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PHONETIC AND ACOUSTIC ANALYSES OF TWO NEW CASES OF FOREIGN ACCENT SYNDROME

by

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B.S. University of Central Florida, 2005

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ABSTRACT

This study presents detailed phonetic and acoustic analyses of the speech characteristics of two new cases of Foreign Accent Syndrome (FAS). Participants include a 48-year-old female who began speaking with an "Eastern European" accent following a traumatic brain injury, and a 45-year-old male who presented with a "British" accent following a subcortical cerebral vascular accident (CVA). Identical samples of the participants' pre- and post-morbid speech were obtained, thus affording a new level of control in the study of Foreign Accent Syndrome. The speech tasks consisted of oral readings of the *Grandfather Passage* and 18 real words comprised of the stop consonants /p/, /t/, /k/, /b/, /d/, /g/ combined with the peripheral vowels /i/, /a/ and /u/ and ending in a voiceless stop. Computer-based acoustic measures included: 1) voice onset time (VOT), 2) vowel durations, 3) whole word durations, 4) first, second and third formant frequencies, and 5) fundamental frequency. Formant frequencies were measured at three points in the vowel duration: a) 20%, b) 50%, and c) 80% to assess differences in vowel 'onglides' and 'offglides'. The phonetic analysis provided perceptual identification of the major phonetic features associated with the foreign quality of participant's FAS speech, while acoustic measures allowed precise quantification of these features. Results indicated evidence of backing of consonant and vowel productions for both participants. The implications for future research and clinical applications are also considered.

This project is dedicated to my family for their faithful support and encouragement throughout my education. To my mother and father, for showing me the value of hard work, self-discipline, and perseverance. To my sister, for her grace, generosity, and belief in my potential to achieve great things. And to my little brother, whose mere presence has helped me strive to become a better student, sister, and friend.

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CHAPTER 1: LITERATURE REVIEW

Foreign Accent Syndrome (FAS) is a rare neurological speech disorder characterized by an unlearned foreign accent following brain injury or stroke. Patients with FAS are known to produce phonetic speech features that are not found in their native language, but comply with the phonological rules of language in general (Blumstein, Alexander, Ryalls, Katz, & Dworetzky, 1987). To date, a few cases of FAS report concomitant diagnoses of aphasia (Ardila, Rosselli, & Ardila, 1988; Graff-Radford, Cooper, Colsher, & Damasio, 1986; Kurowski, Blumstein, & Alexander, 1996; Whitaker, 1982). However, it is important to distinguish FAS as a disorder characterized solely by impairment of speech, rather than one of language or cognition. As stated by Whitaker (1982): "Most aphasic patients retain their accent, or dialect, which they had prior to the onset of disease" (p. 195). A thorough review of the literature portrays FAS as a disorder characterized by some degree of variation in symptomatology, etiology, and speech characteristics across case studies.

Monrad-Krohn (1947) authored the first well-known case of foreign accent syndrome. He described a 30-year-old Norwegian woman who, after being hit with a bomb shrapnel during an air raid in World War II, suffered a severe injury to the left fronto-temporo-parietal region of her brain. The patient lost consciousness and later exhibited symptoms of mild aphasia, right-sided hemiplegia, and multiple seizures. Subsequent to the accident she had developed speech characteristics that sounded German to native Norwegian listeners. Norway at the time had been under German occupation, which caused the patient rejection by members of her own

community. Being erroneously mistaken as German, she was refused service from strangers in local shops. Monrad-Krohn maintained that "dysprosody" or an altered melody of the patient's speech production was the underlying contributor to the perception of her foreign accent. Further notes on Monrad-Krohn's case (Ryalls & Reinvang, 1985) claim that the accent's German quality was due to the patient's inability to produce Norwegian pitch accents like a native speaker.

Whitaker (1982) reported a 30-year-old woman from Michigan who suffered a mild stroke from a presumed middle cerebral artery infarct. Though the site of lesion was not specified, it was speculated on the basis of clinical signs that the insult was in the face area of the motor cortex and its adjacent structures, including Broca's area. The patient lost consciousness and awoke with right arm motor difficulties, muteness, and later exhibited signs of speech apraxia and agrammatism. A phonetic analysis of spontaneous and elicited speech samples revealed consonant production errors (e.g., cluster simplification, deletion, alveolar fronting, and metathesis) and vowel production errors (e.g., vowel fronting and raising and non-reduction of vowels produced in unstressed syllables). According to Whitaker, the combination of these errors in speech resulted in the erroneous perception of a foreign accent (pp. 198; 206). Whitaker was the first to propose that this phenomenon be termed "foreign accent syndrome" (p. 195).

A detailed phonetic analysis of the patient's speech revealed the following changes: production of a trilled /r/; consonant cluster reduction (e.g., /kst/ → [ks]); simplification of affricates (/tʃ/ → [s] or [ʃ]); difficulty transitioning from unstressed words; final consonant deletion of /l/; devoicing of stops and fricatives (*beginning* → [bikɪnɪŋ]); non-reduced vowels in syllables that are normally unstressed; reduced aspiration of initial voiceless stops; dentalization

of /t/ in the initial position; monophthongization of vowels; deletion of /y/ and /w/; alveolar fronting (e.g., /kliŋgz/ → [klɪnz]); fronting of vowels (e.g., /hæv/ → [hɛv]) (Whitaker, 1982).

Concerning her reading difficulties, the patient made an important comment: "When I read to myself I read like I … not like I talk, like, uh, it goes through my mind, I guess like it used to" (p. 206). According to Whitaker (1982) this statement implies that a mental phonemic representation of speech is retained in spite of the foreign accent.

Graff-Radford, Cooper, Colsher, and Damasio (1986) were the first to suggest a tense speech posture as a possible contributor to vowel changes in FAS speech. They examined the speech of a 56-year-old American woman from Illinois who had suffered a left frontal infarction and subsequent transcortical aphasia. Approximately one month following the stroke, friends and family observed a "Nordic" quality to her speech. Using an audio speech sample that was recorded prior to the stroke, Graff-Radford and colleagues were able to compare properties of the patient's speech both with and without the foreign accent. The accent was characterized by a phonetic analysis of free conversation that vowel changes (i.e., diphthongization, lengthening, and a shift toward the cardinal vowels /i/, /a/, and /u/) were ultimately responsible for the foreign quality of her speech. Vowel shifting (e.g., /ɪ/ → [i], /æ/ → [a], /a/ → [o], and /ə/ → [o]) was explained as an increase in tension of the vocal posture. At the sentential level, duration measures revealed a thirty percent increase in discourse length due to unnecessary pauses between words and lengthening of utterance-final words. The patient also used a restricted range and variation in fundamental frequency contours, reflected by below normal valley measures (60%) at the terminal peaks of sentences.

The most comprehensive study of FAS to date was published in 1987 by Blumstein, Alexander, Ryalls, Katz, and Dworetzky. These authors presented the case of a 62-year-old

native-born Bostonian woman who suffered several small lesions to the brain, possibly infarcts. Lesion sites included left hemisphere sensory-motor cortex, left middle frontal gyrus, left temporal frontal gyrus, and right middle frontal gyrus. Acoustic analyses revealed the extent to which the patient's speech differed from a normal American English accent. Both segmental and suprasegmental measures were performed.

Segmental measures included consonant voicing, place of production, manner of production, and vowel quality. Characteristic of Standard English, voiceless stops /p/, /t/, and /k/ were aspirated, and the place of articulation for /t/ and /d/ remained alveolar. However, word-initial voiced stops were prevoiced, and were often preceded by an epenthetic vowel. Monosyllabic CVC utterances typically ended with an epenthetic vowel, changing the utterance to the more canonical CVCV structure. Alveolar stops preceded by a stressed syllable were produced as full stops, rather than flaps. Tense vowel quality was also noted. Regarding suprasegmental features, the patient produced a rise in fundamental frequency at the end of statements and Wh-questions.

Blumstein and colleagues (1987) assert that the patient's primary disorder was one of speech prosody. However, the acoustic changes discussed were neither systematic nor characteristic of any one particular language, and therefore resulted in a "generic" foreign accent (p. 243). These acoustic changes support the hypothesis that FAS patients are perceived as having an accent (rather than a disorder) because their speech is comprised of features naturally found in the world's languages, however atypical of American English. In contrast, patients with Broca's aphasia or dysarthria typically exhibit speech errors that are heard as a "distortion" of natural language (p. 242). As stated earlier, FAS is considered a speech disorder independent of Broca's aphasia (Kurowski, Blumstein, and Alexander, 1996).

Gurd, Bessell, Bladon, and Bamford (1988) reported a 41-year-old right-handed woman who suffered an infarction to the left basal ganglia which resulted in right hemiplegia, facial weakness, and most significantly, a foreign accent similar to French or German. The infarct was located in the lentiform nucleus, and may have extended to the caudate nucleus. In addition to the foreign accent, speech was "dysphasic", characterized by slow, labored speech and low volume. Writing was severely impaired due to right-sided hemiplegia. Reading was unaffected, and unlike many reported cases of foreign accent syndrome, the speech was not agrammatic.

Two phonetic analyses (one three weeks post-onset, followed by another eight months later when speech had improved) were performed to demonstrate FAS speech changes over time. Changes in speech errors over the eight month period were observed in vowel and consonant sounds. An additional spectrographic analysis was conducted on productions of /r/ and /w/. Formant frequency plots (F1, F2, and F3) for both sounds showed productions outside the normal range for English speakers when taken 3 weeks post onset; then a shift toward normal productions at eight months post-onset. Overall, this indicates that abnormal /w/ and /r/ productions were key components in the patient's foreign accent. However, Gurd et al. (1988) maintain that it was the *variety* of erroneous speech sounds that accounted for listeners' inability to categorize the accent as belonging to one particular foreign language (p. 245-246).

In contrast to other cases, the patient's stress-timed rhythm and fundamental frequency contours remained normal. It was noted that such results concur with the notion that the right hemisphere, which is generally deemed accountable for prosodic qualities of speech, remained undamaged. The authors further stated that speakers of all languages are susceptible to making such errors such as "stopping of fricative /ð/, vowel quality errors, weak vowel strengthening, and intonation errors" (p. 244). Similar to Blumstein et al. (1987), these normal phonological

processes explain why the patient was perceived as a foreign speaker rather than having a speech disorder such as apraxia or dysarthria.

Ardila, Rosselli, and Ardila (1988) suggest that agrammatism is often a contributing factor in the perception of a foreign accent. They report a 26-year-old right-handed male with moderate Broca's aphasia, due to a vascular accident. Though the patient was a monolingual Spanish speaker from Colombia, his speech upon recovery consisted of acoustic characteristics similar to American English. A phonological analysis revealed the following changes in vowel production: lowering of vowels (e.g., /i/ → [e]), fronting of posterior vowels (e.g., /o/ → [e]), backing of anterior vowels (e.g., /i/ → [u]), omission of unstressed vowels, stressing of vowels in diphthongs, diphthongization of vowels, and insertion of vowels between consonants (epenthesis). Consonant changes often resulted in sounds not present in the Spanish language. For instance, the patient substituted stops for fricatives, fricatives for stops, changes in place of articulation, devoicing of stops, substitution of liquids for nasals, consonant cluster reduction, and omission of /h/ in the initial-word position.

The patient's speech was described as "aprosodic" due to intonation changes, slow and inconsistent rhythm, and inappropriate juncture between syllables (e.g., /suespálda/ → [sú espálda]) (p. 497). In concurrence with most non-native Spanish speakers, the patient exhibited speech errors such as confusion of /r/ with [γ], diphthongization of vowels, and failure to realize intervocalic voiced stops as fricatives (p. 497). These authors concluded that the accent was a result of: (1) a loss of verbal fluency; (2) phonetic changes; (3) suprasegmental errors (prosody), and (4) agrammatism (giving the listener the impression that the speaker is unaware of the grammatical rules of that particular language). These authors hypothesize, however, that the specific type of foreign accent spoken by the patient is at the discretion of each individual

listener, thereby rendering foreign accent syndrome an “epiphenomenon,” rather than a true aphasic phenomenon (pp. 497-498).

Moen’s (1990) Norwegian FAS patient was compared to Monrad-Krohn’s (1947) patient, both of whom were native speakers of the same Norwegian dialect. However, whereas Monrad-Krohn’s focus was the suprasegmental (i.e., prosodic) characteristics of his patient’s speech, Moen reported detailed segmental aspects as well. Analyses of spontaneous speech revealed deviations in consonant (e.g., /r/ and /l/) and vowel articulations in terms of duration, voicing, labialization, and tongue shape. Both patients presented with similar suprasegmental deviations, specifically a staccato speech rhythm and an abnormal pitch rises in utterance-final positions. Moen’s patient did not present with any language deficits such as word-finding difficulties or agrammatism.

Similar to the study by Graff-Radford and colleagues (1986), Ingram, McCormack, and Kennedy (1992) theorized that their FAS patient’s accent was the result of “a specific articulatory bias characteristic of a tense vocal tract setting” (p. 470). That is, the increased muscular tension of the vocal posture was thought to result in an altered vocal tract posture during speech production. A perceptual analysis of pre- and post-stroke speech was employed to determine phonetic speech changes of a 56 year old Brisbanian woman (Australia). Speech recordings were taken 13 to 15 months following the stroke and compared to an available recording that was made 12 months prior to the stroke. Multiple phonological processes for consonant productions were observed, the most prominent being strengthened consonant productions and devoicing of word-final obstruent sounds for the perception of the foreign accent. However, the most prominent resultant change was the reduction in acoustic vowel space during speech.

Kurowski, Blumstein, and Alexander (1996) analyzed the acoustic properties of stop consonant production, vowel quality, and prosody of a 45-year-old male patient from New York. The patient spoke with an accent similar to British, Scottish, Irish, or Eastern European following a left middle cerebral artery stroke. Prior to acoustic analyses, his accent was determined via listeners' perceptions to be the result of the following speech errors: 1) lax production of tense vowels, 2) vowel centralization (with the exception of /i/ and /u/), 3) weak production of diphthongs, 4) poor articulation of liquids /l/ and /r/, 5) non-reduction of voiced stops to flaps in the medial position, 6) heavy aspiration of voiceless stops, and 7) voiced stops produced as voiceless in the word-final position. In addition to speech disturbances, this patient was one of the few reported cases of FAS with a confirmed diagnosis of Broca's aphasia.

Kurowski and colleagues performed an acoustic analysis similar to that of the previous FAS study by Blumstein et al. (1987). However, in this study a premorbid speech sample was available for analysis. The sample was recorded prior to the patient's stroke and enabled "before" and "after" comparisons of acoustic-phonetic features.

Stop consonants were analyzed through (1) VOT measures of initial stop consonants /p t k b d g/, (2) place and manner of articulation by means of spectral analyses (Linear Predictive Coding) of initial stops /t/ and /d/, and (3) listener judgment of [t] and [d] production in the medial position. Measures were obtained using the same list of 30 monosyllabic words (each beginning with a stop consonant and was followed by the vowel /a/) as that of Blumstein and colleagues (1987). The results of consonant production revealed normal production of VOT for voiced and voiceless consonants. Findings of the spectral analysis for place of articulation revealed post-stroke production of [t] and [d] to be within normal limits and similar to pre-stroke

production. The manner of medial stop consonant production was judged by phonetically trained listeners. Results indicate that the majority of flaps were produced as full stops.

Vowel quality was assessed by vowel duration and formant frequency distribution. Results of vowel duration measures were within normal limits. However, formant frequency distribution of F1 and F2 showed vowel centralization during production of all vowels except [ɪ]. This finding is similar to Blumstein et al.'s study (1987), where a relatively low F1 was interpreted as a sign of reduced vowel space and indicates an abnormally tense vocal tract setting (p. 18).

Prosody measures were obtained from spontaneous and read speech samples and analyzed using pitch plots performed on a computer. Results indicated that long pauses between words comprised the patient's spontaneous speech. However, fundamental frequency patterns or pitch contours were normal, with appropriate falling intonation at the end of sentences. Furthermore, in contrast to results from Blumstein et al. (1987), the patient did not insert epenthetic vowels.

In conclusion, Kurowski and colleagues (1996) determined that the speech errors of their patient could not be characterized as a disturbance of prosody. Instead, abnormal vowel production appeared largely responsible for the patient's foreign accent. Finally, based on the irregularity of error patterns, these authors stated that the term "generic" could be used to describe the type of accent this patient produced.

Moonis and colleagues (1996) found both vowel quality and intonation to contribute to the perception of a "French" accent in their American FAS patient. A PET of their patient revealed a functional lesion not shown on MRI. Phonetic analyses of stop consonant and vowel production were performed. Consonant production was analyzed through VOT measures of

initial stop consonants in real words. Vowel quality was determined by formant frequency (F1 and F2) analysis of vowel production during spontaneous speech and phrase repetitions. Regarding intonation, fundamental frequency plots were also obtained through spontaneous speech and repeated phrases. All acoustic measures were compared to those of normal English speakers.

The results of the analyses revealed normal VOTs for all stop consonant productions compared to normal English speakers. This implies that consonant production for this patient did not contribute to perception of a foreign accent. Results for vowel quality demonstrated a reduction in overall vowel space, indicative of a more closed vocal tract posture than normal. However, formant frequency distributions were similar to that of normal speakers. Fundamental frequency pitch plots were found to be abnormal compared to normal English speakers. In contrast to the case by Graff-Radford et al. (1986), this patient spoke with an abnormally large range and variation of fundamental frequency across phrases and sentences. For example, Moonis et al. (1996) reported a rise in intonation at the end of declarative sentences and "unusually large pitch excursions" throughout production (p. 277).

Dankovičová et al. (2001) performed one of the most thorough phonological and acoustic analyses in a case of FAS using pre- and post-trauma speech samples for their analyses. Their patient was a 43 year old female patient from Southern Britain who, unlike most FAS cases, presented with *right* hemispheric damage due to a right middle cerebral artery infarct. As a result her accent changed from southern British to Scottish-sounding English. Both acoustic and phonological analyses were performed from a VHS recording of speech production prior to the stroke, and an audio tape recording of the patient reading the same passage 27 months following the stroke. The phonological analysis, which involved five professional phoneticians, four native

Scottish speakers, and 43 undergraduate students in a speech and language therapy program at a London university, indicated that the vast majority of participants identified the patient's speech as "Scottish-sounding". Perceptually, the phoneticians characterized the speech changes as an overall increase in vocal pitch, dysprosody, and shortening of diphthongs. However, acoustic analyses measuring changes in vowel quality, duration, rhythm, and fundamental frequency revealed somewhat different changes. It was determined that front vowels post-stroke were produced more peripherally, while back vowels had become more centralized. On average, overall word duration decreased, with a significant shortening of unstressed vowels in bisyllabic words. In contrast, consonants increased in duration. It was asserted that vowel shortening in conjunction with lengthened consonants contributed to the perception of altered rhythmic patterns. Measures of aspiration for initial stop consonant production rendered normal results. Measures of intonation patterns also rendered normal results.

Coelho and Robb (2001) examined the acoustic speech features of an FAS patient and interpreted their findings based on three explanatory models of speech behavior. The models, selected from a review of 16 previous FAS studies, acknowledge articulatory movement, motor speech control, and cognitive planning as major variables underlying the speech production errors typically found in FAS patients.

Their subject was a 51-year-old right-handed woman from Southern New England who experienced a small stroke. Shortly following the accident her accent was heard as "Italian" by listeners (p. 231). Speech was comprised of inconsistent vowel and consonant distortions, mild word-finding difficulty, and omission of articles *a* and *the* (agrammatism). Four speech features were measured, including 1) fundamental frequency, 2) formant frequencies F1 and F2, 3) formant transitions, and 4) VOT. All measurements were obtained from readings of a passage

or word tokens within and across three recording sessions using a Kay CSL-4300 system. The patient's mean fundamental frequency was found to be higher than that of normal female speakers of the same age, but remained within normal limits. Formant frequencies F1 and F2 were obtained from multiple recorded productions of the cardinal vowels /i, u, æ, a/ in the context of [hVt] words. F1 and F2 measures were obtained on an LPC spectrum and were found to be within normal range of production for all four vowels (Hillenbrand et al., 1995). However, a greater F1/F2 dispersion was observed in vowels [æ, a], by 320 and 500Hz, respectively. Also, F1 values were observed to be higher across all vowels compared to normal speakers (Peterson and Barney, 1952), which may be indicative of exaggerated tongue retraction during vowel production. Voice onset time (VOT) values were derived from multiple productions of the words [pVg] and [gVt] containing the vowels /i, a, u/. Average VOT measures for voiced and voiceless stop consonants were somewhat variable. Voiceless stops [p] were produced within normal limits, while voiced stops [g], were within normal limits for that of voiceless stop consonants (greater than 25 milliseconds).

