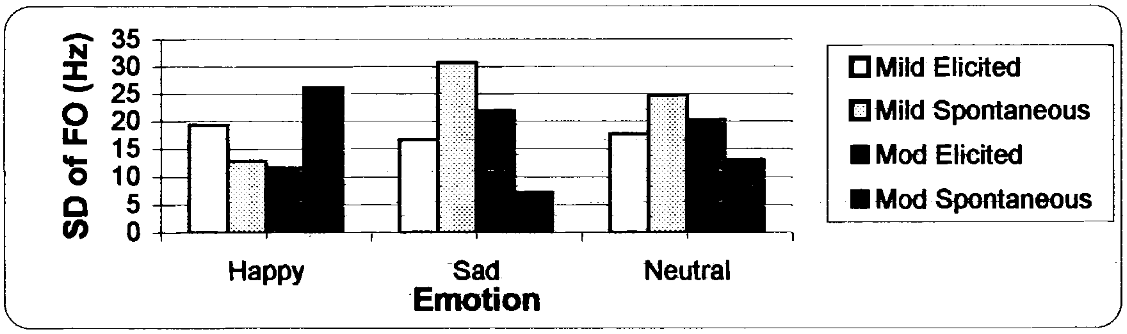

Figure 2. SD of FO of elicited and spontaneous sentences.

A comparison of the elicited versus spontaneous sentences of the moderate AOS subject followed a more predictable pattern. The moderate AOS subject produced a greater SD of FO for the spontaneous happy sentences and lesser SD for sad and neutral spontaneous sentences, as compared to the elicited sentences. Within the spontaneous utterances, the moderate AOS subject produced the greatest SD of FO in the production of happy sentences, followed by the neutral sentences. The smallest amount of SD of FO produced by the moderate AOS subject during spontaneous speech was noted on the sad sentences (as compared to happy and neutral spontaneous sentences).

The findings between the mild and moderate AOS subjects' productions of SD of FO were not similar to each other. The mild AOS produced an unusual pattern of less variability in the FO in the happy spontaneous sentences and more in the sad and neutral spontaneous sentences. The moderate AOS subject's spontaneous utterances were produced with a greater variability in the FO for the happy sentences, and less SD of FO for the sad and neutral sentences.

The findings of the moderate AOS subject's production of variability of the FO during spontaneous sentences when producing happy, sad, and neutral emotional intent is consistent with the literature on the non-brain damaged population's productions of SD of FO to signal happy and sad emotion. Research in the non-brain damaged population has found that when expressing happy emotions, an individual produces more pitch variability (SD of FO), and reduced pitch variability for sad and neutral emotions (e.g., Bachorowski & Owen, 1995). These findings imply that the moderate AOS subject was able to produce the variability of the FO when conveying happy, sad, and neutral emotional intent in a way similar to individuals without brain damage.

Progressive inclination/declination of Fundamental Frequency

The comparison of the progressive inclination/declination of the FO across the sentences between the spontaneous utterances and elicited sentences can be seen in Figure 3. A comparison of the mild AOS subject's happy and sad spontaneous vs. elicited sentences revealed some of an inverse relationship. The mild AOS subject's spontaneous happy and sad sentences were produced with an inclination of FO as compared to a declination of FO during the elicited happy and sad sentences. The mild AOS subject's spontaneous neutral sentences were similar to the elicited neutral sentences in that they were both produced with a progressive declination. Within the spontaneous utterances, the mild AOS subject produced an inclination of FO on the sad and happy sentences, with a progressive declination of FO noted on the neutral sentences.

