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Electropalatographic Measures of Stop Consonants in Speakers with and without Apraxia of Speech on Repeated Sampling Occasions

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Apraxia of speech (AOS) is an acquired motor speech disorder characterized by difficulty producing speech sounds caused by deficits in motor planning. Various tools exist to examine the physiologic aspects of articulation. Unfortunately, very few physiologic studies of AOS have been conducted. Electropalatography (EPG) is one method for examining the tongue's role in articulation by measuring tongue-to-palate contact. However, there is limited research examining the articulatory changes that are attributable to repeated exposure with wearing the pseudopalate as well as desensitization to the pseudopalate. The purpose of this investigation was to examine the impact of repeated measurement using EPG with and without desensitization. Three speakers with AOS and three with normal speech production participated in this study. Stimuli were composed of vowel–consonant–vowel nonsense words with four stop consonants /t, d, k, g/. Data were collected on three sampling occasions with a period of desensitization after the initial sampling occasion. EPG data analyses included maximal contact and variability index to compare performance across time and between populations. Overall, speakers with AOS exhibited greater variability for both measures compared with normal speakers. Findings indicate that desensitization did not result in any obvious changes in EPG measures on subsequent sampling occasions.

INTRODUCTION

Apraxia of speech (AOS) is an acquired motor speech disorder characterized by difficulty producing speech sounds caused by deficits in motor programming or planning. Knowledge of the physiologic, perceptual, and acoustic characteristics of the disorder should presumably lead to the development of more effective treatments. Despite the availability of tools to examine the physiologic aspects of articulation in AOS, few studies exist in this domain.

The tongue is considered the most important speech organ for the production of consonants and vowels (Whalen, Tiede, Ostry, Lehner-LHouilleir, Vatikiotis-Bateson, & Hailey, 2005). One method for examining the tongue's role in articulation is electropalatography (EPG). EPG involves the speaker wearing a pseudopalate, which is a custom-made acrylic plate embedded with a varying

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number of electrodes that fits tightly against the upper palate. The electrodes detect tongue-to-palate contacts, and signals are directed to an external processor through a lead out wire attached to a desktop or laptop computer. This enables the timing and location of tongue-to-palate contacts to be recorded, stored, and displayed. Furthermore, these palatal contacts are displayed in real time and can provide visual feedback to the speaker.

Electropalatography has been used to treat a variety of communication disorders. Several studies have demonstrated the utility of EPG in treating speech deficits associated with articulation or phonological disorders, cleft palate, hearing impairment, glossectomy, and dysarthria (Hardcastle, Gibbon, & Jones, 1991). EPG has had limited application in the evaluation and treatment of individuals with AOS and has only involved case study reports to illustrate EPG's utility in describing as well as improving disordered articulation in AOS (Hardcastle et al., 1991; Howard & Varley, 1995).

Electropalatography has also been used to evaluate tongue-to-palate contact of normal children and adults. The importance of normative EPG data has been recognized as being crucial for the development and interpretation of treatment research (McAuliffe, Ward, & Murdoch, 2001). Normative EPG data are becoming more readily available. Cheng, Murdoch, Goozee, & Scott (2007) examined the variability of tongue-to-palate contact in children, adolescents, and adults in repeated productions of words embedded in short sentences obtained in a single session. Dromey and Sanders (2009) examined variability in repeated productions in a single session for 20 speakers for 15 palatal consonants. Both studies provided data on variability in normal speakers that may be useful in understanding findings from disordered speakers.

However, there is limited research examining the articulatory changes that are attributable to repeated exposure with wearing the pseudopalate compared with the changes that are attributable to treatment. Although desensitization to the pseudopalate has been noted to be important (Cheng et al., 2007), data documenting the actual occurrence of desensitization, especially with disordered speakers, are not available. Furthermore, data pertaining to the reliability of repeated EPG measurements after documented desensitization are not available. The purpose of this investigation was to examine the impact of repeated measurement using EPG with and without desensitization on three sampling occasions in unimpaired speakers and speakers with AOS.

METHOD

Participants

Six individuals, three with AOS and aphasia (mean = 48 years; standard deviation [SD] = 14.5) and three with normal speech production (mean = 47 years; SD = 12.0) participated in the study with one man and two women in each group. All participants were right handed, native English speakers and passed a pure tone air conduction hearing screening at 35 dB at 500, 1000, 2000, and 3000 Hz in at least one ear. Participants reported no history of jaw problems, serious dental abnormalities, or speech disorders (i.e., premorbid speech problems for individuals with AOS and aphasia). The diagnosis of AOS was judged perceptually by an ASHA certified speech-language pathologist using the criteria established by McNeil, Robin, and Schmidt (2009) (i.e., difficulty producing speech sounds, consistently reduced rate of speech, segregated syllable production, and disturbed prosody). Individuals with AOS were not receiving speech/language treatment during their participation in this study. See Table 1 for participant characteristics and Table 2 for assessment results.