Coelho and Robb (2001) interpreted their findings based on three explanatory models for FAS. The first model, presented by Moen (1990), suggests that the foreign quality of FAS speech is largely due to deviations in vowel production. Following neurological damage, the tongue's range of movement throughout the oral cavity is reduced. As a result, tongue setting is less accurate and vowel production falls short of the intended target. The second model refers to FAS as a "subset of apraxia of speech (AOS)" (Coelho & Robb, 2001, p. 230). Because symptoms of FAS are similar to those of AOS (e.g., abnormal VOT values) it is has been suggested that the two may be manifestations of the same impaired motor system(s) for speech planning and production. The third model, derived from a study by Whiteside and Varley

(1998), interprets FAS speech behavior as a breakdown in cognitive *planning*. Two cognitive planning "routes" by which speech is produced are described: a direct route and an indirect route (Coelho & Robb, 2001, p. 231). The *direct route* is activated during production of high-frequency words and renders articulatory movements that are smooth and fully integrated. The *indirect route*, which is activated during the production of low-frequency words, requires verbal-motor patterns to be reconfigured or assembled during each new production, resulting in articulation that is less precise. According to this model, individuals with FAS plan for speech using the less efficient indirect route to compensate for an impaired access to the direct route. As a result, speech characteristics are similar to that of speech apraxia.

In conclusion, all three of the aforementioned explanatory models of FAS were supported by this study. However, because acoustic variability was found to be a major characteristic of this patient's speech, Coelho and Robb (2001) favor the speech apraxia hypothesis. The authors suggest that a "unified model" of foreign accent syndrome be developed for identification and treatment approaches to the disorder.

Fridriksson, Ryalls, Rorden, Morgan, George, and Baylis (2005) employed diffusion tensor imaging (DTI), a relatively new MRI technique, to examine one mild case of FAS. The patient was a 45-year-old man from South Carolina who had recovered quickly from a left hemisphere stroke to the basal ganglia. Speech was subsequently heard as "French," "Greek," or "British English" by coworkers and friends (p. 320). Few language or motor deficits other than weak labial seal secondary to right facial weakness had occurred. However, word-final deletions or insertions (especially involving the /r/ phoneme) and vowel diphthongization influenced listener's perception of a "foreign" accent. DTI was performed during speech tasks and revealed an increase in neural activity in the patient's left motor area (specifically the central sulcus and

ventral angular gyrus). This suggests that the foreign accent was not a manifestation of speech apraxia, but perhaps a compensatory response to subcortical brain damage.

In one of the most recently published cases by Ryalls and Whiteside (2006), the authors describe a 57 year old Caucasian woman from Indiana who spoke with a British or Australian accent after experiencing a small lacunar infarct in the left internal capsule. The stroke resulted in right-sided paresis and minor difficulties with word-finding; however, language impairments did not constitute a diagnosis of aphasia.

Symptomatology for this particular patient was considered atypical of foreign accent syndrome for a number of reasons. First, the patient's average fundamental frequency had increased by approximately 50 dB following the stroke (200 Hz compared to 150 Hz). It was determined that this was due to a greater tension of the vocal folds and vocal tract posture. The second, more unusual symptom was the patient's new use of British expressions. For example, at one time she substituted the British term "lift" for "elevator" during natural conversation. Ryalls and Whiteside (2006) explained this behavior as "an effort on the part of the patient to make her word usage fit with her pronunciation" and was done so unintentionally (p. 159). Though FAS has traditionally been defined in terms of speech behavior, this case exemplifies the contribution of language abnormalities to the overall severity of the patient's perceived "foreign accent".

Recently, Miller, Lowit, and O'Sullivan (2006) aimed to identify the perceptual and acoustic features that make "foreign accent syndrome foreign" in their case study involving a woman from Tyneside, Britain. Their patient, "EJC", experienced a subarachnoid hemorrhage (SAH) due to a right anterior communicating artery aneurysm at the age of 60. One year following the SAH, EJC spoke with an accent that was described as "Italian" by her family

members and neurologist (p. 390). Four years post-onset, an oral examination revealed mildly impaired lip rounding, inadequate lip closure, and slowed diadokokinesis. She reported being unable to voluntarily modify her new accent. Language and cognitive testing yielded normal expressive and receptive abilities and some deficits in short-term memory.

A perceptual analysis was performed to investigate the degree of perceived “foreignness” of EJC’s accent compared to true foreign speakers (Greek, French, Pakistani, and Italian), speakers of British English, and a speaker with mild verbal apraxia. All nine speakers were age and gender matched and had learned to speak English in Tyneside, Britain. Previously recorded audio samples of single words and phrases produced by each speaker were played to native Tyneside listeners, who rated the speech according to degree of foreign quality. Results showed that while variability existed among listeners’ perceptions, participants were most likely to hear a foreign accent when changes occurred in speaker stress patterns, vowels, and use of schwa insertions. For example, a word-initial schwa insertion received higher average ratings of foreignness than a word-medial (specifically, interconsonantal) schwa insertion. The “locus” of these changes was also important in listeners’ perceptions of a foreign accent.

An in-depth phonetic analysis showed that RJC’s foreign accent was mainly characterized by changes in vowel quality (mostly due to changes in duration) and vowel omissions. Vowel quality and duration changes usually occurred in stressed syllable positions. Vowels in general were elongated. This was possibly due to “generally slower articulatory movement” (p. 399). Relatively speaking, vowel omissions showed a lack of consistency throughout speech production. Other inconsistent patterns, such as EJC’s tendency to monophthongize some vowels and diphthongize others, were also present. Cluster reduction and deaffrication accounted for the majority of her consonant changes.

Miller and colleagues (2006) concluded that the numerous and varying speech errors exhibited by this particular patient, in the absence of motor weakness, suggested an apraxic-ataxic speech disorder (p. 405). They further noted that it is difficult to determine whether the FAS speech characteristics in this case are core symptoms or simply compensatory strategies used consciously or unconsciously by the patient. For example, the patient's use of schwa insertion is a tactic commonly seen by speakers with apraxia and other motor speech disorders as an attempt to regain fluency and intelligibility (p. 406).

In Varley, Whiteside, and Hammill (2006), a 40 year old female, "S.D." from northern England began speaking with a "Swedish" accent following a CVA to the left hemisphere (p. 359). Immediate symptoms included non-fluent aphasia, apraxia of speech (AOS), and mild right-sided facial weakness. An investigation involving perceptual and acoustic analyses was performed two years following the incident. Raters transcribed and classified S.D.'s speech production errors during picture naming tasks and repetition of true and non-words. Errors included consonant and vowel substitutions, lengthening of consonants and vowels, consonant omissions, and equal stress placement on polysyllabic words (i.e., lengthening of unstressed syllables). An acoustic analysis involved measures of word duration and response latency of repetition tasks. S.D.'s most prevalent speech errors following both analyses were consistent with previously reported characteristics of FAS: vowel lengthening; word stress deviations (i.e., equal stress on polysyllabic words); consonant cluster lengthening (i.e., vowel epenthesis within clusters); and consonantal distortion. Accuracy of word production was shown to decrease as number of syllables increased. Other, less frequent errors occurred including consonant substitutions, wherein alveolar stops were inconsistently realized as velar stops in the word

medial position (e.g., /r/ produced as [w] or [l]); vowel and consonant epenthesis; cluster reduction; false starts; and shortening and distortions of vowels.

In summary, S.D. produced most speech errors on words with low imageability (non-words compared to true words), low frequency, and increased length. During repetition tasks, there was a significantly slower initiation of non-word production compared to true word production, suggesting that word imageability is a factor in speech performance. Also, accuracy of production was significantly lower for low frequency word forms. According to Varley and colleagues (2006), these later two findings suggest that this subject produced errors in both the conceptual-semantic (true versus non-words) and lexical (high- versus low-frequency words) levels of speech encoding, respectively. It is also possible that S.D. used compensatory mechanisms to maintain some degree of accuracy in speech output.

Di Dio, Schulz, and Gurd (2006) investigated whether Foreign Accent Syndrome is a syndrome that can be identified exclusively by listeners, or "in the ear of the beholder". That is, whether or not identification of the particular accent spoken by the patient is based solely upon listeners' perceptions. In their study, 52 "naive" judges were presented with spliced segments of connected speech produced by six British English and two FAS speakers. The British English speaking controls were of Scottish and French decent. All judges were native speakers of British English and were instructed to identify the spliced recordings as British or foreign. Results indicated that accent identification was poor, as evidenced by the fact that numerous accent types other than Scottish and French were identified. Among them included Polish, Indian, Portuguese, German, Chinese, Swedish, and Spanish accents, to name a few. Nonetheless, judges showed more consistency and accuracy in their ability to identify control (i.e., true

Scottish and French accents) than FAS accents. The high variability of FAS accent identification suggests that FAS cannot be identified exclusively based on “the ear of the beholder.”

In summary, a review of the literature portrays a small, yet growing number of case studies pertaining to foreign accent syndrome. Of them, relatively few (Blumstein et al., 1987; Coelho and Robb, 2001; Dankovičová et al., 2001; Ingram et al., 1992; Kurowski et al., 1996;) have involved detailed acoustic analyses of the speech properties of FAS speakers. More recent studies (Dankovičová et al., 2001; Ingram et al., 1992; Kurowski et al., 1996) have utilized pre- and post-trauma speech samples to investigate the acoustic changes that occur in speakers who acquire FAS.

To date, there are no reported studies that have investigated the acoustic or phonetic properties of an FAS patient who has reacquired his or her normal speech patterns in the same controlled speech task. Past studies have had to compare their acoustic results to either a spontaneous speech reading or to previously published average data.

Thus, the purpose of the present study is to (1) investigate the phonetic and acoustic properties of speech produced by two individuals with FAS; (2) determine whether a pattern of speech “errors” attributable to the overall perception of the foreign accent can be identified; and (3) add to the existing body of literature pertaining to FAS. Furthermore, this study will be unique to previous studies in that two identical speech samples will be obtained from each participant for acoustic-phonetic analyses (i.e., the first with the foreign accent, and a second after the patients have recovered their normal speech patterns). This will enable examination of the phonetic and acoustic changes in speech patterns, while each participant serves as his or her own control. This design allows us to specify exactly what acoustic changes result from FAS.

CHAPTER 2: METHOD

This study investigated the phonetic and acoustic properties of speech produced by two individuals with foreign accent syndrome. Two recorded samples of a controlled speech task were obtained from each participant: one of their respective "foreign" accents, and one of their speech following recovery from FAS. Comparisons were made between changes in FAS speech and recovered speech, thus enabling each participant to serve as his/her own control. First, a phonetic analysis was undertaken to determine if a pattern of phonological processes existed attributable to the foreign quality of each participant's accent. Second, an acoustic analysis of speech parameters was conducted through measures of voice onset time (VOT), vowel and word duration, formant frequency distribution, and fundamental frequency.

Participants

Two patients with foreign accent syndrome, one male and one female, participated in this study. Both participants presented with all four characteristics established by Whitaker (1982), who initially suggested the term "foreign accent syndrome": (1) the accent is considered by the patient, and by the investigator, to sound foreign; (2) the accent is unlike the individual's native dialect prior to cerebral insult; (3) the accent is clearly related to central nervous system damage; (4) and there is no evidence in the patient's background of being a speaker of a foreign language.

Female (J.D.)

Case History. The first participant, J.D., is a 48-year-old, right-handed Caucasian woman from Michigan who presently resides in Central Florida with her husband and two children. On March 26, 2004, J.D. was involved in a motor vehicle accident (MVA) which resulted in a head injury with concussion. A high-resolution 3T magnetic resonance imaging (MRI) scan on April 20, 2004 revealed "scattered foci of abnormal signal intensity in the more peripheral portions of the corona radiate and centrum semiovale bilaterally" and "a small venous angioma in the right frontal lobe extending through the corpus callosum". The lesion was judged ischemic in nature with the possibility of "white matter shearing injury". An EEG conducted on April 24, 2004, indicated normal brain wave activity.

Changes in Speech Patterns. J.D. is a monolingual English speaker with no history of foreign language exposure or instruction. Prior to the accident, she completed her high school education and worked as a secretary for various medical offices. In her medical case history report she used the term "Southern American" to describe her native speech. Immediately following the accident, she presented with speech that was slow, dysfluent, and comprised of single- and two-word utterances. Approximately one month later, J.D. reported an improvement in speech fluency, but with an associated "foreign" accent which was heard by listeners as "Eastern European". Agrammatic speech behaviors, characterized by the omission function words (i.e., articles, prepositions, and auxiliary verbs), existed concomitantly with the new accent. Furthermore, she was reported by her husband to exhibit noticeable affect and personality changes, such as irritability, memory loss, sensitivity to light and noise, and emotional detachment from family and friends.

Since the time of the accident, J.D. has reported several instances of normal speech recovery. Within the first two months following the accident her normal speech patterns returned twice for three-hour durations. During later stages of recovery her normal speech returned for periods lasting several days to several weeks. J.D. reported that the accent often returned or appeared worse during times of high stress or agitation, and was often concomitant with a decreased rate of speech, word-finding difficulties, and omission of function words.

Male (B.S.)

Case History. The second participant, B.S., is a 45-year-old right-handed Caucasian man from South Carolina. He sustained a subcortical, ischemic cerebrovascular accident (CVA) to the left cerebral hemisphere, which resulted in severely slurred speech output. Prior to the stroke B.S. obtained his high school diploma and worked as a salesman. He recovered quickly and returned to work with no symptoms other than mild right facial weakness and a noticeable foreign accent.

Changes in Speech Patterns. A six week post-stroke neuropsychological examination (as reported in Fridriksson, Ryalls, Rorden, Morgan, George, & Baylis, 2005) revealed no impairment of language, cognition, or evidence speech apraxia. However, family and community members heard a distinctive foreign accent when B.S. returned to work. Local listeners often disagreed on the "origin" of the accent, but most frequently reported hearing British English, French, or Greek.

Instrumentation

Audio recordings of the participants' speech were obtained in a quiet clinical environment. A Digital Audio Tape (DAT) recorder manufactured by Tascam DA-P1 and an AKG Acoustics C240 miniature condenser headset microphone (for the female) and a Shure SM57 microphone (for the male) were used to record acoustic stimuli. The microphone was placed at an approximate one inch distance diagonally to the corner of the mouth in accordance with user guide instructions.

Stimuli

A reading of the *Grandfather Passage* (Darley, Aronson, & Brown, 1975), a brief narrative containing all major vowel-consonant phoneme combinations in the English language, was employed as stimuli for a phonological/phonetic analysis of speech in connected discourse.

Stimuli for acoustic analyses were comprised of multiple productions of 18 real, monosyllabic English words of the CVC phonotactic structure. Words began with the six stop consonants, /p/, /t/, /k/, and /b/, /d/, /g/, followed by the peripheral vowels /i/, /a/, /u/, and ending with a voiceless stop consonant (See Table 1). The vowels were chosen to represent maximum differences in the relationship of tongue placement during production (from /i/, the highest front vowel, to /u/, the highest back vowel, and /a/, the lowest vowel). Each of the 18 words were elicited and recorded seven times for a total of 126 stimuli.

Table 1: Word and Vowel Stimuli for Acoustic Measurements

Vowel	Voiceless Stop Consonants			Voiced Stop Consonants		
	/p/	/t/	/k/	/b/	/d/	/g/
/i/	peat	teak	keep	beat	deep	geek
/a/	pot	tot	cot	bop	dot	got
/u/	poop	toot	coup	boot	dupe	goop

Procedure

Prior to recording, both participants were assured of their confidentiality and signed an informed consent form in the presence of a witness. The participants were also made aware that their participation in the project was voluntary, and that withdrawal could occur at any time.

Each participant was independently recorded in a quiet room while seated at a table. The experimenters familiarized the participant with the audio equipment, stimulus materials, and task procedures. Reading of stimulus words were practiced once prior to recording to ensure correct pronunciation.

Task

Participants read aloud from a typed list containing the 18 stimulus words in isolation. Each word was read seven times in a quasi-random order for a total of 126 tokens. Words were randomized to control for order of production of voiced versus voiceless stop consonants and tongue placement for vowels.

For the purpose of exploring acoustic and phonetic changes in FAS speech, both participants were recorded twice: once with their respective foreign accents, and again after normal speech patterns had returned. Before and after speech samples (henceforth referred to as

"FAS speech" and "recovered speech", respectively) were obtained using the same set of stimuli and recording procedures. This method allowed each participant to serve as his or her own control for comparison of speech changes brought on by FAS.

Phonetic Analysis

Two different analysis types were performed. First, a phonetic analysis was conducted of connected speech using "Before" and "After" recovered audio recordings of the *Grandfather Passage* (Darley, Aronson, & Brown, 1975). The samples were transcribed by two skilled listeners who had received formal training in phonetic transcription and analysis. The listeners transcribed all samples narrowly using the International Phonetic Alphabet (IPA) and came to a consensus on the transcription prior to further analysis. The transcriptions were then examined for changes in speech production patterns between FAS and recovered speech.

Acoustic Analysis

Acoustic analyses were performed using the 18 individual words recorded with FAS and recovered speech. Recorded data for both participants was digitized onto a hard disk at a sampling rate of 20 kHz, with 14 bits of amplitude resolution. Acoustic measurements of data were performed in the Speech Science Laboratory at the University of Central Florida's Department of Communication Sciences and Disorders using Brown Lab Interactive Speech System (BLISS) software version 6.01 (Mertus, 1999). BLISS was employed on a Dell PC equipped with a Zafiro sound card. Five accurate productions out of the seven repetitions were used for acoustic analyses. A total of 90 (5 x 18) tokens were thus used for the acoustic

measures. The remaining two samples served as a backup in the case of intrusive noise or incorrect production of target words. The selected samples for analysis were segmented by word and saved to separate audio files on the PC hard drive.

Duration Analyses

VOT. Voice onset time (VOT) measurements of initial stop consonants were performed using visual and auditory cues from the BLISS waveform display. The left cursor was placed at the beginning of the consonant burst. The right cursor was placed at the peak of the first periodic cycle of voicing following the burst, which was judged to mark the onset of the vowel. Duration of the segmented interval between the burst release and the onset of voicing was recorded in milliseconds.

Vowel Duration. Duration measurements were obtained at both the segmental (i.e., vowel) and suprasegmental (i.e., word) level. Vowel duration was determined by placing the left and right cursors at the respective points of the vowel onset and offset. The vowel onset was visually identified as the peak of the first cycle of the vowel waveform following the burst release of the initial stop consonant. The offset of the vowel was visually identified as the point at which the arc of the amplitude envelope from the top and bottom portions of the waveform intersected midline.

Word Duration. Word duration measurements were also obtained by segmenting the entire stimulus word. The left cursor was again placed at the beginning of the initial consonant burst. The right cursor was placed on the peak of last glottal pulse following the release of the final voiceless stop consonant. In addition to visual examination, the examiner listened to the audio portion between cursors to ensure that each duration interval was properly isolated.