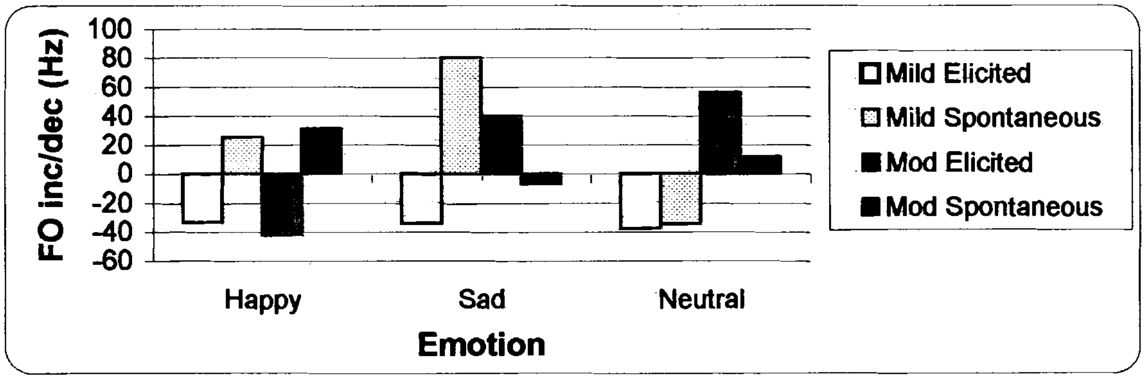

Figure 3. Progressive inclination/declination of the FO across sentences for elicited and spontaneous sentences. Negative numbers in Figure 3 represent declination, positive numbers represent inclination.

The moderate AOS subject produced an inclination of the FO for the happy and neutral sentences and declination of the FO for the sad sentences that is consistent with the elicited neutral sentences. Within the spontaneous sentences, the greatest inclination of the FO was produced on the happy sentences, followed by the neutral sentences. The spontaneous sad sentences were produced with a progressive declination of the FO across the sentence.

The findings between the mild and moderate AOS subjects' production of progressive inclination/declination of FO were not similar. The patterns for the mild AOS subject were unusual. During spontaneous speech, the mild AOS subject produced a progressive inclination of FO on the happy and sad sentences, and progressive declination on the neutral sentences. The moderate AOS subject produced a progressive inclination on the happy and neutral sentences, and progressive declination on the sad sentences, during spontaneous speech. Research in the non-brain damaged population has found that happy emotion is often signaled by a progressive inclination of FO across the utterance, whereas sad and neutral emotion is signaled by a progressive declination of FO across the utterance (e.g., Scherer, 1986). The findings from the moderate AOS subject's spontaneous production of progressive inclination /declination to signal happy, sad and neutral sentences was consistent with what would be expected from non-brain damaged subjects. These findings imply that the moderate AOS subject was able to produce progressive inclination/declination of the FO when expressing happy, sad, and neutral emotional intent during spontaneous speech.

Mean Duration

A comparison of the average duration of syllables across the spontaneous and elicited sentences can be seen in Figure 4. The mild AOS subject produced shorter mean durations for the happy, sad, and neutral spontaneous sentences as compared to the elicited sentences. Within the spontaneous utterances, the sad sentences were produced with greatest mean durations and the happy and neutral sentences had shorter mean durations.

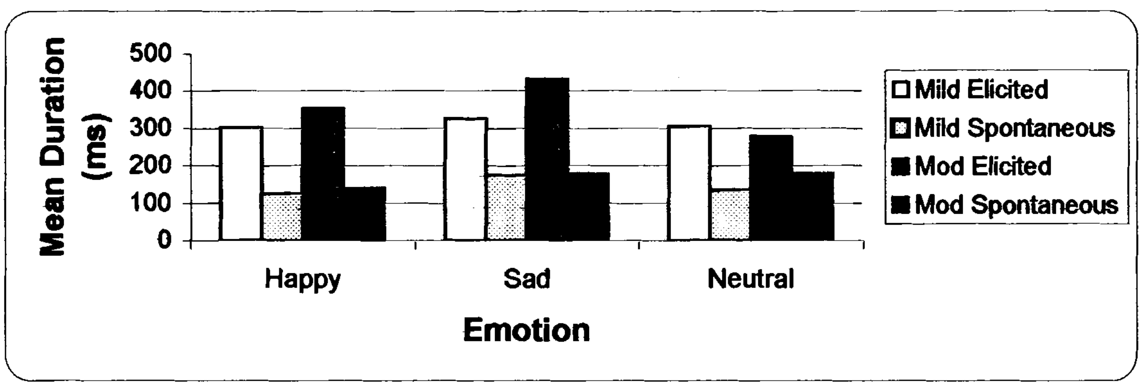

Figure 4. Mean duration of syllables for elicited and spontaneous sentences.