Procedures

Each participant had an impression of his or her upper palate taken from which a custom acrylic pseudopalate was created with 118 electrodes for tracking and recording tongue-to-palate contact.

Stimuli were elicited at three different sampling times over a 6-week period with each participant. Each sampling time was separated by 2 weeks. Data were collected in a quiet room using the LogoMetrix palatometer system to track and record tongue-to-palate contact along with a head-mounted microphone (AKG Acoustics C420) to capture the audio signal. Participants were asked to produce vowel–consonant–vowel (VCV) nonsense words following a model. Participants repeated the list of 15 nonsense words 10 times rather than repeating each word 10 times consecutively.

Before each data collection session, participants wore their pseudopalate for 15 to 20 minutes and

TABLE 1. Participant Characteristics

Characteristic	AOS-1	AOS-2	AOS-3	N-1	N-2	N-3
Age	38	42	65	38	40	61
Gender	Male	Female	Female	Male	Female	Female
Etiology	Stroke	Stroke	Stroke	N/A	N/A	N/A
MPO	48	36	38	N/A	N/A	N/A
Years of education	18	14	14	20	18	13
Occupation	Mortgage broker*	Data entry clerk*	Secretary*	Physician	Speech pathologist	Secretary

*Former occupation.
AOS = apraxia of speech; MPO = months post onset ; N/A = not applicable; N = normal.

TABLE 2. Assessment Results

Assessment Tool	AOS-1	AOS-2	AOS-3	N-1	N-2	N-3
Test of Non-Verbal Intelligence*						
Percentile ranking	66	70	86	84	79	24
Assessment of Intelligibility of Dysarthric Speech†						
Word level (%)	96	98	98	98	92	98
Apraxia Battery for Adults-2‡						
Level of impairment	Mild AOS	Mild to moderate AOS	Mild AOS	N/A	N/A	N/A
Western Aphasia Battery§						
Aphasia quotient	91.8	76.5	91.6	N/A	N/A	N/A
Classification	Anomic	Anomic	Anomic	N/A	N/A	N/A

*Brown, Sherbenou, and Johnsen, 1997.
†Yorkston and Beukelman, 1981.
‡Dabul, 2000.
§Kertesz, 1982.
AOS = apraxia of speech; N/A = not applicable.

were engaged in conversation. This allowed the participant to adapt to the presence of the pseudopalate. Before the second sampling occasion, participants wore a practice palate (i.e., acrylic palate without electrodes) on three occasions for 2 hours for the purpose of desensitization.

Experimental Stimuli

The experimental stimuli from Dromey and Sanders (2009) were used in this investigation. Stimuli consisted of 15 consonants, each in the context of three corner vowels /i, ɑ, u/ in the final position of VCV nonsense words. The initial vowel for each word was a schwa in order to place the tongue in a neutral position before each consonant. However, for this investigation, only a subset of stimuli are presented (four stop consonants /t, d, k, g/ in one vowel context /ɑ/). Thus, 40 productions per sampling occasion resulted in 120 tokens for each participant for a total of 720 tokens for the current analysis.

Data Analyses

All consonant tokens were analyzed perceptually using broad phonetic transcription via audio recordings. Only perceptually accurate tokens were used. When an error did occur on a token, an alternate token was used. Alternate tokens were used to replace just over 1% of the data. EPG analyses included maximal contact and variability index. The maximal contact frame (i.e., the instant at which the highest number of electrodes are activated by the speaker) was used as the representative frame for each consonant production. A total was also calculated for each electrode and represents the number of times across the 10 tokens for each consonant that a given electrode was activated by tongue contact. Then variability index (VI) was calculated by taking the ratio of number of totals that were not zeros or 10s to the total number of electrodes (118). The ratio was multiplied by 100 for convenience. VI provided a measure to quantify variability with a low VI indicating consistent contact and a higher VI indicating less consistent contact.

RESULTS

The overall mean maximal contact and standard deviations for both groups across the three sampling occasions are displayed in Figure 1. The overall mean maximal contact for speakers with AOS ranged from 42 to 47. For normal speakers, the overall mean maximal contact ranged from 52 to 53. Normal speakers had a higher overall mean maximal contact at each sampling occasion, but speakers with AOS exhibited more variability. This same pattern was observed for each stop consonant; however, both groups exhibited a similar amount of variability for /d/.