Frequency Analyses

Fundamental Frequency. Fundamental frequency measures were derived from the center of each peripheral vowel (/i/, /a/, and /u/) in each of the 90 CVC word tokens. Average fundamental frequency values were be obtained across ten consecutive periods and then averaged for each vowel. For each measure, the left cursor was placed at the beginning of a selected period located at approximately 50% into the vowel duration. The beginning of the period was defined as the point at which the waveform crossed the horizontal midline. The right cursor was then placed at the end of the tenth consecutive period, thus segmenting the center 10 periods of the vowel. The end of the period is defined as the point at which the waveform again crossed midline to complete the cycle. The resultant value was divided by 10 to obtain the average fundamental frequency. The process was repeated across five repetitions of each of the 18 stimulus words.

Formant Frequencies. Information pertaining to formant frequency patterns were obtained using linear predictive coding (LPC) analysis. Formants one (F_1), two, (F_2), and three (F_3) were measured at the onglide (20% of total vowel duration), midpoint (50% of total vowel duration), and offglide (80% of total vowel duration) of each vowel (Armorer, 2003; Ferguson & Kewley-Port, 2002; Hillenbrand, Getty, Clark, & Wheeler, 1995). Measurements were derived by placing a 25.6 millisecond Hamming window at points representing 20%, 50%, and 80% of the vowel duration. The onglide, midpoint, and offglide points were determined by measuring the entire vowel duration and then multiplying the obtained value (in milliseconds) by .20, .50, and .80, respectively.

Reliability

In order to establish reliability, a total of 864 acoustic measures (10% of the total sample) were recalculated. To determine intra-rater reliability, the primary investigator of the study reanalyzed the data of one participant selected at random. To determine inter-rater reliability, a second investigator who had substantial experience using BLISS software for acoustical analyses reanalyzed the data of the remaining participant. The averages were then compared calculating Pearson product correlation coefficients to the data that was analyzed initially by the primary investigator for both inter- and intra-judge reliability.

Experimental Hypotheses

The hypotheses for this study were generated based on the results of previously published acoustic analyses of Foreign Accent Syndrome. Outcomes for each hypothesis will be addressed within the text of the Discussion.

1. Greater differences will be observed in frequency measures than temporal measures in FAS speech.

VOT of Initial Stop Consonant Production

2. Differences in VOT measures will be observed for stop consonants in FAS speech compared to recovered speech.

Vowel Duration

3. Longer average vowel duration will be observed in FAS speech compared to recovered speech.

Word Duration

4. Longer average word duration will be observed as a result of vowel elongation in FAS speech compared to that of recovered speech.

Formant Frequencies

5. A reduction in formant frequency differences (F_1 and F_2) for vowel production (i.e., vowel centralization) will be observed in FAS speech compared to recovered speech.
6. Significant differences will be observed in formant frequency values of FAS speech compared to recovered speech at the on-glide (20% of vowel duration) and off-glide (80% of vowel duration) of the vowel.

Fundamental Frequency

7. An increase in average fundamental frequency (fo) will be observed in FAS speech compared to recovered speech.

CHAPTER 3: RESULTS

Phonetic Analysis

The purpose of the phonetic analysis was to identify and describe a pattern of speech changes associated with the foreign quality of each participant's accent during an oral reading of the *Grandfather Passage* (Darley et al., 1975). Recordings of the participants' disordered speech were analyzed independently for phonetic errors and compared to identical readings obtained when their normal speech had recovered. To clarify, speech "errors" were defined as phonetic productions which (a) deviated from those of the participant's normal, or recovered speech, and (b) were considered atypical of American English speakers. The reported errors as follows were believed to contribute to the perceived foreign quality of the participants' FAS speech.

Changes in speech patterns were found to exist at the single phoneme (i.e., segmental) as well as prosodic (i.e., suprasegmental) levels. Segmental errors were atypical phonetic features associated with single consonants or vowels, while suprasegmental errors referred to atypical features of syllables, words, and connected speech (i.e., changes in fluency, rate of speech, juncture, and stress). The raw phonetic transcriptions of each participant's pre- and post-recovery speech samples can be found in Appendix A.

Total phonemic errors produced by each participant prior to normal speech recovery are presented in Table 2 below. Note that "Total Phonemes" refers to the number of phonemes produced by the participant during his/her reading of the Grandfather Passage. It would be expected, due to inherent dialectal variations, that the total phoneme count would vary slightly

per speaker. However, each participant produced a total of 454 phonemes. The female "J.D." produced 43 phonemic errors, resulting in an error rate of approximately 9 percent. The male "B.S." produced 24 phonemic errors, rendering an error rate of approximately 5 percent. This result alone suggests that the male participant was affected by FAS to a lesser degree.

Table 2: Phonemic Error Rate per Participant during Grandfather Passage Reading (with FAS)

	Phonemic Errors	Total Phonemes	Percent Error
Female	43	454	9%
Male	24	454	5%

Segmental Changes

Specific error productions and their transcriptions are listed as they occurred in individual words in Table 3 (consonants errors) and Table 4 (vowel errors) for each participant. Multiple productions of error words (i.e., those produced more than once throughout the reading) are indicated in parentheses.

Consonants. To begin, those consonants generally affected by the female's FAS included stops, fricatives, affricates and liquids. The voiceless stop /t/ was often fully released [t^h] in phonetic contexts where it is typically unaspirated [t] or unreleased [t˺] by American English speakers. For example, there were 7 occasions in which /t/ was fully released in the word-final position (e.g., *about* was produced as [əbaʊt^h]; *yet* as [jɛt^h]; and *bit* as [bɪt^h]). In addition, she failed to reduce /t/ to the alveolar flap [ɾ] or glottal stop [ʔ] when it occurred in the intervocalic position following a stressed syllable (e.g., *buttons* /bʌʔɪnz/ was produced as [bʌt^{h}ɪnz]).

Other consonant errors included reduction or deletion of consonant sounds. The interdental fricative /ð/ was either backed to a lingua-dental (e.g., *the* produced as [d̪ i]) or was omitted entirely (e.g., *with* reduced to [wɪ]). The affricate /tʃ/ was reduced to [ʃ] (e.g., *ancient* was produced as [æːnʃəntʰ]). Other instances of consonant deletion occurred in the final position of words in clusters (e.g., *and* produced as [æn]).

Regarding liquids, dark /ɫ/ productions replaced clear /l/ productions and visa-versa. Unlike a clear /l/, which is often realized pre-vocalically, a dark or neutralized /ɫ/ usually functions as a syllabic consonant in a word and is produced with a more posterior lingual contact (Small, 1999). However, J.D. appeared to violate this rule on several occasions. For example, *all* was produced as [oʊɫ], *well* as [wɪːɫ], *nearly* as [nɛrɫi], in addition to eight other occasions (see Table 3). One instance of /r/ trilling also occurred in the word *ninety-three* (heard as [naɪndiθr̗ i]).

Consonant errors in the male participant's FAS speech were generally less severe given that they were fewer in number and less varied than those of the female. Lingual place of production for the alveolar fricative /s/ was either slightly backed (e.g., [s̠ noʊ] for *snow*, [aɪs̠] for *ice*) or completely palatalized (e.g., [ʃloʊli] for *slowly*, [ʃmɑl] for *small*). Similar to the female, the male's voiceless stop /k/ was fully released when it occurred in the final position of stressed, monosyllabic words (e.g., *black* was produced as [blækʰ], and *frock* as [frɑkʰ]). He also clearly substituted the vowel [ɛ] in place of the entire word *and*.

Table 3: Consonant Errors

Error	Description	Word	Transcription
Female			
/t/ → [tʰ]	Released in word-final position	*about*	əbaʊtʰ
		yet	jɛtʰ
		ancient	æːnʃəntʰ
		coat	koʊtʰ
		bit	(x2) bɪtʰ
		short	ʃɔrtʰ
/ʔ/ → [tʰ]	Failure to reduce to flap/glottal stop following stressed vowel	*buttons*	bʌtʰɪnz
/tʃ/ → [ʃ]	Deaffricated	*ancient*	æːnʃəntʰ
/ð/→ [d̪]	Dentalized	*the*	d̪ i
/ð/→ __	Deleted final consonant	*with*	wɪ
/d/→ __		*and*	æn
/l/ → [ɫ]	Dark /ɫ/ substituted for clear /l/	*all*	oʊɫ
		well	wɪːɫ
		nearly	nɛrɫi
		old	oʊɫd
		still	stɪɫ
		himself	hɪmsɪɫf
		several	sɛvrɪɫ
		feeling	fiɫiŋ
		skillfully	skɪlfʊɫi
		small	smɑɫ
		oil	ɔɪɫ
/r/ → [rˏ]	Trilled	*ninety-three*	naɪndiθrˏ i
Male			
/s/ → [s̡]	Palatalized	*snow*	s̡ noʊ
		ice	aɪs̡
/s/ → [ʃ]		*slowly*	ʃloʊli
		small	ʃmɑl
/k/ → [kʰ]	Released in word-final position	*black*	blækʰ
		frock	frɑkʰ
/nd/ → __	Deleted final consonant	*and*	ɛ

Vowels. It appeared that changes in vowel production contributed the most to the perceived foreign accent in J.D's speech. Her vowels were characterized by atypical productions regarding manner and/or articulatory placement, epenthetic insertions, lengthening, diphthongization, and variable changes in vowel tenseness.

Changes in manner and place of production primarily included excessive lip rounding or fronting of certain vowels. Additional lip rounding was heard for productions of /ɑ/ which were often realized as [ɔ] or [oʊ]. Thus, the word *walk* was heard as [woʊk], *often* as [ɔftən], and *always* as [oʊwez].

Vocalic or syllabic /r/ productions were either weak, missed the target, or were omitted entirely. Changes included /ɝ/ and /ɚ/ produced as [ɑr] (*grandfather* as [grændfɑðɑr], *winter* as [wɛnt^{h}ɑr], and *urged* as [ɑrʤd]); /iɚ/ produced as [ɛr] (*years* as [jɛrz] and *nearly* as [nɛrɫi]); and /ɔr/ produced as [ɑr] (*organ* as [ɑrgæn]). Vocalic /r/ was once completely derhotacised (or perhaps "vowelized") in the word-final position of *ever* (produced as [ɛvɑ]).

A general pattern of vowel tensing (i.e., substitutions of tense vowels such as /i/ for lax vowels such as /ɛ/) was identified for the female. A prime example of this tendency was found in the first sentence of her reading. The sentence, produced with FAS as [ju wɪʃ t^{h}u̲ noʊ o̲ʊ̲l əbaʊt^h maɪ grændfɑðar] maintained a tense production of the vowels /u/ and /oʊ/ in place of the centralized or lax vowels /ə/ and /ɑ/. Following recovery, she reduced these vowels to the lax productions [ju wɪʃ tə̲ noʊ ɑ̲l əbaʊt˺ maɪ grænfɑðɚ] as is typical in connected speech. However, this feature was sometimes reversed such that lax vowels were substituted at times for tense

vowels, as in the vowels /ɛ/ and /ɪ/. The vowel /ɛ/ was raised to [ɪ] in stressed positions (*well* as [wɪːɫ], *except* as [ɪksɛpt]) and vice-versa (*winter* produced as [wɛntɑr]).

Other atypical vowel productions included vowel epenthesis, perhaps perceived as diphthongization, which occurred once with the word *him* (produced as [hiəm]). Also, words were often produced with increased duration of the stressed vowel, as heard in the words *well* ([wɪːɫ]), *ancient* [æːnʃənt^h], and the second syllable of *observe* [əbzɝːv].

It appeared that the majority of the male participant's speech errors were altered vowel productions. Similar to the female, epenthetic insertions were produced in word-final positions following a vowel (e.g., *pronounced* produced as [pronaʊnstə]). Changes to the rhotic /r/ vowels included weak or omitted productions, again in the final positions of words. Most often the syllabic /ɝ/ or /ɚ/ was completely reduced to the schwa [ə] following consonants at the end of a word (e.g., *grandfather* produced as [grænfɑðə], *ever* as [evə], *observe* as [əbzəv], etc.) and vowels in the middle of a word (*nearly* as [nɪəli], *years* as [jɪəz], *beard* as [bɪəd], etc.). Finally, triphthongization occurred on one occasion in the word *coat* (realized as [koʊɪt]).

Table 4: Vowel Errors

Error	Description	Word	Transcription
Female			
/ɚ/ → [ɑr]	Weak production/Missed target	*grandfather*	grændfɑðɑr
		winter	wɛntʰɑr
/ɝ/ → [ɑr]		*urged*	ɑrʤd
/iɚ/ → [ɛr]		*years*	jɛrz
		nearly	nɛrɫi
/ɔr/ → [ɑr]		*organ*	ɑrgæn
/ɚ/ → __	Derhotacized	*ever*	ɛvɑ
/ɑ/ → [oʊ]	Excessive lip rounding	*walk*	woʊk
		always	oʊwez
/ɑ/ → [ɔ]		*often*	ɔftən
/ɛ/ → [ɪ]	Substitution of /ɛ/ and /ɪ/	*well*	wɪːɫ
		except	ɪksɛpt
/ɪ/ → [ɛ]		*winter*	wɛntɑr
/i/ → [iə]	Epenthetic insertion	*him*	hiəm
/ɪ/ → [ɪː]	Lengthened	*well*	wɪːɫ
/æ/ → [æː]		*ancient*	æːnʃəntʰ
/ɝ/ → [ɝː]		*observe*	əbzɝːv
Male			
/ɚ/ → [ə]	Derhotacized	*grandfather*	grænfɑðə
		ever	evə
		observe	əbzəv
		quivers	kwɪvəz
		winter	wɪntə
		answers	ænsəz
		nearly	nɪəli
		years	jɪəz
		beard	bɪəd
/ɛr/ → [ɛə]		*air*	ɛə
/ɔr/ → [oʊə]		*more*	moʊə
+[ə]	Epenthetic insertion	*pronounced*	pronaʊnstə
/oʊ/ → [oʊɪ]	Triphthongized	*coat*	koʊɪt

Suprasegmental Changes

Although the main concern of the phonetic analysis was segmental changes, some suprasegmental characteristics are briefly considered below.

Fluency. While both participants maintained relatively fluent speech despite their respective accents, their rate of speech was slightly prolonged. The female's rate of speech was slow and slightly labored and lasted 61 seconds; whereas the same reading obtained following recovery was relatively more fluent and lasted only 43 seconds. The agrammatisms which persisted during her natural conversation had resolved in the oral reading. Similarly, the male participant's respective times were 55 seconds pre- and 50 seconds post-recovery. Several FAS studies have likewise reported a reduction in speech rate (Ardila et al., 1988; Coelho & Robb, 2001; Kurowski et al., 1996; Moonis et al., 1996).

Rhythm. Additionally, FAS speech was produced with a staccato rhythm, characterized by a greater degree of juncture between syllables and words throughout the passage. J.D.'s abnormal /t/ productions, which were released at the end of words and intervocalically, also contributed to the excessive juncture in her disordered speech. This was apparent in the phrases "*ancient black frock coat*" [æn꞉ʃəntʰ·blæk·frɔkʰ·koʊtʰ] and *"Twice each day"* [twaɪs·itʃ·deɪ] which were produced with a staccato speech rhythm. Also affecting rhythm, though to only a small degree, was an increase in syllable stress of the word *observe* ([əbˈzɝ꞉v]) in the female participant, which was heard as unusually loud and longer in duration.

Acoustic Analyses

Without accounting for reliability, a total of 4,680 measures were obtained for the acoustic analysis of this study using the 18 CVC stimulus words described in the Methods chapter. Of them, 1,080 were measures of duration (360 VOT, 360 vowel duration, 360 word duration), and 3,600 were measures of frequency (3,240 formant frequencies, 360 fundamental frequency). For all acoustic measures, 5 of the 7 CVC word repetitions were employed. In the following tables and figures, all measures of duration are expressed in milliseconds (ms) and all measures of frequency are expressed in Hertz (Hz). Missing data for formants (N=56) was due to poor detection of F2 values by linear predictive coding (LPC) when harmonic amplitude was low. The distribution of acoustic data measures including missing values are presented in Tables 5 and 6. Lists of individual raw data for each participant can be found in Appendix B (duration measures) and Appendix C (frequency measures).

Table 5: Distribution of Acoustic Data for Female Participant

Measure	1st Recording (Disordered)	2nd Recording (Normal)	Missing	Total
VOT	90	90	0	180
Vowel Dur.	90	90	0	180
Word Dur.	84	90	0	180
Formants	778	792	50	1570
Fo	90	90	0	180
Total	1132	1152	56	2290

Table 6: Distribution of Acoustic Data for Male Participant

Measure	1st Recording (Disordered)	2nd Recording (Normal)	Missing	Total
VOT	90	90	0	180
Vowel Dur.	90	90	0	180
Word Dur.	90	90	0	180
Formants	804	809	6	1613
Fo	90	90	0	180
Total	1164	1169	6	2333

Duration Analyses

VOT. VOT measures were obtained for all 15 correct productions of the six stop consonants /p/, /t/, /k/, and /b/, /d/, /g/ (5 repetitions x 3 different vowels), resulting in 180 total VOT measures per participant (90 pre-recovery + 90 post-recovery). Pre- (with FAS) and post-recovery VOT means and standard deviations are presented for the female participant in Table 7, and those of the male participant in Table 8 below. Due to the frequent occurrence of prevoicing, plus (+) and minus (-) signs are used to differentiate positive and negative VOT values for voiced stop consonants. The distribution of positive and negative VOT values are indicated in parentheses (number of productions out of a possible 15) for each voiced stop.

A general comparison of pre- and post-recovery data reveals a tendency to increase the VOT of all 3 voiceless stop consonants (with the exception of /t/, which was decreased by 8 ms in the female). Nonetheless, pre- and post-recovery VOT data for both participants were within normal limits for all voiceless stops. VOT values for voiceless stops increased in value as lingual retraction increased (i.e., from bilabial [p], to alveolar [t], to velar [k]). This is considered a normal characteristic of American English and is reported in Blumstein et al. (1987).

For the voiced stops /b/, /d/, and /g/, a greater tendency toward atypical VOT production was observed for the female only. Of the two participants, the female incurred a lower number of negative VOT values. Initially, 26 of her 45 voiced stop productions were prevoiced. This number was then reduced to 6 prevoicing instances following recovery. In addition, negative VOT values improved slightly (up 11 ms when pre- and post-recovery averages are compared). The same pattern of recovery was not observed for the male, who prevoiced on nearly all voiced stop productions before (41 out of 45) as well as after (44 out of 45) his normal speech patterns had returned. In summary, these data evidence a general post-recovery tendency toward more normal VOT of voiced stops for the female participant, and no change from abnormal VOT production of voiced stops for the male participant. This indicates also that VOT must be compared pre- and post-recovery due to individual variations.

Table 7: VOT Means and Standard Deviations (in milliseconds) for the Female Participant

	Voiceless			Voiced					
	/p/	/t/	/k/	/b/		/d/		/g/	
				(+)	(-)	(+)	(-)	(+)	(-)
FAS Speech									
x	105	128	128	13	- 147	22	- 128	30	- 100
sd	30	43	38	2	20	8	15	4	33
count (n/15)	(15)	(15)	(15)	(5)	(10)	(10)	(5)	(4)	(11)
Recovered									
x	121	120	133	16	- 145	24	- 109	32	- 87
sd	28	15	24	4	61	10	11	11	0
count (n/15)	(15)	(15)	(15)	(12)	(3)	(13)	(2)	(14)	(1)
Change									
x	+16	- 8	+ 5	+ 3	+ 2	+ 2	+19	+ 2	+13
sd	- 2	-28	-14	+ 2	+41	+ 2	- 4	+ 7	-33

Table 8: VOT Means and Standard Deviations (in milliseconds) for the Male Participant

	Voiceless			Voiced					
	/p/	/t/	/k/	/b/		/d/		/g/	
				(+)	(-)	(+)	(-)	(+)	(-)
FAS Speech									
x	61	72	86	14	- 153	24	- 139	23	- 152
sd	18	15	15	0	48	4	17	0	26
count (n/15)	(15)	(15)	(15)	(1)	(14)	(2)	(13)	(1)	(14)
Recovered									
x	66	80	102	0	- 148	0	- 143	34	- 126
sd	14	9	17	0	20	0	30	0	30
count (n/15)	(15)	(15)	(15)	(0)	(15)	(0)	(15)	(1)	(14)
Change									
x	+ 5	+ 8	+16	-14	+ 5	-24	- 4	+ 11	+26
sd	- 4	- 6	+ 2	0	- 28	+ 4	+13	0	+ 4

Vowel Duration. Vowel duration measures were obtained for all productions of the cardinal vowels /i/, /a/, and /u/. Means and standard deviations of the 90 pre-recovery vowel duration measures are compared to those of the 90 post-recovery measures for both participants in Table 9 below. Mean durations of all three vowels increased for the male and female following recovery, with an average increase of 16 and 14 milliseconds, respectively. That is to say, vowel durations were shorter when the patients had their FAS. Standard deviations for the male participant also increased by an average of 15 milliseconds across all three vowels. Changes for the female, however, were inconsistent. Standard deviations for J.D. either decreased (/i/, -10 msec), increased (/a/, +5 msec), or remained unchanged (/u/, 0 msec).