The moderate AOS subject's productions of spontaneous happy, sad, and neutral sentences were all produced with shorter mean durations when compared to her elicited happy, sad, and neutral sentences. Within the spontaneous utterances, the moderate AOS subject's happy sentences were produced with the shortest mean duration, followed by the sad and neutral sentences (respectively).

Research has shown that happy emotion is often produced with shorter mean durations of syllables, while sad and neutral sentences are produced with longer mean durations (e.g., Bachorowski & Owen, 1995). Both the mild and moderate AOS subjects produced syllable duration patterns consistent with the research in the non-brain damaged population. During spontaneous speech, both AOS subjects produced shorter mean syllable durations for the happy sentences, and longer mean syllable durations for the sad and neutral sentences. These findings imply that the mild and moderate AOS subjects were able to produce the acoustic cues within syllable durations when signaling happy, sad, and neutral emotional intent, similar to individuals without brain damage.

A comparison between the total duration of spontaneous sentences and elicited sentences was not performed as the spontaneous sentences did not contain the same constraints in terms of number of words and syllables as the elicited sentences. In addition, a comparison between the mean and SD of amplitude of spontaneous sentences and elicited sentences was not performed due to decreased intensity of some of the spontaneous utterances when the subject was not wearing the head set.

The analyses of the spontaneous sentences indicated that both the mild and moderate AOS subjects may be able to produce some acoustic cues to signal emotion in ways similar to individuals who do not have brain damage. The mild AOS subject was able to produce the acoustic cue of mean syllable duration with emotional intent, similarly to individuals without brain damage. The moderate AOS subject produced the acoustic cues of mean FO, SD of FO, syllable duration, and progressive inclination/ declination of the FO which conveys emotional intent, similarly to individuals within the non-brain damaged population. However, the degree to which these acoustic cues can signal specific types of emotion could not be ascertained based on the descriptive analyses that were performed and small sample size.

GENERAL DISCUSSION

The purpose of this study was to examine the ability of two subjects with varying severities of AOS to volitionally produce specific prosodic features that perform the paralinguistic function of portraying happy and sad emotions. Analyses were performed to determine if the acoustic characteristics of the prosodic structures that convey emotion are retained in the verbal expression of subjects with varying severities of AOS, thus enabling naïve listeners to understand this aspect of meaning. Four experiments were designed to assess the abilities of a subject with mild and a subject with moderate AOS to produce emotional prosody and to identify the acoustic features that naïve listeners use to perceive emotion in utterances produced by AOS speakers. One experiment involved the acoustic analysis of the production of emotional phrases by a normal and the AOS subjects elicited through verbatim repetition of semantically neutral sentences. In a second experiment, the subjects were asked to read a short story (4 sentences) that portrayed either a happy or sad emotion. The final two experiments involved naïve listeners who were asked to judge the productions of the AOS and normal speakers from the previous experiments in terms of which emotion was being expressed.

Although the normal speaker produced acoustic cues sufficient to convey different emotions identified by naïve listeners, the AOS subjects did not. The findings from Experiment 1 revealed that the normal subject produced differences in prosodic structures to convey happy vs. sad or neutral emotional intent. These differences were found in mean FO, SD of FO, total sentence duration, mean amplitude, and progressive inclination/declination of FO across sentences. No differences were found between sad and neutral sentences. The mild and moderate AOS subjects were unable to produce any of the acoustic parameters that signal differences in emotion.

The findings for Experiment 2 were comparable to Experiment 1, although the normal subject produced differences only in two acoustic parameters (mean FO and mean amplitude) to signal emotional intent. Again, both the mild and moderate AOS subjects were unable to produce acoustic variations to signal differences in emotion.