The overall mean VI was similar for both groups across the three sampling occasions with means ranging from 22 to 25. Figure 2 displays the overall mean VI and standard error for both groups across sampling occasions. Although the overall mean VI was comparable between the two groups across sampling times, speakers with AOS exhibited greater variability with larger values for standard error at each sampling time. For individual stop consonants, patterns were observed for each group. Speakers with AOS exhibited greater variability for /t/ and /d/ across sampling occasions. Conversely, normal speakers exhibited more variability at each sampling occasion for /k/ and /g/ in comparison to speakers with AOS.

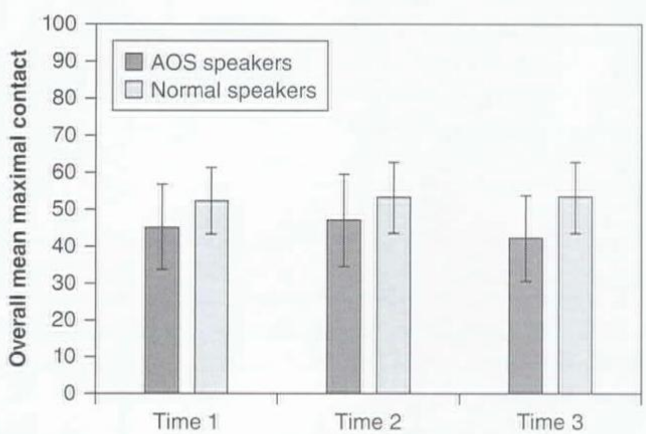

Figure 1. Overall mean maximal contact and standard deviation (error bars) for speakers with apraxia of speech (AOS) and normal speakers across the three sampling occasions.

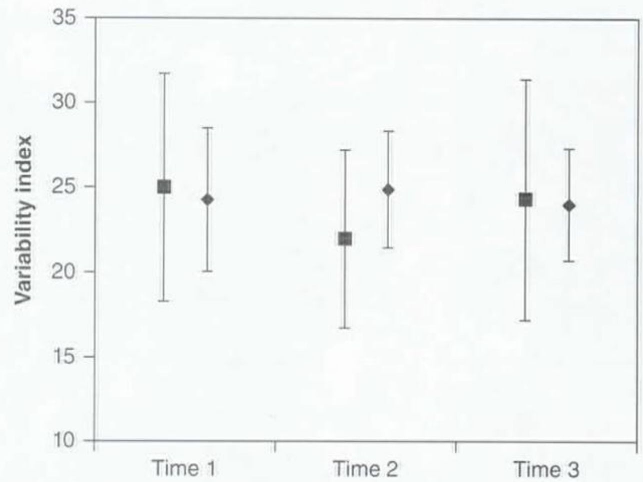

Figure 2. Overall mean and standard error for variability index for speakers with apraxia of speech (*squares*) and normal speakers (*diamonds*) across the three sampling occasions.

DISCUSSION

This investigation examined the impact of repeated measurements using EPG with and without desensitization on three sampling occasions in unimpaired speakers and speakers with AOS. The mean values for maximal contact were different between the two groups; however, these values were consistent across sampling occasions, and the same pattern was observed for individual consonants. Interestingly, both groups exhibited greater variability for /d/ across sampling occasions, which is similar to findings by Dromey and Sanders (2009) examining variability in normal speakers in a single session.

The overall mean VI was similar for both groups across sampling occasions; however, speakers with AOS exhibited more variability with greater values for standard error. These findings are similar to the results of other physiologic studies involving speakers with AOS (McNeil et al., 2009). For individual consonants, speakers with AOS exhibited more variability for alveolar consonants. These results are similar to findings by Dromey and Sanders (2009), who found that alveolar stops tended to be more variable than velars in their sample of college-aged speakers. However, in the present investigation, normal speakers exhibited the opposite pattern with greater variability on velar stops. These findings differ from those of Dromey and Sanders, who reported greater variability for alveolar stops. The difference in findings may be attributable to the small sample size as well as the age of speakers in the present investigation. This study only involved three normal speakers with a mean age of 47 years compared with 20 speakers with a mean age of 25 years in the study conducted by Dromey and Sanders (2009).

In this investigation, findings indicate that desensitization did not appear to have a significant influence on maximal contact or VI for either group of speakers. The desensitization task carried out after the first sampling occasion did not result in any obvious changes for these EPG measures on subsequent sampling occasions. Although findings revealed differences between the two groups, these differences were consistent across sampling occasions, suggesting that desensitization did not have an effect on the speakers in this investigation. This study was one of the first to examine the impact of repeated measurements using EPG with and without desensitization on repeated sampling occasions in speakers with AOS as well as normal speakers. Certainly, additional research is needed to further examine the issue of desensitization in both normal and disordered speakers.

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