Table 9: Comparison of Pre- and Post-Recovery Vowel Duration Measures (in milliseconds)

Participant	Vowel		FAS	Recovered	Change
Female	/i/	x	182	187	+ 5
		sd	28	18	- 10
	/a/	x	212	230	+18
		sd	27	32	+ 5
	/u/	x	174	198	+24
		sd	23	23	0
	Total	x	189	205	+16
		sd	30	31	+ 1
Male	/i/	x	212	218	+ 6
		sd	28	32	+ 4
	/a/	x	247	278	+31
		sd	30	45	+15
	/u/	x	196	199	+ 3
		sd	23	29	+ 6
	Total	x	218	232	+14
		sd	34	49	+15

Word Duration. Comparisons of pre-and post-recovery word duration means and standard deviations for each participant are presented in Table 10 below. Opposite trends regarding word duration changes in recovered speech were observed. While the female decreased her average word duration by 105 ms, the male evidenced an increase of nearly the same amount (l06 ms). This finding indicates that word duration analyses should not necessarily be based on FAS versus normative information.

Table 10: Comparison of Pre- and Post-Recovery Word Duration Measures (in milliseconds) by Vowel

Participant	Vowel		FAS	Recovered	Change
Female	/i/	x	673	606	- 67
		sd	88	72	- 16
	/a/	x	761	631	-130
		sd	97	80	- 17
	/u/	x	707	594	-113
		sd	101	70	- 31
	Total	x	715	610	-105
		sd	101	75	- 26
Male	/i/	x	552	593	+ 41
		sd	78	82	+ 4
	/a/	x	548	692	+144
		sd	77	67	- 10
	/u/	x	588	594	+ 6
		sd	73	72	- 1
	Total	x	520	626	+106
		sd	72	87	+ 15

Frequency Analyses

Fundamental Frequency. Measures of fundamental frequency were obtained at the vowel midpoint (50% of the total vowel duration) for all stimulus word productions. Comparisons of average fundamental frequency data (presented in Table 11 below) indicate an average decrease of 15 Hz for both participants following normal speech recovery, while changes in standard deviations appear unremarkable.

Table 11: Pre- and Post- Recovery Fundamental Frequency Measures per Participant

	FAS Speech	Recovered Speech	Change
Female			
x	251 Hz	236 Hz	- 15
sd	26 Hz	29 Hz	+ 3
Male			
x	134 Hz	119 Hz	- 15
sd	18 Hz	13 Hz	- 5

Formant Frequencies. Formant frequency outcomes are illustrated in the following tables and figures. Tables 12 through 14 display the means and standard deviations of F1, F2, and F3 for all vowels at the three different points of the vowel duration as described in the methods section: 20% (Table 12), 50% (Table 13), and 80% (Table 14). However, the main focus of the analysis was on the first two formants since they are considered the most important indicators of vowel quality. Vowel plots to follow are likewise for F1 and F2 only.

Table 12: Means and Standard Deviations for F_1, F_2, and F_3 at 20% of the Vowel Duration

Pt			FAS Speech	Recovered Speech	Change
Female	/i/	F_1	421 61	296 34	-125 -27
		F_2	2486 357	2787 119	+301 -238
		F_3	3350 386	3284 208	-66 -178
	/a/	F_1	648 91	966 171	+318 +80
		F_2	1076 113	1597 492	+521 +397
		F_3	2836 267	2817 538	-9 +271
	/u/	F_1	465 35	394 41	-71 +6
		F_2	1333 356	1856 240	+523 -116
		F_3	2991 265	2896 81	-95 -184
Male	/i/	F_1	260 26	285 24	+25 -2
		F_2	2327 129	2403 144	+76 +15
		F_3	2959 182	2996 213	+37 +31
	/a/	F_1	741 122	699 87	-42 -35
		F_2	1382 294	1295 154	+521 +397
		F_3	2512 142	2380 212	-132 +70
	/u/	F_1	264 23	299 29	+35 +6
		F_2	1064 289	1518 253	+454 -36
		F_3	2430 204	2507 101	+77 -100

Table 13: Means and Standard Deviations for F_1, F_2, and F_3 at 50% of the Vowel Duration

Pt			FAS Speech	Recovered Speech	Change
Female	/i/	F_1	425	293	-132
			60	30	-30
		F_2	2782	2880	+98
			291	121	-170
		F_3	3440	3399	-41
			397	277	-120
	/a/	F_1	710	1033	+323
			58	100	+42
		F_2	1126	1595	+469
			105	583	+478
		F_3	2857	2816	-41
			172	440	+268
	/u/	F_1	482	385	-97
			55	44	-11
		F_2	1215	1743	+528
			343	236	-107
		F_3	2906	2887	-19
			528	61	-467
Male	/i/	F_1	282	269	-13
			17	17	0
		F_2	2460	2546	+86
			91	66	-25
		F_3	3045	3116	+71
			93	87	-6
	/a/	F_1	844	775	-69
			73	109	+36
		F_2	1315	1248	-67
			236	70	-166
		F_3	2437	2370	-67
			186	90	-96
	/u/	F_1	284	293	+9
			19	19	0
		F_2	1021	1516	+495
			226	268	+42
		F_3	2416	2504	+88
			116	71	-45

Table 14: Means and Standard Deviations for F_1, F_2, and F_3 at 80% of the Vowel Duration

Pt			FAS Speech	Recovered Speech	Change
Female	/i/	F_1	424 56	414 251	-10 +195
		F_2	2482 554	2668 537	+186 -17
		F_3	3368 523	3414 603	+46 +80
	/a/	F_1	797 81	975 137	+178 +56
		F_2	1348 191	1444 108	+96 -83
		F_3	2709 414	2645 211	-64 -203
	/u/	F_1	478 62	372 43	-106 -19
		F_2	1144 472	1506 192	+362 -280
		F_3	2937 432	2937 97	0 -335
Male	/i/	F_1	274 25	258 15	-16 -10
		F_2	2540 114	2592 224	+52 +110
		F_3	2983 142	3106 151	+123 +9
	/a/	F_1	747 65	769 67	+22 +2
		F_2	1550 180	1475 154	-75 -26
		F_3	2444 153	2393 85	-51 -68
	/u/	F_1	292 30	274 13	-18 -17
		F_2	1063 276	1410 263	+347 -13
		F_3	2471 78	2498 63	+27 -15

When comparing the vowel midpoint, where formants are more likely to be "steady state", results reveal an increased difference between the mean F1 and F2 for vowels /i/ and /u/ (but not for /a/) post-recovery. For the /i/ vowel, the difference between F1 and F2 increased regardless of point of measure across the vowel duration. This is illustrated clearly in Figure 1, which shows that while F1 decreased in value, F2 increased, thereby broadening the difference between the two formants following speech recovery. For the /a/ vowel (Figure 2), F1 and F2 increased across all duration means.

Figure 1: Comparison of Pre- and Post-Recovery Formant Values at 20%, 50%, and 80% of /i/ Vowel Duration for Female Participant

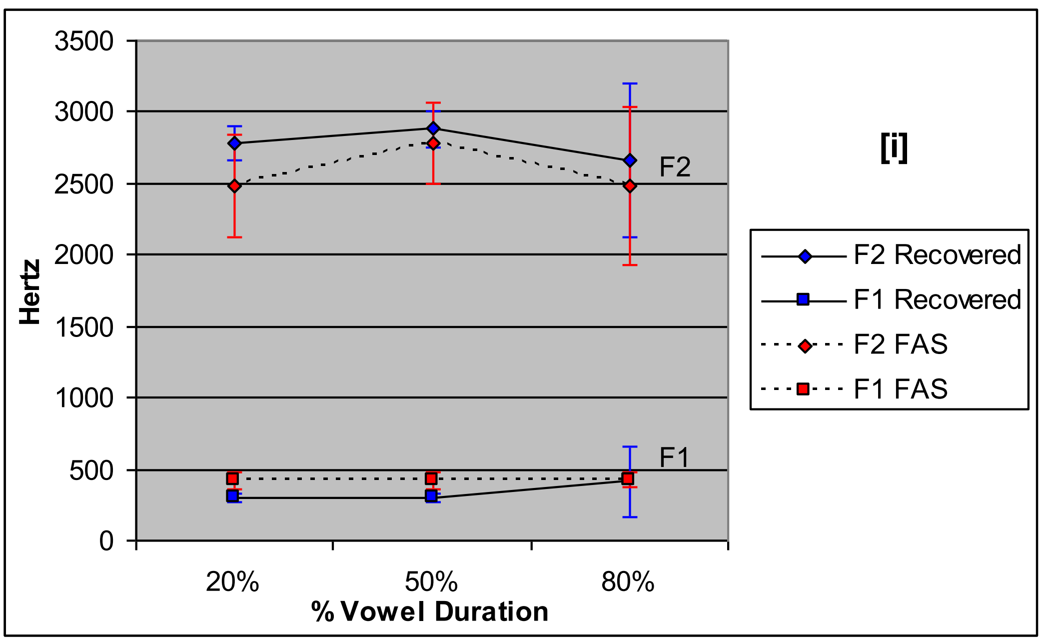


Figure 2: Comparison of Pre- and Post-Recovery Formant Values at 20%, 50%, and 80% of /a/ Vowel Duration for Female Participant

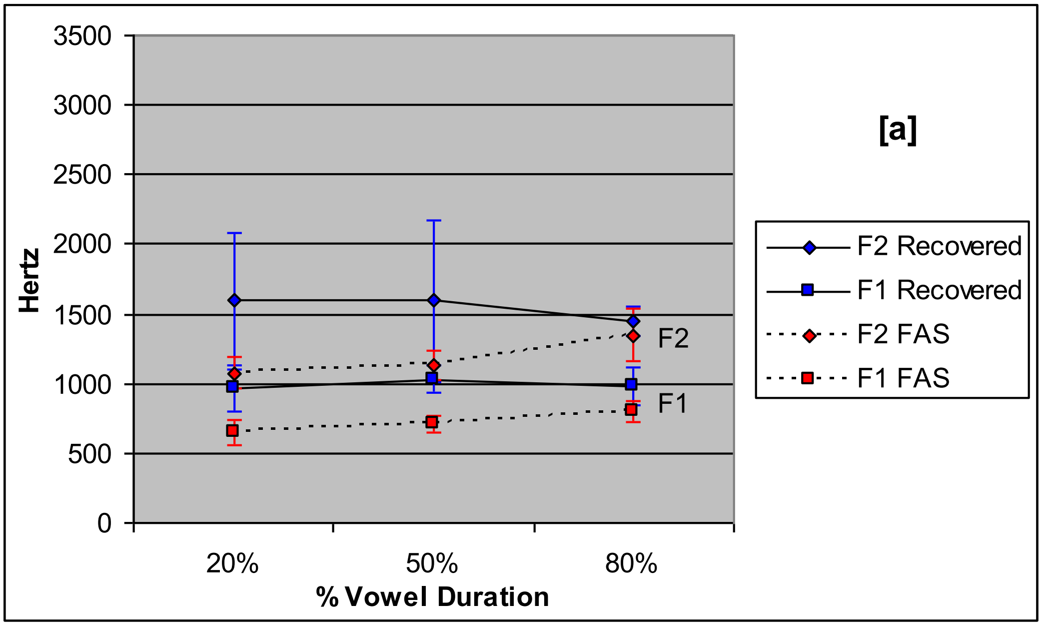
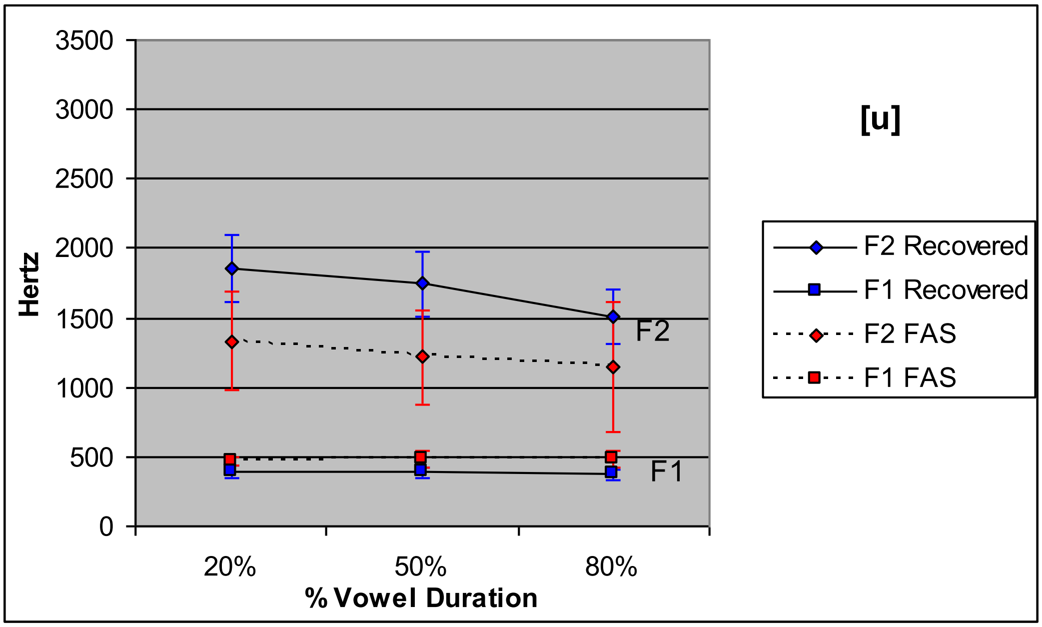


Figure 3: Comparison of Pre- and Post-Recovery Formant Values at 20%, 50%, and 80% of /u/ Vowel Duration for Female Participant



Changes in the male participant's formant averages are depicted in Figures 4 through 6. Overall, formant means and standard deviations following recovery varied to a greater degree compared to those changes observed in the female. For /i/ and /a/ (Figures 4 and 5), F1 and F2 means were similar at all 3 measurement points of the vowel duration. In addition, pre- and post-recovery standard deviations overlapped, indicating very little variation in vowel quality following recovery of normal speech. It was the /u/ vowel (Figure 6) with respect to F2 that underwent the most change following speech recovery. While F2 was relatively stable across the entire vowel duration for both pre- and post-recovery productions, it increased by greater than 300 Hz at each point in the vowel duration.

Figure 4: Comparison of Pre- and Post-Recovery Formant Values at 20%, 50%, and 80% of /i/ Vowel Duration for Male Participant

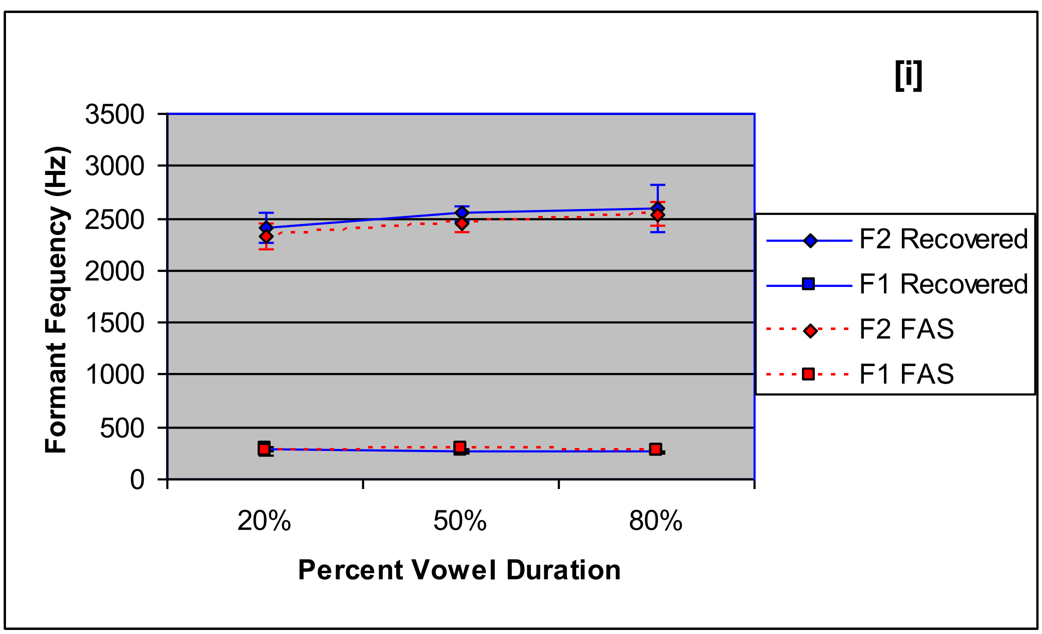


Figure 5: Comparison of Pre- and Post-Recovery Formant Values at 20%, 50%, and 80% of /a/ Vowel Duration for Male Participant

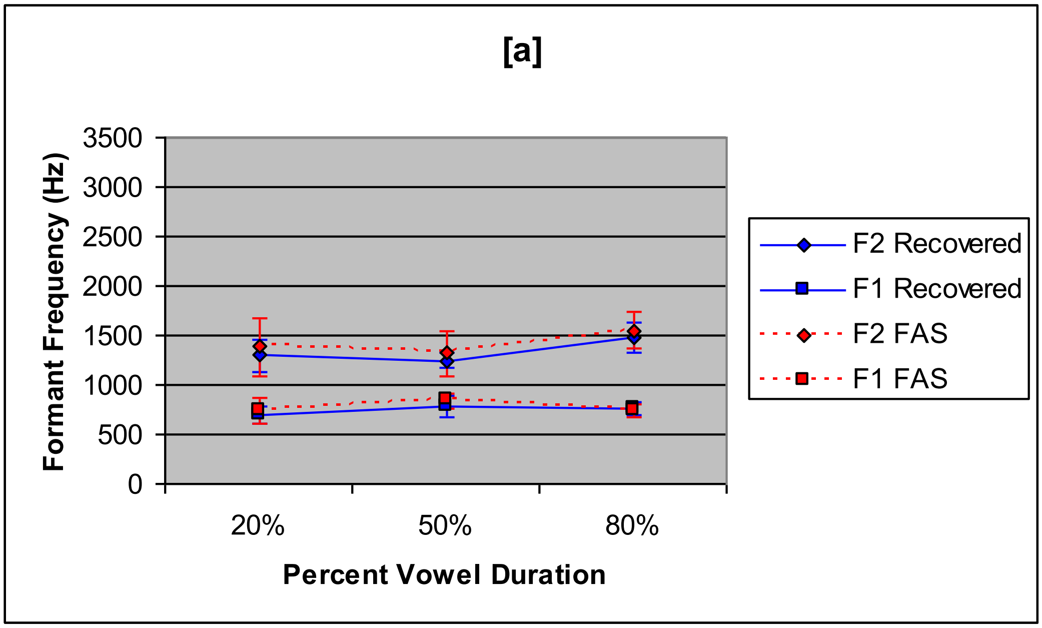
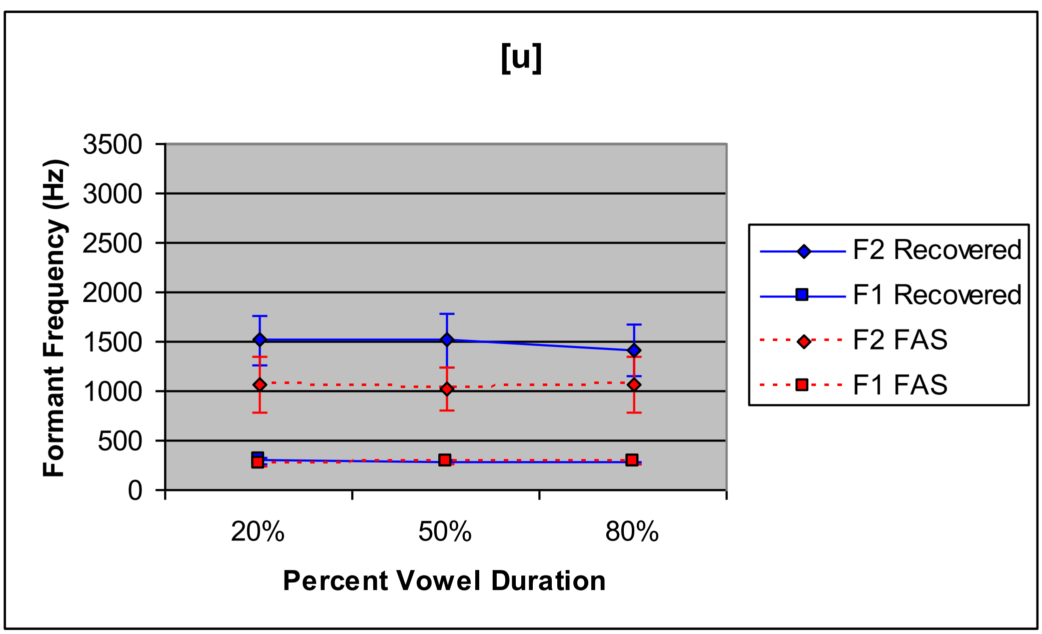