The difficulty producing the acoustic parameters to signal emotion during Experiment 1 and Experiment 2, that was experienced by the mild and moderate AOS subjects, was probably attributed to apraxic errors that contributed to the disruption of prosody as seen in lack of differences in the FO, duration and amplitude means and variability. These results are consistent with Kent and Rosenbek's (1983) findings that reveal prosodic abnormalities in AOS including: slow speaking rate, increased mean duration of syllables, and reduced intensity. In addition to the AOS subjects' difficulty producing the sentences due to the nature of their apraxia, aphasia also played a role in their verbal productions (e.g., paraphasias, word finding difficulties). During Experiment 1, the mild and moderate AOS subjects presented 55% and 69%

apraxic involvement in their verbal productions (respectively). Although these figures reflect a greater involvement of apraxia than aphasia, there is still evidence to suggest aphasia involvement.

Experiments 3 and 4 were developed to see if naïve listeners were able to correctly identify the intended emotion of the sentences produced by the three subjects in Experiments 1 and 2. Based on Experiments 1 and 2, it would be expected that the naïve listeners would be able to correctly identify the normal subject's sentences, but have difficulty identify the mild and moderate AOS subjects' productions. This was mostly true. Experiment 3 revealed that the naïve listeners were able to correctly identify the normal subject's productions as happy, sad, and neutral sentences with percentages greater than chance. Further more, naïve listeners had difficulty identifying between the happy, sad and neutral utterances of both AOS subjects. A higher percentage of accuracy in identifying neutral sentences of the mild AOS subject was attributed to a default response strategy (when in doubt, select neutral), which artificially inflated the percentage for identification of the neutral sentences.

The findings from Experiment 4 were similar to those of Experiment 3. Naïve listeners were able to correctly identify the normal subject's happy and sad sentences. Although the naïve listeners were guessing, the mild AOS subject's happy sentences were correctly identified with 76% accuracy. Reasons for the mild AOS subject's happy sentences being correctly identified are unknown. Naïve listeners were unable to identify the difference between the happy and sad sentences produced by the moderate AOS subject.

In addition to the analyses of the two production and two identification experiments, analyses also were completed on happy, sad, and neutral sentences produced by the mild and moderate AOS subjects during spontaneous speech. These additional sentences were collected and analyzed to determine if the AOS subjects had greater success in producing the acoustic parameters associated with a happy, sad, or neutral emotion in spontaneous rather than in elicited utterances. Comparisons between the mild AOS subject's elicited and spontaneous sentences produced some unusual patterns that at the very least suggest that this subject may have produced differences in mean syllable durations to convey emotion. During spontaneous speech, the moderate AOS subject was able to produce differences in mean syllable durations, SD of FO, mean FO, and progressive inclination/declination of FO across the sentence to signal happy, sad, and neutral emotions. These additional analyses suggest that the mild and moderate AOS subjects are able to produce some acoustic cues when expressing emotion, a result consistent with previous research in this area with the non-brain damaged population. It is uncertain whether the acoustic cues produced by the AOS subjects are sufficient to convey emotion, as no inferential statistical analyses were performed. The AOS subjects' ability to produce prosodic cues during spontaneous speech to signal emotion encourages further research.

Although the supplementary findings suggest that the AOS subjects may be producing some acoustic cues to express emotion, other findings suggest that extralinguistic cues to signal emotion also were present in both AOS subjects. Throughout the testing, the mild apraxic accurately used sound effects (e.g., vocalizations), crying, and complete phrase responses during conversation (e.g., "It doesn't sound right", "Let me say that one again", and "No, lost that one. Gee that's funny!") to help her express herself. Additionally, the mild AOS subject seemed to produce mixed cues (paralinguistic along with extralinguistic) on several occasions. For example, when discussing a sad topic, the mild AOS subject often ended her statement with a laugh, or she would produce a neutral/sad sentence followed by a laugh (cueing the listener to perceive the sentence as happy!). These mixed cues were also noted in the moderate AOS subject. She smiling appropriately throughout the session, laughed a lot, responded to jokes with, "Oh, boy!", demonstrated a sense of humor, and frequently used automatic phrases (e.g., " I can't say that one, it gets stuck!") It can even be speculated that the AOS subjects may be using extralinguistic cues to help compensate for their difficulties producing paralinguistic cues to express themselves.