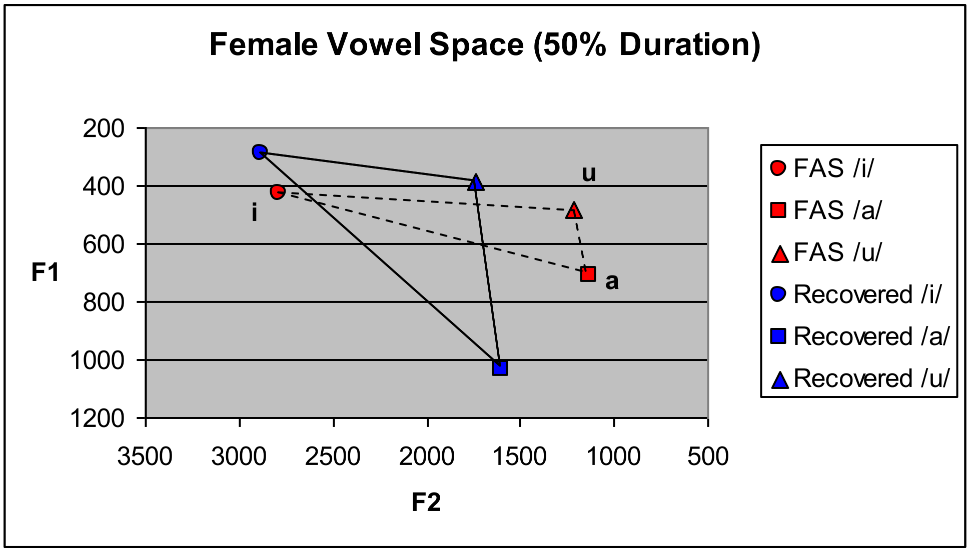
Figure 6: Comparison of Pre- and Post-Recovery Formant Values at 20%, 50%, and 80% of /u/ Vowel Duration for Male Participant



Vowel spaces for each participant are displayed in Figures 7 and 8 below to illustrate the difference between disordered (pre-recovery) and normal (post-recovery) articulation patterns underlying the production of each vowel. The vowel spaces were created by plotting average F1 values against average F2 values for each of the three vowels /i/, /a/, and /u/ on an x/y plot. This was done for the formants derived at the midpoint (50%) of the vowel duration only. Note that the x/y axes, representing F2 and F1, respectively, descend numerically. This was done to provide a more accurate representation of each vowel to its associated place of production within the oral cavity. Thus, the highest front vowel [i] is plotted in the upper left hand corner; the highest back vowel [u] is plotted in the upper right-hand corner; and the lowest of the three vowels [a] is plotted near the bottom.

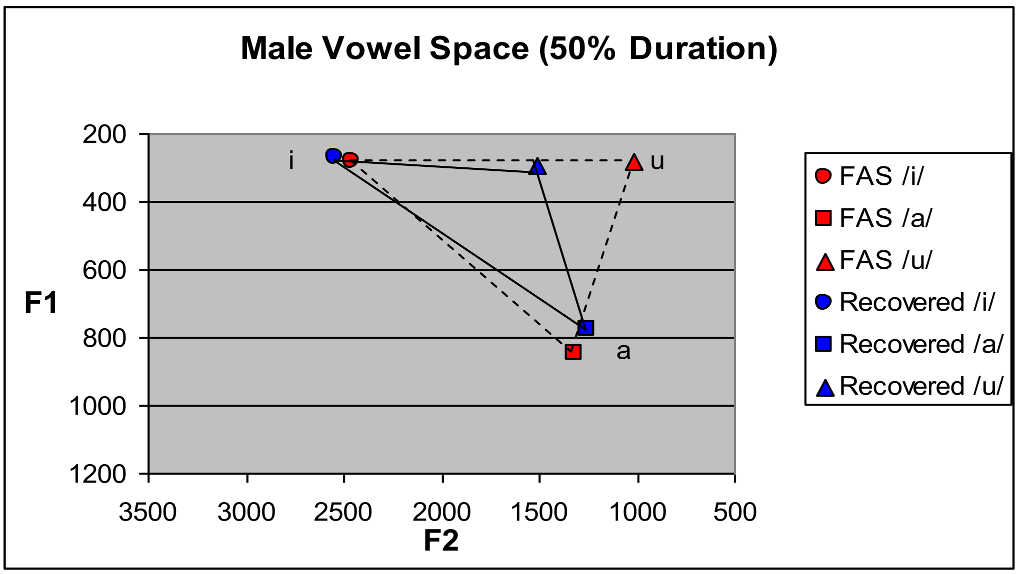
The vowel space for the female participant (Figure 7) illustrates a clear and obvious anterior shift subsequent to recovery, particularly for vowels /a/ and /u/. The /a/ shifted from a low pre-recovery F2 (x=1126) to a high post-recovery F2 (x = 1595) value; /u/ also shifted from a low (x = 1215) to a high (x = 1743) F2 value. This demonstrates a change of over 450 Hz for both vowels and accounts for the clear forward shift in vowel space. Also, /a/ production in J.D.'s FAS speech was much higher than her production following recovery. This is evidenced by the change in F1 from a low 710 Hz to a relatively high 1033 Hz ($\Delta = 323$) following recovery.

Figure 7: Comparison of Vowel Space Pre- and Post- Recovery for Female Participant (50% of Vowel Duration)



Similar to the female, the vowel space for the male participant (Figure 8) indicates an anterior shift in /u/ production post-recovery. Otherwise, no other notable changes occurred with respect to his articulatory patterns of /i/ and /a/. Again, this supports the previous assertion that the male's articulatory patterns were affected by FAS to a lesser degree than that of the female.

Figure 8: Comparison of Vowel Space Pre- and Post- Recovery for Male Participant (50% of Vowel Duration)



For both participants, it appears that the standard deviations were smaller for the 50% duration points. Otherwise, no clear pattern of change in standard deviations pre- and post-recovery was obvious.

Reliability

The Pearson correlation coefficients indicated high inter- and intra-rater reliability agreement for 10% of the acoustic data (Table 15). All re-measures were obtained from the first of the five token repetitions of each participant so that reliability would encompass all acoustic variables employed in the study (VOT, vowel duration, word duration, fundamental frequency, and formant frequencies). All correlations were significant at the .01 level, 2-tailed. The relatively lower agreement rate obtained for the word duration (r = .772) was likely due to subjective differences between investigators in marking the termination point of the voiceless stop consonants at the end of each stimulus word.

Table 15
Reliability rates using Pearson product correlation coefficients

Acoustic Variable	Inter-rater	Intra-rater
VOT	.858**	.999**
Vowel Duration	.866**	.985**
Word Duration	.772**	.952**
Fundamental Frequency	.996**	.998**
Formant Frequencies*	.960**	1.000**

*For all 3 vowels
** p < .01 (2-tailed)

CHAPTER 4: DISCUSSION

This study provided valuable insight to the phonetic and acoustic speech properties of two new cases of Foreign Accent Syndrome (FAS). No previous study has performed acoustic measures in FAS on identical speech samples produced in the same speaking conditions. Therefore, the present study has achieved a previously unobtained level of control. Disordered speech characteristics included 1) changes in vowel quality, 2) poor voice onset time control, and 3) phonological changes such as diphthongization and epenthetic insertions. Perhaps the most remarkable finding, however, was a consistent pattern of articulatory "backing" that emerged in the FAS speech of both participants. This pattern, initially observed in the phonetic analysis, was based on numerous instances of posterior consonant and vowel productions, including dentalization of the interdental fricatives (/ð/ and /θ/), substitutions of "dark" [ɫ] for clear /l/, trilling or tapping of /r/, palatalization of the alveolar /s/, and an apparent backing tendency of the vowels /a/ and /u/. Subsequently, further evidence of this pattern was confirmed in the acoustic analysis, which revealed a pronounced backing tendency on productions of vowels /a/ and /u/. A further elaboration of this backing tendency follows, as well as discussion of other experimental findings that emerged from this study.

Phonetic Analysis

The phonetic analyses revealed changes at both segmental and suprasegmental levels of speech for both participants. Though phonetic errors of FAS speech have been known to vary from case to case (Dankovičová et al, 2001; Duffy, 2005), several common errors were found in both patients. Similar to previous analyses of FAS speech (Dankovičová et al, 2001), the majority of the phonetic changes within each participant were quite consistent and suggested a strong pattern, while a few of the phonetic changes varied.

Consonants

Consonant errors were primarily characterized by changes in place and manner of articulation. To begin, a fully released or aspirated /t/ was produced in all phonetic contexts and was consistent across participants and both types of analyses. While observed initially in the outcomes of the phonetic transcription of the participants' connected speech, this tendency was also observed in their productions of the word-final stops in the CVC words employed throughout the acoustic analysis. Though VOT measures were only obtained for the initial stops of each word, both participants were heard to aspirate or fully release the final stops /t/ and /p/ in their FAS speech. This type of production, as well as a failure to reduce phonemes /t/ and /d/ to a flap [ɾ] or glottal stop [ʔ] following a stressed vowel in words, is a characteristic found more commonly in British rather than American English alveolar productions (Blumstein et al., 1987). These patterns have been observed by previous researchers (Blumstein et al., 1987; Kurowski et al., 1996) and in the present study were believed to contribute largely to the perceived foreign quality of both participants' speech. In regard to the underlying cause of this behavior, a fully released stop may indicate poor tactile coordination involving the tongue and palate or alveolar ridge. Or, it is plausible to interpret this behavior in association with a reduced anterior motion.

That is, the hard release of /t/ would have been an exaggerated attempt to thrust the tongue forward to achieve the target sound.

Similar to the Dancovicova et al. (2001) patient, dark [ɫ] productions occurred consistently in the female. As previously described, a dark [ɫ] is produced with the tongue contacting the palate in a relatively posterior position. This again may suggest a reduced ability to achieve the more anterior lingual motion necessary for a "clear" [l] production. Also, while her /r/ trilling (as in [naɪndiθr̗ i]) appeared initially as a change in articulatory manner, closer examination suggests that the tongue was placed in a retracted position, such that the sound resulted from a change in place of production from dental to alveolar or even palatal contact.

Both participants deleted consonant singletons (/d/) or clusters (/nd/) in the final position of words. Interestingly, those sounds which were deleted were always anterior productions (i.e., either interdentals or alveolars). This result may further support the assertion that both participants had difficulty coordinating or achieving anterior targets.

Vowels

In her connected speech, the female's vowels were perceived as generally more "tense" or elongated. "Tense vowels" (/i/, /u/, /o/, etc.) from an articulatory standpoint are produced with an advanced lingual position and are supposed to involve greater vocal tract tension (Borden, Harris, & Raphael, 1994; Small, 1999). In acoustic terms, they tend to be longer in duration. On the other hand, lax vowels (/ɪ/, /ə/, /ɛ/, etc.) are more neutralized and always occur in closed syllables (i.e., those ending with a final consonant). The only exception to this rule is the production of the schwa /ə/, which often occurs as an open syllable at the end of a word (as in the

word *soda*). Previous studies have also reported generalized tensing or elongation in FAS (Blumstein et al., 1987; Graff-Radford et al., 1986).

The perception of vowel tensing in the female participant was based on three deviant articulatory behaviors: First of all, simple substitutions of lax for tense vowels were made. For example, the vowel /iɚ/ was reduced, or lowered, to [ɛr], so that the words *years* and *nearly* were realized as [jɛrz] and [nɛrɫi]. Other rhotacized vowels were similarly substituted for lax, back vowels while maintaining their rhotic quality. For example, /ɚ/ or /ɝ/ were backed to [ɑr] as in [grændfɑðɑr] and [wɛntʰɑr]. The fact that one production of /ɝ/ was completely derhotacised on one occasion ([ɛvɑ] for *ever*) further suggests that or tense, anterior vowels were difficult to achieve. Secondly, lax vowels such as /ɑ/ were diphthongized and hence extended to [oʊ] in the words *walk* ([woʊk]) and *always* ([oʊwez]). Thirdly, the diphthong productions were often accompanied by excessive lip rounding, a feature that is normally associated only with tense, back vowels. Again, the unrounded /ɑ/ was realized as a rounded [ɔ] in *often* ([ɔftən]). This tendency to round the lips may have been an attempt to compensate for reduced anterior lingual movement. In other words, as the tongue would not advance, she would "reach" or "grope" for the vowel with her lips. Vowel tensing was also mentioned in Graff-Radford et al. (1986) and Blumstein et al. (1987), who described their respective patients' vowel productions as more peripheral. This contrasts with other FAS studies (Kurowski et al., 1996) which reported laxer or more centralized productions of vowels.

While the male's FAS speech was not overtly characterized by vowel tensing, he produced other anomalous features that seemed to affect the structure of the vowels themselves. These errors, broadly characterized as vowel additions, included diphthongization,

triphthongization, and epenthetic insertions. Epenthetic insertions have been reported throughout the FAS literature (Blumstein et al., 1987; Kurowski et al., 1996; Miller et al., 2006), whereby patients have been known to precede voiced stops with a schwa vowel /ə/. For example, while the male participant in this study pronounced *coat* as [koʊɪt], the Miller et al. (2006) patient "EJC" pronounced *coat* by substituting the /o/ diphthong for [əʊ] (thus realizing the word as [kəʊt]). Diphthongization and triphthongization, though relatively infrequently among both participants' speech errors, has also been reported in the speech of several previously published cases of FAS (Ardilla et al., 1988; Dankovičová et al., 2001; Graff-Radford et al., 1986).

Suprasegmentals

Many of the changes in vowel quality at the segmental level can be described as additions (i.e., diphthonized, triphthongized, insertions, etc.), which in turn affected speech at the suprasegmental level as well. As seen in Kurowski et al. (1996), the general rhythm or prosody of their speech was influenced by vowel changes. Stress patterns throughout the reading seemed to be altered due to the perceived elongation and insertion of vowels. Quantitatively, the rate of speech for both participants was slightly longer with their FAS compared to that of their recovered speech.

The release of the plosives /t/ and /k/ for both participants resulted in a staccato speech rhythm, while the perceived changes in vowel stress and epenthetic insertions or triphthongizing resulted in a disruption of speech rhythm. This contributed to the impression of a general dysprosody related to timing changes. Taken together, the combined segmental changes thus far discussed in the phonetic analysis (i.e., epenthetic vowel insertions, tiphthongization, and full release of /t/ and /k/) affected speech prosody in what was perceived as altered stress patterns, reduced speech rate, and, intermittently, a staccato speech rhythm. Several previous studies

(Dankovičová et al., 2001; Moen, 1990) dating back to the first well-known case by Monrad-Krohn (1947), have also reported dysprosody as one of the major contributors to the perception of a foreign accent. In this sense it would be appropriate to describe the changes in the speech features of the present FAS patients as primarily segmental and prosodic in nature.

In summary, the phonetic analysis provided consistent support of a general backing tendency of consonants and vowels produced by the participants in connected speech. Specific examples of this behavior were drawn directly from the phonetic analysis results in the previous chapter (refer to Tables 3 and 4). Several of the segmental errors, including the few not characterized by backing, affected the participants at the prosodic speech level as well. Cumulatively, all segmental and suprasegmental errors contributed to the foreign quality which characterized each of the participant's accents. Among the various findings of the acoustic analysis, as follows, is further evidence of vowel backing.

Acoustic Analysis

While the phonetic analysis revealed numerous details regarding changes in the characteristics of "foreign" versus "normal" speech, acoustic analyses were conducted to better specify the perceived changes related specifically to stop consonant production and vowel quality. For example, changes in vowel "tension" as observed in the female participant were based on a perceived increase in vowel length as well as altered vowel quality, which can be assessed objectively by formant frequency measures. The following is a discussion of the acoustic findings of the participants' speech following accent recovery.

Duration Measures

VOT. Similar to the studies by Blumstein et al. (1987) and Kurowski et al. (1996), the rationale for examining voice onset time was to determine whether changes in voicing of stop consonants had occurred, and, if such changes contributed to the perceived foreign accent of the participants. In support of the original hypothesis, this study showed a change in stop consonant production in FAS speech when compared to recovered speech, with the most obvious changes occurring in the female participant.

While the average VOT of voiceless stop consonants was normal in both speech samples, prevoicing of voiced stop consonants occurred frequently. This particular finding was not surprising given the similar changes in VOT that have been documented in previous studies of FAS (Blumstein et al., 1987). Voice onset time is the time between the release of the oral constriction (correlated with the "burst" in the acoustic signal) to the onset of vocal fold vibration. In their acoustic analysis of stop consonants in FAS speech, Blumstein and colleagues (1987) noted that speakers of American English produce voiced stops with a "short lag" voicing onset, while voiceless stops are typically produced with a relatively "long-lag" (p. 222). It is essentially the timing between the burst and onset of voicing that determines whether a listener perceives a voiced stop (e.g., /b/, short-lag VOT) or its voiceless cognate (e.g., /p/, long-lag VOT). Abnormal changes in VOT of stop consonants have been documented in speech disorders such as Broca's aphasia (Blumstein et al., 1980). Both participants not only prevoiced the majority of their voiced stops, but the duration of the prevoicing was unusually long (i.e., between 100 and 153 ms for FAS speech). Blumstein et al. (1987) also noted that in foreign languages such as French or Spanish, voiced stops are often produced with prevoicing, and while some prevoicing in American English does occur, it is usually less than 100 ms (p. 224). Thus, it

can be asserted that the prevoicing of /b/, /d/, and /g/ may indeed be an underlying acoustic characteristic of the foreign nature of these participants' FAS speech.

Acoustically, the male showed more differences in consonant production than the female, as evidenced by his tendency to prevoice nearly all voiced stop productions pre- and post-recovery. However, it cannot be ruled out that the male participant's prevoicing in general may have simply been influenced by his age, since Ryalls, Simon and Thomason (2004) found more prevoicing in older normal speakers.

In addition to voicing changes, there may have been some subtle changes in articulatory place of production. Again returning to Blumstein et al (1987), a characteristic of French and Spanish languages is a dental place of particulation for anterior consonants. Though neither participant in this study exhibited an accent similar to French or Spanish in particular, dental productions of the fricatives /ð/ and /θ/ did occur.