It is acknowledged that this study has limitations and generalization of these results is cautioned. This study addressed the production of emotional prosody in only two AOS subjects where a limited number (12) acoustic parameters were identified and analyzed. The sample size and data sets were small. Furthermore, repetition and reading elicitation procedures were utilized which may have interfered with the AOS subjects' abilities to produce acoustic cues to signal emotion as seen in their spontaneous utterances.

This study may provide a foundation for future research addressing the production of emotional prosody in AOS speakers. Future studies may include AOS subjects with co-existing aphasia and aphasic subjects without AOS to assist in differentiating between apraxic and aphasic deficits that limit the production of prosodic cues that convey emotion. Other acoustic parameters than those addressed in this study may be analyzed. In addition, research comparing strategies used by AOS subjects to convey emotion through the production of paralinguistic cues (e.g., prosody) and extralinguistic cues (e.g., facial expression) is encouraged.

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APPENDIX A: EXPERIMENT 1

Table A.1. Articulation load of stimulus sentences for Experiment 1. The columns indicate the total number of plosives, fricatives, and affricates that were contained within each stimulus sentence.

#	Sentence	Plosives	Fricatives	Affricates	Total
1	The car turns the corner.	3	3	0	6
2	The cake is yellow.	2	2	0	4
3	Sarah is looking at Aaron.	2	2	0	4
4	The lucky number is three.	2	3	0	5
5	The letter arrives Monday.	2	2	0	4
6	Tom calls my name.	1	2	0	3
7	The plane flies away.	2	2	0	4
8	The girl is walking.	2	2	0	4
9	The boy raises his hand.	2	4	0	6
10	The girl shakes her head.	3	3	0	6
11	The price is one dollar.	2	3	0	5
12	Sam is a dog.	2	2	0	4

Table A.2. The acoustic measurements of the normal subject's productions on 7 parameters analyzed for Experiment 1.

	Fundamental Frequency			Duration		Amplitude	
Emotion Type	Mean FO (Hz)	SD of FO	Inc/Dec FO (Hz)	Mean Syllable Duration (ms)	Total Sentence Duration (ms)	Mean Amplitude (dB)	SD Amplitude
Happy	197	42	11.7	232	1310	61.5	12.7
Sad	169	25	-23.5	243	1610	58	12
Neutral	177	24	-39.6	218	1440	60.6	11.8

Table A.3 The acoustic measurements of the mild subject's productions on 7 parameters analyzed for Experiment 1.

	Fundamental Frequency			Duration		Amplitude	
Emotion Type	Mean FO (Hz)	SD of FO	Inc/Dec FO (Hz)	Mean Syllable Duration (ms)	Total Sentence Duration (ms)	Mean Amplitude (dB)	SD Amplitude
Happy	148	17	-22.9	316	3392	54.3	13.5
Sad	147	17	-30.4	330	3525	52.5	14.0
Neutral	146	17	-37.5	305	3825	56.0	13.8

Table A.4. The acoustic measurements of the moderate subject's productions on 7 parameters analyzed for Experiment 1.

	Fundamental Frequency			Duration		Amplitude	
Emotion Type	Mean FO (Hz)	SD of FO	Inc/Dec FO (Hz)	Mean Syllable Duration (ms)	Total Sentence Duration (ms)	Mean Amplitude (dB)	SD Amplitude
Happy	140	14	N/A*	357	4000	47.2	17.1
Sad	148	30	N/A*	428	N/A*	43.0	15.7
Neutral	142	20	N/A*	278	4434	54.4	14.9

* Due to limited number of syllables and/or lack of final syllables produced by the moderate AOS subject during Experiment 1, results were unable to be calculated

APPENDIX B: EXPERIMENT 2

Table B.1. Articulatory load of sentences for Experiment 2. Columns indicate total number of plosive, fricative and affricate phonemes contained within each stimulus sentence.