Vowel Duration. While the phonetic analysis revealed a number of perceived changes in vowel production (particularly characterized by lip rounding and lingual retraction affecting vowel quality), an acoustic analysis of vowels was performed to better quantify these perceptual impressions with objective acoustic measures. Contrasting the original hypothesis, average vowel durations were shorter in the participants' disordered speech than recovered speech. The male exhibited an average increase in vowel duration (+14 ms) and word duration (+106 ms). The female likewise increased her vowel duration (+16 ms), but decreased her average word duration (-105 ms). This result was unexpected given the perceived increase in vowel duration (or tensing) in the female's connected speech, and contrasts with findings in previous studies, such as that of the Miller et al. (2006) patient, "EJC", whose FAS speech was characterized by elongated vowels. However, the results for both participants are similar to those found in

Dankovičová et al. (2001) where the duration of the patient's post-stroke (disordered) speech were shorter than those of his pre-stroke speech.

Word Duration. Given the indication of some kind of disruption in speech rhythm by the phonetic analysis, it was important to investigate the timing changes of speech through measures of word and vowel duration together. A close look at the duration data as a whole reveals a subtle shift in the participants' timing of individual phonemes. While the female's word duration became shorter in her recovered speech, average vowel duration and VOT became longer. In essence, her FAS speech was characterized by changes in the proportion of total word duration comprised by the consonants and vowels. This finding may be comparable to the unusual and labored speech of dysarthrics who exhibit equal timing of phoneme units (Kent, Nutsell, & Abbs, 1979). Likewise, the changes in timing patterns of the female may in part have contributed to the unfamiliar "accent" heard in her speech.

Frequency Measures

Formant Frequencies. Previous studies have described changes in vowel quality as a major factor contributing to the perceived foreign quality of FAS speech (Dankovičová et al., 2001; Kurowski et al., 2006). It was for this reason that acoustic measures of vowels, particularly those of the first and second formant frequencies, were a major focus of this study. To begin, if the perceived "backing" of vowels observed in the participants' connected speech did, in fact, occur, then it would be confirmed quantitatively in the acoustic analysis by a lower F2 value in FAS vowel production compared to recovered vowel production. Indeed, F2 for both participants was lower prior to recovery at the vowel midpoint for all three vowels. The only exception was the average F2 for /a/ in the male, which was 67 Hz higher in the accented speech. Overall, this decrease in F2 serves as evidence that lingual positioning for these vowels

was more posterior when the participants still spoke with their foreign accents. This phenomenon is illustrated in the participants' vowel space pre- and post-recovery in Figures 7 and 8.

The vowel plot for the female participant indicates a general backing tendency, with vowels /a/ and /u/ being the most affected. The /a/ vowel in particular evidenced the most change following speech recovery. With the foreign accent, her production of /a/ was associated with a relatively high and back oral position. Following recovery, /a/ was lower and more anterior due to an increase in F1 and F2 averages. Furthermore, it appears that the movement of /u/ from its high to relatively low position on the vowel plot accounts for the overall impression of a restricted, if not centralized, vowel space. The only exception to this pattern is /i/, which remained relatively unchanged.

Change in vowel production for the male participant was less obvious, as evidenced by the relatively minimal shift in his vowel space following speech recovery. For this participant, the greatest amount of change occurred in /u/, which shifted toward a more anterior place of production following recovery.

It is interesting to note that for both participants, there was a general anterior shift in vowel plots after their normal speech patterns had returned. This suggests that both participants were somewhat restricted in their ability to produce anterior articulatory movements for normal vowel production during the FAS period. Also, for both participants, the /i/ vowel changed the least in terms of average F1 and F2 values. This is not surprising, however, because /i/ is considered a quantal sound.

Fundamental Frequency. The 15 Hz decrease in fundamental frequency (Fo) exhibited by both participants, though subtle (a difference of less than one standard deviation), supported

the initial hypothesis that average fundamental frequency would be higher in FAS speech when compared to recovered speech. This finding was expected based on similar previous findings throughout the FAS literature (i.e., Ryalls & Whiteside, 2006). In addition, some neurologically-based speech disorders have been characterized by an abnormal increase in vocal pitch. The female FAS patient in Ryalls and Whiteside (2006) exhibited a post-morbid Fo increase of approximately 50 Hz. These researchers explained this change as a general increase in tension of the vocal folds secondary to a generalized increase in tension of the vocal tract. Likewise, the reduced Fo observed in the present cases may indicate reduced longitudinal tension on the vocal folds.

Theoretical Interpretation

To conclude, the participants of this study presented with several speech characteristics consistent with the contemporary literature on Foreign Accent Syndrome. At the conversational level, both participants were heard to speak with an accent from a particular foreign country or region. The female generally portrayed an “Eastern European” accent, and the male, though relatively less severe, a “British” or “New England” accent. However, close examination of the phonetic errors support a “generic” foreign accent (Kurowski et al., 1996) in that native sound productions seemed to be combined with those of one or more different languages. Regardless of language of origin, all of the phonetic features produced by the speakers complied with the general phonological rules of language. In agreement with previous assertions about FAS (Blumstein et al., 1987; Blumstein & Kurowski, 2006; Gurd et al., 2000; Moen, 2000), it is for this reason that the patients were perceived as “foreign” rather than disordered.

The female exhibited a unique characteristic in her conversational speech that is worth mentioning, though it was not captured in the samples obtained for the phonetic and acoustic investigations. In addition to the phonetic changes, her speech was slightly agrammatic, characterized by intermittent omissions of function words (e.g., articles, prepositions, and auxiliary verbs). This symptom occurred concomitantly with her foreign accent during natural discourse and subsided once her speech patterns had returned to normal. While agrammatism is typically considered a linguistic rather than speech deficit, its contribution to her foreign speech was that of a non-native trying to learn English (Ardila et al., 1988). Likewise, in addition to her speech disorder, it may have been symptomatic of a relatively mild Broca's aphasia.

As stated previously, the combined findings of the phonetic and acoustic analyses suggest that both participants were limited in their anterior articulatory movements for several of the target phonemes. Specifically, tongue advancement seemed to be reduced for the production of anterior speech sounds. Those affected included anterior vowel sounds as well as consonant sounds, such as lingua-alveolars and lingua-dentals. Previously published cases of FAS have noted a similar tendency toward backing of vowels when disordered and recovered speech were compared (Coelho & Robb, 2001; Dankovičová et al., 2001). A consistent pattern of consonant and vowel backing was observed for the female. She not only substituted back vowels for relatively anterior productions, but often rounded front vowel productions, a feature normally associated only with back vowels such as /u/ and /o/. This rounding behavior was interpreted as an attempt to compensate for the inability to fully achieve the anterior motion necessary to produce front vowels. The same pattern was evidenced by dentalized productions of the interdentals /ð/ and /θ/, "dark" /ɫ/ substitutions for anteriorly placed clear /l/s, the palatal trill of /r/, and deaffrication of /tʃ/ (reduced to /ʃ/). The male participant evidenced the same pattern,

though to a lesser degree, in palatal productions of /s/ in various phonetic contexts. It is thus not surprising that in retrospect the male and the female together presented with phonetic and acoustic speech errors that were very similar.

Taken together, these results strongly suggest that Foreign Accent Syndrome is a speech disorder characterized by a limited range of movement (ROM) and, to some degree, limited coordination. A foreseen problem in this theory is the variation of speech features reported within and across FAS cases. In fact, FAS has been described as the result of a "constellation" of speech feature changes (Kurowski et al., 1996). However, the results of this particular study suggest that there is some consistency in the articulatory patterns of FAS. Dankovičová et al. (2001, p. 215) made the following key observation regarding changes in vowel quality:

> "Although, for example, both centralisation and peripheralization of vowels were attested in previous FAS cases, no study has, to our knowledge, reported a mixed pattern of centralization (back vowels) and peripheralization (front vowels) in the same patient".

Though no further elaboration was made, this observation may have implications for consistency of error within select FAS cases throughout the literature. Consistency of error plays a vital role in identifying and understanding the nature of any speech problem, and likewise dictates the type of approach used in therapy. On the other hand, if both "centralization" and "peripherilization" were found in the speech of one such patient, then range of motion as an underlying characteristic would be ruled out given the patient's ability to alternate advanced and retracted movements. In theory, a tendency toward only advancement *or* retraction would legitimize ROM as the underlying problem of FAS.

In regard to articulatory coordination, findings from this study imply that FAS is characterized to some extent by impaired coordination comparable to apraxia of speech (AOS). Several studies throughout the literate have interpreted FAS as a "mild" or "modified" form of AOS, likely due to segmental issues (Coelho & Robb, 2001; Fridriksson et al., 2005; Varley et al., 2006). Again, the tongue appeared to be primarily affected of all the moving articulators. Given that, the underlying cause of stop consonant errors was less clear. For instance, why was /t/ realized as a full stop when it followed an accented vowel? And why did the participants prevoice a generous portion of their voiced stop consonants? For /t/, the patients may have been trying to overcome a limited anterior motion, thus resulting in a more intense or "overshot" lingua-alveolar contact. This would fall in line with the rationale given for the excessive lip rounding observed in the female's attempt to produce front vowels. However, this does not explain the abnormal production of voiced stop consonants portrayed in the acoustic results. Both patients prevoiced many of their voiced stops or sometimes preceded them with an "audible swallow". Again, coordination or motor planning problems appears to be an issue in that vocal fold vibration was not appropriately timed with the release of the consonant burst.

Despite the limiting effects of reduced coordination and motor planning, patients with apraxia typically maintain the motoric integrity to produce the majority of speech sounds. Similarly, this study's phonetic analysis showed that while some consonants were produced in error, evidence of their correct productions were achieved elsewhere in their speech. For instance, while the female was able to achieve the glottal stop [ʔ] in *utmost*, it was erroneously replaced with a fully released [t^h] in *buttons*. This is similar to AOS in that while the patient maintained a functional level of articulatory strength and posterior range necessary to produce most speech sounds (albeit some are more difficult to achieve than others), it may have been

faulty motor planning that caused her to intermittently miss the target sound. However, the consistent and extensive evidence of backing in this study suggests that this is only a mild symptom of speech. To that end, perhaps FAS differs from AOS only in that the neurological breakdown results in a reduced range of motion in addition to a mild reduction in coordination, though perhaps to a lesser degree than AOS. The commonality and that which differentiates both disorders from dysarthria, is that articulatory strength remains relatively normal.

It is important to note that the observed phonetic and acoustic changes, while atypical for the participants' native language (as evidenced by the post-recovery samples), still complied with the general phonological rules of language (Blumstein et al., 1987; Kurowski et al., 1996). Like speakers with AOS, these individuals were able to produce clear substitutions of consonant and vowel sounds instead of the slurred or distorted sounds observed in speakers with dysarthria (Blumstein & Kurowski, 2006). All of the sounds produced were recognized as those which occur in one language or another. Thus, FAS is differentiated even more so from dysarthria, which is characterized by some slurring and distortions of speech sounds secondary to articulatory weakness.

Clinical Implications

Overall, the findings of this study suggest that range of motion deficits play a critical role in Foreign Accent Syndrome, and as such will be discussed as the basis for clinical implications. When considering diagnostic and therapy approaches for patients with FAS (or any other motor speech disorder), it is important to maintain an appropriate perspective. In this study, the characteristics of disordered speech were presented in the form of phonological processes (e.g., "deaffrication", "final consonant deletion", etc.). However, this was done for the sake of

simplicity and does not reflect a phonological basis for the disorder itself. Like many other neurologically-based speech disorders, FAS is acquired rather than developmental in nature, usually resulting from left hemisphere CVA or traumatic brain injury (Coelho & Robb, 2001). As such, it is essential that treatment reflect neurological breakdown of motor speech rather than a disruption in the development of the individual's articulatory or phonological system. Approaching treatment from the standpoint that FAS is motorically-based and characterized largely by reduced ROM (as must be determined per case) can provide a starting point for therapy.

As mentioned previously, a foreseen problem in FAS therapy may lie in the rather wide diversity of phonetic speech changes that have been observed within and across case studies throughout the literature (Coelho & Robb, 2001). It is not surprising then, that a unique and evidence-based approach for effective assessment and treatment of FAS is difficult to find. As such, a thorough and skilled assessment of individual cases is necessary in order to understand the underlying speech characteristics contributing to the foreign accent. Combined phonetic and acoustic analyses similar to the present study, though simplified greatly in the number of measures obtained per patient, may serve as an effective evaluation procedure. In theory, this would provide the clinician with a pattern of patient's consonant errors (via the phonetic analysis), as well as a pattern of vowel errors (via a phonetic and acoustic analysis combined) to accurately quantify the errors. In fact, the *Grandfather Passage* (Darley et al., 1975) as the stimulus for phonetic transcription may serve as a useful initial assessment because it is a reading comprised of all phonemes found in the English language.

It has been widely documented that changes in vowel quality constitute a generous preponderant of FAS speech. Evidence of these changes per individual would be best identified

initially through a skilled phonetic analysis of a connected speech sample. This would enable the investigator or clinician to begin identifying those vowels most severely affected by the disorder. Confirmation of the vowel errors could then be obtained through formant analyses of the vowels in isolation (i.e., using the appropriate acoustic analysis software). The configuration of the patient's vowel space may be best illustrated using an F1 x F2 grid and comparison to documented norms (i.e., such as those provided by Hillenbrand et al., 1995) to determine whether or not a systematic shift in vowel space has occurred. Likewise, it would be the responsibility of the investigator to examine whether resultant placement errors can be confirmed in the phonetic analysis.

If, indeed, the underlying problem of FAS is a reduction in range of motion, then the goal for speech therapy may be more clearly defined. For example, therapy may commence with traditional treatment techniques targeting range of motion. Based on this particular study, the following techniques may have been employed for the female participant: (1) Lip retraction exercises to reduce excessive rounding on anterior vowels, (2) minimal pair drills contrasting anterior and posterior vowel and consonant productions, and (3) minimal contrast pairs targeting improved coordination of stop consonants (released versus unreleased). For each therapy task, it would be important to differentiate ROM and coordination as the underlying problem. The goal for stop consonant production in this case would target coordination and sequencing of speech sounds, while all other errors would target range of motion. Errors without a clear motoric base, such as the female's agrammatisms, would be addressed accordingly. Because the agrammatisms were interpreted as a symptom of Broca's aphasia, language techniques would need to be employed.

From a clinical perspective, it is also important to consider Foreign Accent Syndrome a legitimate concern based on the adverse social and emotional response of the individuals affected. Negative social reaction to FAS was documented sixty years ago in the case described by Monrad-Krohn (1947). The Norwegian woman in his study was essentially rejected by members of her community because she had developed a German accent during a time of German invasion. While these patients maintain speech that is relatively fluent with language skills superior to those typically seen in aphasic patients, FAS is legitimately an undesirable condition whereby neurological damage renders negative altering effects on speech quality. Because the social and emotional response to FAS is poorly documented, future research may be warranted to investigate the and thereby legitimize the seriousness of the disorder and the need for therapeutic intervention.

APPENDIX A: GRANDFATHER PASSAGE PHONETIC TRANSCRIPTIONS

Female "J.D.": Disordered Speech (pre-recovery sample)

Recorded October 2004

ju wɪʃ tʰu noʊ oʊɫ əbaʊtʰ maɪ grændfɑðar

wɪːɫ hi ɪz nɛrli naɪndiθ̬r̩ i jɛrz oʊɫd jɛtʰ hi stɪɫ θɪŋks æz swɪfli æz ɛvɑ

hi drɛsɪz hɪmsɪɫf ɪn ən æːnʃəntʰ · blæk · frɔkʰ · koʊtʰ juʒəli mɪsɪŋ sɛvrɪɫ bʌtʰɪnz

ʌ lɔŋ bɪɚd kliŋgz tu ɪz tʃɪn gɪvɪŋ ðoʊz hu əbzɝːv hiəm ə pronaʊnst fiɫiŋ ʌv

d̪i ʌʔmost rispɛktʰ

wɛn hi spiks hɪz vɔɪs ɪz ʤʌst ə bɪtʰ krækt æn kwɪvɚz ʌ bɪtʰ

twaɪs · itʃ · de hi pleɪz skɪlfuɫi æn_ wɪ_ zɛst ʌpən ə smɑɫ argæn

ɪksɛpt ɪn ðə wɛntʰar wɛn ðə snoʊ ɔr aɪs prɪvɪnts hi sloʊli tʰeɪks ʌ ʃɔrtʰ

woʊk ɪn ði oʊpən ɛr itʃ deɪ

wi hæv ɔftən arʤd hɪm tu wɔk mɔr ɔftɛn æn_ smoʊk lɛs bʌt̬ i oʊwez

ænsɚz bənænə ɔɪɫ

grænfɑðɚ ɪz mɔdɚn ɪn hɪz læŋgwɪʤ

Female "J.D.": Normal Speech (Post-recovery sample)

Recorded September 2005

ju wɪʃ tə noʊ ɑl əbaʊt̚ maɪ grænfɑðɚ

wɛl hi ɪz nɪɚli naɪndiθri jɪɚz old jɛt hi stɪl θɪŋks æz swɪfli æz ɛvɚ

hi drɛsɪz hɪmsɛlf ɪn ən æntʃɛnt blæk frɑk^{h} kot juʒəli mɪsɪŋ sɛvrɪl bʌʔɪnz

ʌ lɑŋ bɪɚd kliŋz tu ɪz tʃɪn gɪviŋ ðoʊz hu əbzɝv hɪm ə pronaʊnst filɪŋ ʌv ði

ʌʔmost rispɛkt

wɛn hi spiks hɪz vɔɪs ɪz ʤʌst ə bɪt krækt ænd kwɪvɚz ʌ bɪt^{h}

twaɪs itʃ deɪ hi pleɪz skɪlfʊli ænd wɪð zɛst əpɑn ə smɑl ɔrgən

ɛksɛpt ɪn ðə wɪntɚ wɛn ðə snoʊ ɔr aɪs privɛnts hi sloʊli teɪks ə ʃɔrt wɑk

ɪn ði opən ɛr itʃ deɪ

wi hæv ɑftɛn ɝʤd hɪm tu wɑk mɔr ɑftɛn æn smok lɛs bʌt̬i ɔwez ænsɚz

bənænə ɔɪl

grænfɑðɚ ɪz mɑdɚn ɪn hɪz læŋgwɪʤ

Male “B.S.”: Disordered Speech (pre-recovery sample)

Recorded March 2004

ju wɪʃ tu no ɑl əbaʊʔ maɪ grænfɑðə

wɛl hi ɪz nɪəlɪ nɑniθri jɪəz oʊːld jɛt hi stɪl θɪŋks æz swɪfli æz ɛvə

hi drɛsɪz hɪmsɛlf ɪn ən oʊl blækʰ frɑkʰ koʊɪt juʒəli sɛvrɪl bʌʔɪnz mɪsɪŋ

ə lɑŋ bɪəd kliŋgz tuɪz tʃɪn gɪvɪŋ ðoʊz hu əbzɜv hɪm ə pronaʊnstə filɪŋ ʌv ðə

ʌʔmost rɪspɛkt

wɛn hi spiks hɪz vɔɪs ɪz ʤʌst ə bɪt krækt æn kwɪvəz ə traɪfol

twaɪs itʃ deɪ hi pleɪz skɪlfʊli ɛ wɪðə zɛst əpʌn ɑr ʃmɔl ɔrgɪn

ɪksɛpt ɪn ðə wɪntə wɛn ðə s̡no ɔr aɪs̡ prɪvɛnts hi ʃloʊli teɪks ə ʃart wɔk ɪn

ði opən ɛə itʃ deɪ

wi hæv ɑftɪn ɝʤd hɪm tu wɑk moə æn smoʊk lɛs bʌt hi ɔwez ænsəz

bənænə ɔɪl

grændfɑðə laɪks tu bi mɑdɚn ɪn hɪz læŋgwɪʤ

Male “B.S.”: Normal Speech (Post-recovery sample)

Recorded August 2005

ju wɪʃ tu no ɑl əbaʊʔ maɪ grændfɑðɚ

wɛl hi ɪz nɪrli naɪndiθri jɪrz oʊld jɛt hi stɪl θɪŋks æz swɪfli æz ɛvɚ

hi drɛsɪz hɪmsɛlf ɪn æn oʊld blæk frɑk̚ koʊtʰ juʒuli sɛvrʊl bʌʔɪnz mɪsɪŋ

ʌ lɑŋ bɪrd kliŋgz tuɪz tʃɪn gɪvɪŋ ðoʊz hu əbzɝv hɪm ə pronaʊnst filɪŋ ʌv ði

ʌʔmost rɪspɛkt

wɛn hi spiks hɪz vɔɪs ɪz ʤʌst ə bɪt krækt æn kwɪvɚz ə traɪfol

twaɪs itʃ deɪ hi pleɪz skɪlfʊli ænd wɪð zɛst əpʌn ɑr smɔ ɔrgɛn

ɪksɛpt ɪn ðə wɪnt̬ɚ wɛn ðə snoʊ ɔr aɪs prɪvɛnts hi sloʊli teɪks ə **345**ʃɔrt

wɔk ɪn ði opən ɛr itʃ deɪ

wi hæv ɔftən ɝʤd hɪm tu wɔk mɔr æn smoʊk lɛs bʌt̬i ɔwez ænsɚz bənænə

ɔɪl

grændfɑðɚ laɪks tə bi mɑdɚn ɪn hɪz læŋgwɪʤ

APPENDIX B: ACOUSTIC DATA FOR PARTICIPANTS (DURATION MEASURES)

Voice Onset Time

Female: Pre-Recovery (Disordered)

		/p/	/t/	/k/	/b/	/d/	/g/
	Repetition	pit	tik	kip	bit	dip	gik
/i/	1	90	111	124	-147	15	-108
	2	134	90	112	-115	44	-28
	3	46	75	110	-175	18	-129
	4	109	123	87	-142	-135	-131
	5	137	132	99	10	-103	-55
		pat	tat	kat	bap	dat	gat
/a/	1	110	123	137	13	20	-106
	2	146	189	252	13	-132	-79
	3	70	148	107	13	17	-111
	4	82	42	124	-132	-143	30
	5	132	166	135	-157	15	35
		pup	tut	kup	but	dup	gup
/u/	1	106	143	135	14	24	-105
	2	140	212	145	-138	-129	28
	3	103	112	112	-180	25	-119
	4	70	144	116	-136	23	-124
	5	106	116	128	-148	23	27

Female: Post-Recovery (Normal)

		/p/	/t/	/k/	/b/	/d/	/g/
	Repetition	pit	tik	kip	bit	dip	gik
/i/	1	140	118	160	22	15	51
	2	115	130	99	22	-101	42
	3	120	157	152	-132	21	54
	4	162	127	121	-211	26	52
	5	122	117	101	-92	-117	-87
		pat	tat	kat	bap	dat	gat
/a/	1	191	121	135	19	13	21
	2	147	92	134	13	15	19
	3	106	117	133	13	16	34
	4	105	105	139	14	20	29
	5	112	115	85	10	13	27
		pup	tut	kup	but	dup	gup
/u/	1	105	139	159	23	26	24
	2	83	113	139	15	42	33
	3	100	121	164	14	27	21
	4	107	125	155	14	42	31
	5	97	105	123	14	33	40

Voice Onset Time

Male: Pre-Recovery (Disordered)

	Repetition	/p/	/t/	/k/	/b/	/d/	/g/
	Repetition	pit	tik	kip	bit	dip	gik
/i/	1	76	51	103	-149	-121	-143
	2	38	93	97	-139	-117	-102
	3	44	62	86	-215	-146	-149
	4	45	70	103	-134	-160	-184
	5	42	57	87	14	-162	-152
		pat	tat	kat	bap	dat	gat
/a/	1	86	62	88	-86	26	-107
	2	96	74	77	-211	21	23
	3	65	55	100	-159	-118	-132
	4	51	74	102	-185	-157	-154
	5	36	86	95	-245	-132	-150
		pup	tut	kup	but	dup	gup
/u/	1	75	79	82	-106	-153	-173
	2	68	67	66	-111	-135	-193
	3	74	65	72	-116	-117	-163
	4	59	106	84	-109	-138	-153
	5	57	79	54	-182	-153	-168

Male: Post-Recovery (Normal)

	Repetition	/p/	/t/	/k/	/b/	/d/	/g/
	Repetition	pit	tik	kip	bit	dip	gik
/i/	1	54	79	98	-117	-157	-121
	2	54	81	97	-152	-105	-103
	3	68	68	89	-132	-205	-127
	4	54	75	97	-157	-170	-158
	5	51	76	84	-148	-143	-157
		pat	tat	kat	bap	dat	gat
/a/	1	67	73	119	-163	-127	-124
	2	87	85	91	-170	-129	-138
	3	92	103	129	-160	-112	-156
	4	90	78	139	-126	-103	-145
	5	63	88	103	-135	-105	34
		pup	tut	kup	but	dup	gup
/u/	1	59	72	104	-126	-152	-128
	2	68	78	84	-134	-153	-85
	3	70	87	104	-188	-139	-57
	4	56	72	81	-161	-157	-152
	5	58	90	106	-157	-183	-106

Vowel Duration

Female: Pre-Recovery (Disordered)

	/i/			/a/			/u/		
Repetition	pit	tik	kip	pat	tat	kat	pup	tut	kup
1	151	134	140	197	178	180	152	173	139
2	179	177	150	221	209	204	143	167	167
3	189	174	144	170	220	199	146	177	156
4	177	173	169	151	226	231	176	191	155
5	147	153	159	204	211	185	185	179	175
	bit	dip	gik	bap	dat	gat	but	dup	gup
1	220	172	201	218	215	172	152	175	141
2	183	201	220	205	218	256	224	151	182
3	191	200	221	224	220	221	191	183	169
4	167	225	217	222	243	205	231	182	185
5	219	215	194	243	218	281	208	202	170

Female: Post-Recovery (Normal)

	/i/			/a/			/u/		
Repetition	pit	tik	kip	pat	tat	kat	pup	tut	kup
1	186	166	175	248	230	211	177	200	181
2	169	166	165	262	215	206	206	191	198
3	187	181	194	149	247	229	196	206	187
4	180	157	178	150	227	222	185	211	192
5	164	167	192	248	228	228	200	215	171
	bit	dip	gik	bap	dat	gat	but	dup	gup
1	186	197	210	275	281	222	214	229	165
2	187	193	204	185	257	240	230	150	191
3	216	178	182	223	258	221	226	247	200
4	217	185	178	216	251	208	170	210	213
5	196	206	237	233	284	257	147	216	211

Vowel Duration

Male: Pre-Recovery (Disordered)

	/i/			/a/			/u/		
Repetition	pit	tik	kip	pat	tat	kat	pup	tut	kup
1	221	176	189	236	242	221	152	182	155
2	236	190	188	188	249	215	166	164	165
3	234	152	175	215	240	241	199	184	186
4	240	164	190	227	250	207	204	174	183
5	226	179	176	221	260	236	217	174	209
	bit	dip	gik	bap	dat	gat	but	dup	gup
1	232	203	232	211	238	295	217	170	201
2	250	216	227	233	304	254	222	197	209
3	225	203	228	256	288	290	226	195	215
4	234	250	230	223	282	272	223	203	236
5	240	229	238	230	293	290	212	226	203

Male: Post-Recovery (Normal)

	/i/			/a/			/u/		
Repetition	pit	tik	kip	pat	tat	kat	pup	tut	kup
1	190	167	174	197	223	246	157	155	149
2	253	208	180	232	327	264	208	196	180
3	159	175	221	180	278	280	155	187	172
4	215	176	211	226	318	304	198	206	168
5	213	181	214	251	292	302	151	204	172
	bit	dip	gik	bap	dat	gat	but	dup	gup
1	210	219	245	240	263	302	207	189	223
2	203	235	228	241	344	312	241	222	229
3	245	245	253	275	339	358	203	224	229
4	234	251	282	263	322	338	204	238	242
5	258	229	255	253	258	314	245	196	218

Word Duration

Female: Pre-Recovery (Disordered)

	/i/			/a/			/u/		
Repetition	pit	tik	kip	pat	tat	kat	pup	tut	kup
1	603	572	566	766	747	670	522	739	719
2	828	635	659	843	883	959	666	836	700
3	702	673	679	761	885	707	606	707	753
4	678	758	612	613	650	799	765	778	680
5	765	727	614	853	825	780	682	783	726
	bit	dip	gik	bap	dat	gat	but	dup	gup
1	747	459	678	587	801	725	588	564	830
2	782	540	673	745	861	700	821	623	677
3	788	673	709	668	703	815	871	559	751
4	765	673	730	722	933	622	852	570	785
5	652	647	605	806	653	760	829	630	591

Female: Post-Recovery (Normal)

	/i/			/a/			/u/		
Repetition	pit	tik	kip	pat	tat	kat	pup	tut	kup
1	665	651	726	895	733	670	576	716	784
2	617	585	526	742	633	657	587	650	665
3	623	654	627	642	634	654	545	614	710
4	740	650	601	620	660	675	577	640	625
5	646	593	594	687	620	623	575	593	582
	bit	dip	gik	bap	dat	gat	but	dup	gup
1	504	471	553	652	658	602	695	616	504
2	545	633	561	599	618	573	600	531	492
3	617	580	571	442	635	677	556	632	520
4	780	467	511	560	594	508	510	520	560
5	626	620	630	516	579	573	524	556	560

Word Duration

Male: Pre-Recovery (Disordered)

	/i/			/a/			/u/		
Repetition	pit	tik	kip	pat	tat	kat	pup	tut	kup
1	575	430	571	610	515	522	456	475	461
2	509	530	454	534	540	509	378	466	442
3	505	430	443	513	474	583	502	417	499
4	530	449	520	588	555	523	421	524	478
5	528	451	475	469	585	604	460	455	478
	bit	dip	gik	bap	dat	gat	but	dup	gup
1	672	562	636	529	562	616	539	563	596
2	644	532	576	696	584	498	536	575	577
3	716	564	581	632	641	674	574	523	603
4	619	601	632	617	692	711	561	580	595
5	475	601	632	714	704	638	707	564	600

Male: Post-Recovery (Normal)

	/i/			/a/			/u/		
Repetition	pit	tik	kip	pat	tat	kat	pup	tut	kup
1	568	509	599	716	655	652	505	521	591
2	559	548	623	671	672	652	619	537	562
3	564	449	548	650	644	678	474	558	503
4	560	438	565	580	666	706	591	527	559
5	513	442	515	571	618	679	504	545	484
	bit	dip	gik	bap	dat	gat	but	dup	gup
1	649	638	658	688	766	855	635	654	706
2	664	633	543	728	759	758	630	729	545
3	662	819	613	766	737	804	642	610	631
4	663	682	651	625	749	753	690	721	622
5	629	675	597	640	718	595	626	695	614

APPENDIX C: ACOUSTIC DATA FOR PARTICIPANTS (FREQUENCY MEASURES)

Fundamental Frequency

Female: Pre-Recovery (Disordered)

		/p/	/t/	/k/	/b/	/d/	/g/
	Repetition	pit	tik	kip	bit	dip	gik
/i/	1	270	257	250	272	235	252
	2	260	268	242	257	268	253
	3	247	274	254	279	295	239
	4	313	273	294	246	246	240
	5	254	273	285	257	257	255
		pat	tat	kat	bap	dat	gat
/a/	1	233	234	235	219	230	180
	2	265	257	261	189	229	237
	3	200	247	242	240	238	241
	4	180	247	231	228	234	221
	5	223	234	253	233	261	228
		pup	tut	kup	but	dup	gup
/u/	1	246	281	303	232	245	213
	2	280	259	267	268	209	264
	3	277	257	267	248	273	253
	4	256	262	303	250	235	252
	5	258	306	295	205	266	271

Female: Post-Recovery (Normal)

		/p/	/t/	/k/	/b/	/d/	/g/
	Repetition	pit	tik	kip	bit	dip	gik
/i/	1	275	237	257	259	233	269
	2	233	257	221	247	230	267
	3	251	267	275	257	206	240
	4	279	255	279	252	232	227
	5	284	240	260	242	230	221
		pat	tat	kat	bap	dat	gat
/a/	1	234	226	217	213	239	181
	2	247	220	207	189	198	206
	3	173	225	217	219	205	193
	4	183	226	196	204	196	205
	5	213	209	241	221	225	209
		pup	tut	kup	but	dup	gup
/u/	1	271	282	289	241	248	177
	2	288	269	275	230	215	261
	3	257	226	247	249	263	224
	4	249	246	246	208	224	245
	5	212	316	275	197	251	247

Fundamental Frequency

Male: Pre-Recovery (Disordered)

		/p/	/t/	/k/	/b/	/d/	/g/
	Repetition	pit	tik	kip	bit	dip	gik
/i/	1	163	149	126	134	130	145
	2	156	153	163	156	135	145
	3	169	142	140	147	131	130
	4	167	147	150	153	142	145
	5	153	145	147	150	141	145
		pat	tat	kat	bap	dat	gat
/a/	1	112	106	125	102	112	94
	2	134	115	132	97	98	114
	3	129	111	123	102	106	115
	4	129	127	128	118	113	120
	5	124	108	130	109	102	110
		pup	tut	kup	but	dup	gup
/u/	1	151	129	162	117	125	136
	2	141	141	148	131	128	140
	3	149	149	142	137	125	138
	4	159	154	166	146	134	135
	5	164	132	146	126	151	139

Male: Post-Recovery (Normal)

		/p/	/t/	/k/	/b/	/d/	/g/
	Repetition	pit	tik	kip	bit	dip	gik
/i/	1	115	130	109	123	116	124
	2	123	119	156	121	121	118
	3	196	144	117	122	115	123
	4	132	123	116	122	121	126
	5	110	140	116	121	119	119
		pat	tat	kat	bap	dat	gat
/a/	1	106	108	115	104	105	104
	2	128	111	116	102	112	109
	3	99	106	112	106	104	103
	4	102	102	106	109	112	103
	5	114	104	117	114	98	106
		pup	tut	kup	but	dup	gup
/u/	1	124	110	135	115	119	117
	2	129	124	128	122	119	123
	3	134	122	123	123	124	119
	4	132	118	129	114	117	118
	5	148	118	127	118	112	116

Formant Frequencies

Female: Pre-Recovery (Disordered)

		pit			tik			kip		
Repetition		20%	50%	80%	20%	50%	80%	20%	50%	80%
1	F1	474	341	420	485	485	467	441	459	443
	F2	2886	2898	2874	2168	1870	1769	2062	X	X
	F3	3412	3961	3378	2905	2817	3009	2985	2972	3014
2	F1	485	493	443	488	372	355	434	445	454
	F2	2676	2869	1803	2187	X	X	2686	2905	1722
	F3	4466	3233	3030	3316	3394	3355	3228	3339	3906
3	F1	377	413	294	485	413	490	437	358	396
	F2	1749	2255	1967	2688	2820	X	3011	2230	1768
	F3	3349	3132	3178	3280	3749	3047	3456	3030	2994
4	F1	327	376	370	501	381	330	375	339	411
	F2	2783	2817	1423	2487	2857	2885	2788	2868	2929
	F3	3533	3451	2859	3552	3405	3411	3468	3474	3314
5	F1	465	489	468	510	512	459	421	363	466
	F2	2687	2793	2803	2481	X	2883	2895	3341	1989
	F3	3518	3554	3522	3359	3272	3329	3432	4550	3224

		bit			dip			gik		
Repetition		20%	50%	80%	20%	50%	80%	20%	50%	80%
1	F1	469	482	424	449	440	406	357	476	487
	F2	2671	2851	2650	2524	X	X	2834	2798	2973
	F3	3242	X	3158	3314	2824	2990	4478	4511	4658
2	F1	457	484	474	471	510	496	358	490	408
	F2	2490	2835	2947	2528	X	3150	1767	3049	2983
	F3	2786	3307	4690	3186	3059	4714	3145	3364	3318
3	F1	388	329	401	359	377	384	254	335	456
	F2	2487	3118	2952	2458	2642	2627	X	2841	2956
	F3	3282	3591	3364	3273	3303	3110	3339	3403	X
4	F1	346	390	466	435	468	474	377	385	470
	F2	2728	2668	1753	2027	2857	X	2887	2873	2077
	F3	3562	3479	2838	3308	3301	3011	3654	3671	2921
5	F1	419	460	323	372	390	320	407	490	459
	F2	1835	2844	2880	2571	2839	X	2054	2811	2801
	F3	2683	3530	X	3202	3521	3202	2797	3573	3477

Repetition		pat			tat			kat		
		20%	50%	80%	20%	50%	80%	20%	50%	80%
1	F1	913	732	905	683	687	734	679	706	855
	F2	X	1091	1445	1147	1171	1074	1163	1173	X
	F3	2700	2776	2727	2766	2824	2684	2617	2642	2634
2	F1	743	803	880	692	764	903	671	697	722
	F2	1255	1310	1397	1165	1285	1616	1132	1188	1629
	F3	2636	2908	1775	2844	X	3252	2336	2515	2611
3	F1	642	601	842	704	725	807	684	706	808
	F2	1008	976	1343	1164	1223	1463	1188	1208	1477
	F3	2922	3110	2982	2797	3002	2962	2697	2796	2764
4	F1	583	700	756	735	749	828	651	669	696
	F2	1012	1020	1263	X	1046	1090	1115	1154	1675
	F3	2733	2584	2518	2574	2992	1760	2532	2574	2833
5	F1	725	791	872	675	688	711	719	756	809
	F2	1037	1332	1694	1152	1179	1336	1171	1233	1447
	F3	2571	2632	2568	X	2933	2762	2594	2631	2739

Repetition		bap			dat			gat		
		20%	50%	80%	20%	50%	80%	20%	50%	80%
1	F1	663	792	1003	477	628	783	533	684	784
	F2	843	X	X	1012	948	X	983	1009	1180
	F3	3595	2850	2884	2853	3048	3039	3166	2876	2832
2	F1	674	847	849	516	634	739	679	698	839
	F2	1054	1060	1253	940	968	1297	1151	1173	1617
	F3	2960	3013	2813	3065	3079	3160	2973	2873	2820
3	F1	668	704	761	669	702	943	471	682	738
	F2	1127	1198	1309	X	1144	1495	930	1142	1264
	F3	2922	2863	2864	3093	2937	2917	3225	2925	2952
4	F1	618	684	740	557	674	707	620	653	700
	F2	1075	1128	1230	1287	1132	1250	1075	1096	1258
	F3	2942	X	X	2868	3018	3064	2980	2771	2410
5	F1	696	813	810	570	667	694	526	664	703
	F2	1090	1104	1151	868	1009	1054	913	956	1080
	F3	3108	3145	3048	2794	2748	1422	2395	2940	2773

		pup			tut			kup		
Repetition		20%	50%	80%	20%	50%	80%	20%	50%	80%
1	F1	480	487	485	510	530	557	510	505	355
	F2	1195	1130	981	1687	1410	1182	1068	897	779
	F3	2903	2944	2344	2947	3070	2991	3234	2963	1982
2	F1	464	476	542	460	503	541	490	508	537
	F2	1056	970	X	1679	1283	1115	1036	1028	X
	F3	2714	2381	2398	2961	3105	3118	3032	3089	3219
3	F1	477	369	468	473	506	496	466	396	493
	F2	1008	1029	839	1792	1513	1388	984	1000	912
	F3	3099	3013	3041	3098	2895	3171	2184	2946	3173
4	F1	372	474	366	491	518	517	460	550	448
	F2	1278	1146	869	1820	1519	1284	X	838	872
	F3	3050	3062	2189	3343	2878	3216	3049	3159	2656
5	F1	503	507	505	561	605	583	500	549	489
	F2	1003	2543	966	1771	1542	1295	918	858	863
	F3	3086	3066	3000	2872	3099	2845	2991	2955	2358

		but			dup			gup		
Repetition		20%	50%	80%	20%	50%	80%	20%	50%	80%
1	F1	425	418	410	452	489	509	411	416	388
	F2	1013	920	X	1815	1454	1258	1125	1004	913
	F3	2941	2357	2977	2888	2979	3094	2887	3039	2575
2	F1	467	495	387	432	414	420	448	509	434
	F2	1106	1037	868	1978	1393	1218	1160	1073	1037
	F3	3151	2981	3083	2927	3032	3046	3112	3135	3146
3	F1	446	487	509	461	355	553	446	490	389
	F2	1081	976	3133	1884	1546	1195	1137	1001	665
	F3	3068	372	4121	2862	3001	3065	3223	3014	3015
4	F1	467	497	504	449	465	486	454	487	494
	F2	1148	1208	1847	1852	1632	1201	1403	1062	1020
	F3	3720	3345	3253	2447	2887	3413	2880	3188	2507
5	F1	430	435	493	464	523	551	469	510	420
	F2	874	1012	X	1605	1368	1057	1192	1067	976
	F3	3068	3228	2557	2815	X	3147	3191	3096	3395