	Sentence	Plosives	Fricatives	Affricates	Total
1.1.1	Dave bends on one knee.	4	2	0	6
1.1.2	He shows her the ring.	1	3	0	4
1.1.3	She smiles.	0	3	0	3
1.1.4	He takes her hand.	3	0	0	3
1.2.1	He saw the accident.	3	3	0	6
1.2.2	He starts to cry.	4	1	0	5
1.2.3	The girl is hurt.	2	2	0	4
1.2.4	He takes her hand.	3	0	0	3
2.1.1	Nell finished the race.	1	4	0	5
2.1.2	She won the gold medal.	3	2	0	5
2.1.3	The press was there.	1	3	0	4
2.1.4	She reads the story.	2	4	0	6
2.2.1	Nell gets the paper.	4	2	0	6
2.2.2	There had been a crash.	3	2	0	5
2.2.3	A child died.	3	0	1	4
2.2.4	She reads the story.	2	4	0	6
3.1.1	The parade is coming.	3	2	0	5
3.1.2	The boy hears the music.	2	4	0	6
3.1.3	He can see the balloons.	2	3	0	5
3.1.4	He looks out the window.	3	2	0	5
3.2.1	Mom and dad are fighting.	4	1	0	3
3.2.2	Dad leaves.	2	2	0	4
3.2.3	The boy cries.	2	2	0	4
3.2.4	He looks out the window.	3	2	0	5
4.1.1	It is BINGO night.	4	1	0	5
4.1.2	Everyone is there.	0	3	0	3
4.1.3	Mary wins five hundred dollars.	3	4	0	7
4.1.4	She leaves the church.	0	4	2	6

4.2.1	Ron died at age five.	4	2	0	6
4.2.2	His funeral is over.	0	4	0	4
4.2.3	His mom is crying.	1	2	0	3
4.2.4	She leaves the church.	0	4	2	6
5.1.1	Today Sarah receives her degree.	4	3	0	7
5.1.2	She walks to the front.	3	4	0	7
5.1.3	Neil hands Sarah her degree.	3	2	0	5
5.1.4	Sarah shakes his hand.	2	6	0	8
5.2.1	Sarah's mom died.	2	2	0	4
5.2.2	The funeral is today.	2	3	0	5
5.2.3	John is here saying good-bye.	3	2	1	6
5.2.4	Sarah shakes his hand.	2	6	0	8
6.1.1	Sarah turns three today.	3	3	0	6
6.1.2	She is having a party.	2	3	0	5
6.1.3	There is a clown.	1	2	0	3
6.1.4	Neil takes a picture.	3	1	1	5
6.2.1	Neil is watching his son.	0	3	1	4
6.2.2	His son strikes out.	3	4	0	7
6.2.3	His son's team loses.	1	5	0	6
6.2.4	Neil takes a picture.	3	1	1	5
7.1.1	Sarah receives a letter.	1	3	0	4
7.1.2	She opens it.	2	1	0	3
7.1.3	She won five million dollars.	1	4	0	5
7.1.4	Sarah goes to tell her mom.	3	2	0	5
7.2.1	There was an accident.	3	3	0	7
7.2.2	Three people are hurt.	3	1	0	4
7.2.3	The police arrive.	1	3	0	4
7.2.4	Sarah goes to tell her mom.	3	2	0	5
8.1.1	Mel is failing math.	0	3	0	3
8.1.2	He gets all Ds.	4	3	0	7
8.1.3	Friday, he had his final exam.	3	4	0	7
8.1.4	He got a B.	3	0	0	3
8.2.1	Mel got all As.	2	1	0	3

8.2.2	Friday he had his final exam.	3	4	0	7
8.2.3	He hoped for an A.	2	0	0	2
8.2.4	He got a B.	3	0	0	3
9.1.1	The family is leaving for camp.	2	5	0	7
9.1.2	They pack up their stuff.	4	3	0	7
9.1.3	They are ready to leave.	2	2	0	4
9.1.4	They pack the car.	3	2	0	5
9.2.1	Dad lost his job.	4	2	0	6
9.2.2	The house is up for sale.	1	5	0	6
9.2.3	The family has to move.	1	4	0	5
9.2.4	They pack the car.	3	2	0	5
10.1.1	Mary just gave birth.	3	3	1	7
10.1.2	It is a boy.	2	1	0	3
10.1.3	They pack up their stuff.	4	3	0	7
10.1.4	The family leaves for home.	0	5	0	5
10.2.1	Dad is very sick.	3	2	0	5
10.2.2	No one can help him.	2	0	0	2
10.2.3	He dies during the night.	3	2	0	5
10.2.4	The family leaves for home.	0	5	0	5

Table B.2. The acoustic measurements of the normal subject's productions on 7 parameters analyzed for Experiment 2.

	Fundamental Frequency			Duration		Amplitude	
Emotion Type	Mean FO (Hz)	SD of FO	Inc/Dec FO (Hz)	Mean Syllable Duration (ms)	Total Sentence Duration (ms)	Mean Amplitude (dB)	SD Amplitude
Happy	192	33	-49.9	190	970	60	11.7
Sad	158	30	48.6	200	1110	57	11.2

Table B.3 The acoustic measurements of the mild subject's productions on 7 parameters analyzed for Experiment 2.

	Fundamental Frequency			Duration		Amplitude	
Emotion Type	Mean FO (Hz)	SD of FO	Inc/Dec FO (Hz)	Mean Syllable Duration (ms)	Total Sentence Duration (ms)	Mean Amplitude (dB)	SD Amplitude
Happy	142	22	-43.5	285	3255	52	11.7
Sad	144	16	-37.6	323	2588	53	12.0

Table B.4. The acoustic measurements of the moderate subject's productions on 7 parameters analyzed for Experiment 2.

	Fundamental Frequency			Duration		Amplitude	
Emotion Type	Mean FO (Hz)	SD of FO	Inc/Dec FO (Hz)	Mean Syllable Duration (ms)	Total Sentence Duration (ms)	Mean Amplitude (dB)	SD Amplitude
Happy	156	9	-42.0	349	4714	47	16.5
Sad	162	14	-40.1	436	5362	44	16.5

APPENDIX C: EXPERIMENT 3

Table C.1. Percentages of the naïve listeners' correct identifications of each subject's productions for Experiment 3.

	Normal Subject	Mild AOS	Moderate AOS
Happy	94%	31%	21%
Sad	54%	23%	38%
Neutral	78%	70%	44%

Table C.2. Breakdown of the incorrect identifications of sentences made by naïve listeners for Experiment 3. The three main columns represent each subject. The number in far left of column is total number of naïve listeners that misidentified the sentences (happy, sad, neutral as identified by far left column). Middle and right numbers in columns represent exact errors in identification (S= sad, H=happy, N=neural).

	Normal Subject			Mild AOS			Moderate AOS		
Happy	5/80	1(S)	4(N)	50/72	14(S)	36(N)	19/24	7(S)	12(N)
Sad	37/80	7(H)	30(N)	37/48	5(H)	32(N)	5/8	1(H)	4(N)
Neutral	18/80	2(H)	16(S)	19/64	7(H)	12(S)	18/32	3(H)	15(S)

APPENDIX D: EXPERIMENT 4

Table D.1. Percentages of the naïve listeners' correct identifications of each subject's productions for Experiment 4.

	Normal Subject	Mild AOS	Moderate AOS
Happy	89%	76%	31%
Sad	70%	45%	79%

Table D.2. Breakdown of the incorrect identifications of sentences made by naïve listeners for Experiment 4. The three main columns represent each subject. The number in the column is number of naïve listeners that misidentified the sentences and emotion it was misidentified for (S= sad, H=happy).

	Normal Subject	Mild AOS	Moderate AOS
Happy	9/80 (S)	17/72(S)	44/64(S)
Sad	24/80(H)	40/72(H)	15/72(H)

BIOGRAPHY OF THE AUTHOR

Steffany M. Van Putten, was born in Grand Rapids, Michigan on October 13, 1976. She was raised in Grand Rapids, Michigan and graduated from Grand Rapids Christian High School in 1994. She attended Central Michigan University and graduated in 1998 with a degree in Communication Disorders and French. She moved to Maine and entered the graduate program of the Communication Sciences and Disorders department.

After receiving her degree, Steffany will be continuing her position as a Speech-Language Pathologist at Eastern Maine Medical Center. Steffany is a candidate for the Master of Arts degree in Communication Sciences and Disorders from The University of Maine in May, 2001.