Female: Post-Recovery (Normal)

Repetition		pit 20%	pit 50%	pit 80%	tik 20%	tik 50%	tik 80%	kip 20%	kip 50%	kip 80%
1	F1	274	281	284	289	288	969	283	267	273
	F2	2928	2775	2817	2800	2865	1558	3002	3392	2973
	F3	3534	3285	3217	3363	3388	2725	3513	4337	3517
2	F1	274	268	290	288	276	951	343	342	320
	F2	2822	2944	2809	X	2842	1586	2810	2968	2974
	F3	3376	3312	3134	3019	3284	2764	3402	3384	3236
3	F1	266	258	268	307	287	961	298	289	279
	F2	2850	2881	2838	2918	2968	1386	2832	2779	2908
	F3	3317	3203	3171	3344	4388	2642	3409	3324	X
4	F1	294	291	366	315	306	953	277	285	312
	F2	2926	2903	2932	2782	2782	1358	2854	3051	2909
	F3	3565	3223	4482	3321	3291	2662	3274	3548	3206
5	F1	272	292	301	354	309	979	298	297	325
	F2	2718	2827	3021	2769	2923	1601	2775	2823	2963
	F3	3185	3417	4424	3331	3374	2691	3267	3427	4448

Repetition		bit 20%	bit 50%	bit 80%	dip 20%	dip 50%	dip 80%	gik 20%	gik 50%	gik 80%
1	F1	270	273	285	299	275	281	273	290	306
	F2	2902	2940	2946	2716	2788	2894	2875	2788	2876
	F3	2447	3431	3380	3394	3336	4419	3205	3206	4504
2	F1	287	255	277	251	264	266	319	299	318
	F2	2756	2907	2837	2715	2808	2839	2818	2922	2796
	F3	3249	3405	3355	3249	3416	3252	3244	3453	3139
3	F1	285	266	298	409	387	332	327	354	322
	F2	2782	2838	2871	2530	2762	2936	2772	2833	2904
	F3	3269	3298	X	3227	3245	3194	3267	3303	4505
4	F1	271	268	335	295	271	261	293	320	359
	F2	2802	2809	2899	2506	2799	2878	2902	2894	2991
	F3	3614	3406	3302	3246	3275	3189	3363	3247	3374
5	F1	291	288	285	335	299	283	236	335	387
	F2	2591	2887	2854	2569	X	3000	2803	2831	2872
	F3	2992	3372	3206	3262	3233	3187	3276	3152	3256

Repetition		pat 20%	pat 50%	pat 80%	tat 20%	tat 50%	tat 80%	kat 20%	kat 50%	kat 80%
1	F1	1176	1012	969	1111	1116	1121	1109	1134	1114
	F2	2618	1332	1558	X	X	1511	X	X	1521
	F3	3905	2674	2725	2667	2708	2708	2542	2572	2610
2	F1	421	962	951	999	X	1047	875	1074	885
	F2	994	X	1586	1280	1299	1367	1320	X	1499
	F3	1430	2670	2764	2649	2657	2624	2488	2486	2543
3	F1	1289	1243	961	1073	903	892	1017	1164	1074
	F2	2609	2707	1386	1275	1334	1548	1334	X	1435
	F3	3830	3787	2642	2635	2690	2765	2417	2398	2505
4	F1	978	981	953	1168	989	1106	1010	954	933
	F2	1310	1312	1358	2613	1324	1500	1321	1350	1422
	F3	2636	2640	2662	3876	2684	2686	2500	2535	2572
5	F1	1234	1004	979	1089	1051	1019	1121	1104	982
	F2	2490	1271	1601	2599	2641	1637	X	X	1463
	F3	3856	2613	2691	3893	3898	2632	2536	2593	2636

Repetition		bap 20%	bap 50%	bap 80%	dat 20%	dat 50%	dat 80%	gat 20%	gat 50%	gat 80%
1	F1	1036	1068	X	900	1310	376	822	890	898
	F2	1402	X	1326	1523	3067	1099	1419	1344	1423
	F3	2720	2747	2722	2871	3926	1663	2671	2690	2577
2	F1	939	1019	1093	848	1000	1115	828	1010	1055
	F2	1378	1343	1369	1476	1370	X	1412	1405	1498
	F3	2656	2812	2796	2705	2447	2771	2595	2599	2589
3	F1	1015	1096	951	818	949	898	836	937	886
	F2	1448	2887	1424	1452	1320	1323	1458	1376	1411
	F3	2904	3945	2829	2697	2836	2779	2664	2663	2612
4	F1	995	1022	1019	866	950	998	761	879	985
	F2	1389	1377	1331	1422	1248	1395	1271	1386	1489
	F3	2685	2838	2772	2623	2615	2571	2699	2640	2567
5	F1	929	1060	1064	860	X	1000	855	1032	942
	F2	1294	1310	1385	1525	1259	1476	1482	1416	1540
	F3	2738	2731	2673	2753	2713	2982	2671	2658	2674

Repetition		pup 20%	pup 50%	pup 80%	tut 20%	tut 50%	tut 80%	kup 20%	kup 50%	kup 80%
1	F1	390	343	358	342	327	316	428	343	360
	F2	1570	1443	1354	1966	1705	1452	1373	1407	1232
	F3	2908	2974	2992	2983	2839	2877	2948	2900	3113
2	F1	424	352	360	352	307	332	384	297	315
	F2	1581	1498	1399	2217	2116	1651	1556	1397	1094
	F3	2840	2867	2995	3007	2917	2828	2819	2975	2966
3	F1	477	463	313	421	395	374	449	413	419
	F2	1957	1814	1612	2129	1865	1635	1819	1735	1548
	F3	2860	2835	2972	2836	2729	2774	2851	2932	2931
4	F1	437	436	385	346	407	314	434	410	356
	F2	1802	1742	1498	2111	1979	1744	1701	1733	1394
	F3	2797	2785	2856	2859	2841	2804	2845	2919	3110
5	F1	413	410	411	337	352	333	334	325	304
	F2	1754	1696	1539	2049	1845	1450	1539	1359	1105
	F3	2853	2920	2893	2870	2897	2974	2837	2958	3110

Repetition		but 20%	but 50%	but 80%	dup 20%	dup 50%	dup 80%	gup 20%	gup 50%	gup 80%
1	F1	419	403	352	325	376	288	361	323	390
	F2	1588	1445	1303	2050	1766	1313	1553	1431	1344
	F3	2983	2930	3051	2839	2855	2980	2953	2897	3127
2	F1	442	447	419	386	383	427	374	405	381
	F2	1726	1624	1539	2184	2160	1906	1651	1482	1312
	F3	2875	2791	2842	3059	2906	2793	2890	2892	2933
3	F1	452	467	437	357	353	361	412	412	388
	F2	1790	1736	1531	2111	2100	1614	1861	1661	1586
	F3	2851	2876	2848	3091	2894	2912	2831	2924	2946
4	F1	410	401	388	346	409	405	398	407	411
	F2	1785	1860	1715	2234	2115	1658	1925	1736	1567
	F3	2933	2957	2932	2997	2895	2825	2740	2782	2929
5	F1	411	396	425	348	390	391	399	401	438
	F2	1868	1882	1737	2130	1998	1703	2091	1948	1644
	F3	2906	2970	2938	2975	2841	2889	2839	2898	2981

Formant Frequencies

Male: Pre-Recovery (Disordered)

Repetition		pit 20%	pit 50%	pit 80%	tik 20%	tik 50%	tik 80%	kip 20%	kip 50%	kip 80%
1	F1	296	327	254	293	298	299	272	272	292
	F2	2360	2600	2609	2365	2449	2534	2381	2394	2514
	F3	2899	3000	3082	2951	2995	2848	2968	2928	2913
2	F1	291	291	243	292	299	296	291	313	277
	F2	2369	2511	2639	2482	2555	2695	2539	2572	2399
	F3	2990	3084	3063	3007	3081	2910	3169	3157	2730
3	F1	292	278	217	276	289	306	255	273	280
	F2	2463	2561	2658	2418	2598	2698	2453	2457	2245
	F3	3166	3196	3114	2987	3116	2996	3170	3125	2661
4	F1	290	279	249	275	293	295	273	293	287
	F2	2467	2627	X	2372	2482	2616	2439	2435	2380
	F3	2859	3183	2925	3005	3037	2934	2975	2855	2740
5	F1	293	298	246	254	286	290	237	283	294
	F2	2419	2494	2587	2392	2516	2660	2493	2476	2402
	F3	3082	3053	3079	3017	3033	2970	3046	2881	2706

Repetition		bit 20%	bit 50%	bit 80%	dip 20%	dip 50%	dip 80%	gik 20%	gik 50%	gik 80%
1	F1	247	265	297	270	266	308	231	287	272
	F2	2190	2403	2579	2038	2199	2318	2261	2435	2603
	F3	2702	3169	3122	2713	2859	2852	3093	2998	3131
2	F1	256	279	266	232	256	285	236	292	291
	F2	2219	2445	2609	2164	2328	2426	2420	2492	2613
	F3	2694	3066	3061	2779	3011	2971	3521	3022	3049
3	F1	253	268	233	226	254	294	215	254	291
	F2	2195	2467	2580	2166	2329	2461	2341	2471	2600
	F3	2753	3057	3193	2758	2991	3054	2980	3101	3137
4	F1	256	291	249	229	257	250	222	291	286
	F2	2224	2485	2591	2101	2363	2443	2336	2405	2600
	F3	2806	3127	3100	2831	3014	2879	3210	3197	3153
5	F1	264	291	245	249	275	295	228	272	237
	F2	2190	2449	2539	2212	2410	2485	2340	2400	2582
	F3	2840	2950	3008	2815	3073	3071	2984	3002	3026

Repetition		pat 20%	pat 50%	pat 80%	tat 20%	tat 50%	tat 80%	kat 20%	kat 50%	kat 80%
1	F1	897	969	757	747	789	704	810	762	719
	F2	2563	2401	1661	1225	1173	1624	1409	1211	1561
	F3	3158	3276	2467	2397	2372	2415	2423	2402	2483
2	F1	1058	977	681	833	X	670	834	860	716
	F2	X	1417	1675	1441	1335	1626	1530	1513	1670
	F3	2598	2551	2633	2454	2421	2428	2488	2406	2426
3	F1	801	816	652	802	818	723	868	827	741
	F2	1045	1295	1641	1512	1271	1652	1433	1388	1659
	F3	2535	2319	2460	2401	2278	2411	2528	2428	2484
4	F1	796	807	680	808	830	676	883	926	632
	F2	1100	1316	1669	1428	1249	1610	1174	1169	1669
	F3	2439	2301	2387	2420	2432	2479	2275	2217	2362
5	F1	761	812	690	X	699	722	866	890	760
	F2	1387	1276	1621	1285	1193	1580	1328	1202	1665
	F3	2501	2431	2539	2415	2567	2547	2464	2530	2436

Repetition		bap 20%	bap 50%	bap 80%	dat 20%	dat 50%	dat 80%	gat 20%	gat 50%	gat 80%
1	F1	727	759	870	763	926	809	597	859	739
	F2	1118	1050	1132	1375	1300	1707	1504	1280	1610
	F3	2475	2553	2442	2464	2574	3071	2513	2366	2361
2	F1	687	756	761	669	858	778	679	913	793
	F2	1028	1117	1151	1420	1223	1587	1463	1482	1618
	F3	2500	2470	2435	2502	2365	2326	2618	2280	2287
3	F1	735	884	926	527	796	700	561	904	784
	F2	1098	1176	1204	1529	1248	1521	1589	1383	1617
	F3	2563	2365	2664	2566	2404	2325	2461	2285	2244
4	F1	690	974	846	635	899	805	538	787	738
	F2	994	X	1144	1563	1345	1621	1536	1447	1612
	F3	2560	2519	2504	2531	2365	2310	2455	2298	2277
5	F1	644	736	773	634	868	786	626	783	770
	F2	1034	1126	1185	1475	1281	1641	1491	1276	1556
	F3	2499	2529	2349	2605	2360	2413	2545	2454	2357

Repetition		pup 20%	pup 50%	pup 80%	tut 20%	tut 50%	tut 80%	kup 20%	kup 50%	kup 80%
1	F1	282	293	315	295	302	311	293	313	311
	F2	855	852	837	1165	1158	1350	1058	874	904
	F3	2486	2537	2544	2582	2571	2597	2458	2446	2461
2	F1	273	274	311	271	274	275	276	291	301
	F2	818	839	829	1514	1636	1463	753	848	822
	F3	2210	2369	2325	2463	2529	2478	2510	2492	2562
3	F1	267	293	268	257	291	251	263	278	313
	F2	811	763	828	1225	1222	1579	923	838	803
	F3	2489	2440	2523	2355	2386	2391	2461	2416	2495
4	F1	282	315	291	258	292	246	295	312	292
	F2	824	832	793	1218	1301	1391	898	984	835
	F3	2512	2500	2544	2426	2716	2463	2416	2424	2345
5	F1	312	312	218	253	261	293	273	284	253
	F2	786	784	767	1396	1327	1392	898	872	861
	F3	3314	2386	2385	2583	2645	2526	2350	2309	2410

Repetition		but 20%	but 50%	but 80%	dup 20%	dup 50%	dup 80%	gup 20%	gup 50%	gup 80%
1	F1	303	331	372	270	288	298	236	273	313
	F2	841	952	1637	1569	1266	1189	884	966	915
	F3	2568	2522	2677	2405	2333	2475	2296	2292	2470
2	F1	273	267	314	235	254	303	241	272	292
	F2	853	924	1265	1588	1358	1013	1043	947	893
	F3	2420	2483	2537	2243	2271	2391	2244	2295	2462
3	F1	252	273	343	234	253	295	221	271	272
	F2	758	955	1406	1446	1161	827	980	916	867
	F3	2497	2480	2554	2229	2210	2433	2270	2341	2434
4	F1	259	274	257	249	271	312	236	269	275
	F2	833	794	1348	1701	1444	1165	1147	907	866
	F3	2455	2421	2503	2335	2318	2463	X	2277	2370
5	F1	273	271	293	253	292	265	234	272	295
	F2	832	881	1307	1404	1167	927	896	850	817
	F3	2380	2386	2429	2297	2371	2497	2228	2308	2397

Male: Post-Recovery (Normal)

		pit			tik			kip		
Repetition		20%	50%	80%	20%	50%	80%	20%	50%	80%
1	F1	294	273	233	272	272	255	264	241	230
	F2	2491	2601	2643	2580	2587	2692	2517	2572	2549
	F3	3153	3136	3146	3123	3186	3137	3188	3146	3090
2	F1	307	265	240	334	315	274	287	304	297
	F2	2469	2626	2725	2287	2460	2567	2558	2623	2602
	F3	3033	3297	3293	2900	3049	3001	3568	2986	3004
3	F1	308	298	246	291	280	276	284	275	274
	F2	2555	2719	2759	2431	2565	2663	2573	2565	2488
	F3	3137	3349	3103	3035	3089	3050	X	3082	2769
4	F1	306	273	249	317	294	268	308	259	271
	F2	2422	2583	2691	2321	2434	2576	2512	2539	2485
	F3	2965	3107	3224	2857	3043	3406	3258	3113	3009
5	F1	309	249	252	312	278	257	275	257	273
	F2	2527	2624	2700	2398	2540	2661	2532	2560	2631
	F3	2956	3126	3084	3001	3052	3008	2882	3168	3128

		bit			dip			gik		
Repetition		20%	50%	80%	20%	50%	80%	20%	50%	80%
1	F1	274	253	253	293	281	254	255	257	254
	F2	2201	2461	1470	2195	2488	2534	2479	2547	2659
	F3	2818	3049	2619	2767	3175	3371	3359	3087	3141
2	F1	277	253	269	301	262	257	248	281	269
	F2	2297	2533	2630	2150	2435	2541	2513	2571	2760
	F3	2744	3078	3119	2766	3062	3190	3369	3137	3174
3	F1	318	264	255	281	269	236	245	255	255
	F2	2317	2609	2738	2271	2480	2545	2514	2560	2626
	F3	2814	3154	3140	2914	3098	3038	2936	3082	3110
4	F1	273	264	258	277	263	254	238	254	270
	F2	2288	2535	2631	2091	2439	2594	2585	2582	2705
	F3	2871	2960	3117	2733	3325	3277	3191	3087	3124
5	F1	282	250	233	270	253	260	252	273	258
	F2	2309	2539	2657	2224	2495	2620	2478	2508	2614
	F3	2998	3090	3106	2775	3103	3071	2786	3049	3141

		pat			tat			kat		
Repetition		20%	50%	80%	20%	50%	80%	20%	50%	80%
1	F1	734	757	935	709	749	809	773	856	778
	F2	1143	1178	1430	1338	1204	1399	1293	1341	1579
	F3	2465	2456	2315	2373	2307	2218	2409	2442	2462
2	F1	723	839	810	747	913	712	767	809	692
	F2	1116	1247	1602	1265	1322	1647	1216	1248	1577
	F3	2464	2444	2504	2405	2387	2564	1343	2321	2390
3	F1	718	765	891	757	846	797	891	807	735
	F2	1082	1166	1321	1252	1279	1586	1213	1248	1641
	F3	2423	2221	2152	2276	2488	2336	2410	2398	2425
4	F1	767	791	768	756	811	716	722	822	648
	F2	1178	1330	1591	1263	1230	1597	1249	1433	1711
	F3	2384	2174	2370	2330	2352	2534	2274	2260	2445
5	F1	746	778	760	736	834	670	853	803	717
	F2	1148	1256	1576	1253	1237	1572	1287	1269	1602
	F3	2361	2295	2390	2312	2195	2424	2428	2340	2440

		bap			dat			gat		
Repetition		20%	50%	80%	20%	50%	80%	20%	50%	80%
1	F1	724	787	759	572	770	819	528	776	817
	F2	1146	1114	1166	1485	1219	1372	1561	1290	1441
	F3	2510	2457	2384	2499	2450	2378	2376	2347	2334
2	F1	716	774	905	665	761	780	517	791	726
	F2	1128	1170	1229	1420	1225	1543	1567	1289	1509
	F3	2548	2475	2380	2494	2383	2500	2400	2305	2423
3	F1	700	745	775	649	780	673	604	797	758
	F2	1123	1143	1212	1447	1246	1462	1471	1271	1616
	F3	2522	2439	2351	2450	2392	2335	2393	2278	2443
4	F1	706	723	748	595	729	748	572	816	768
	F2	1124	1187	1211	1482	1229	1455	1528	1271	1399
	F3	2507	2488	2366	2526	2483	2373	2274	2368	2424
5	F1	721	814	829	604	240	806	690	767	721
	F2	1147	1135	1189	1498	1335	1426	1423	1325	1577
	F3	2468	2466	2384	2488	2397	2302	2298	2303	2446

Repetition		pup 20%	pup 50%	pup 80%	tut 20%	tut 50%	tut 80%	kup 20%	kup 50%	kup 80%
1	F1	296	290	293	299	290	256	277	274	273
	F2	1297	1228	1113	1856	1915	1834	1329	1217	1167
	F3	2488	2469	2410	2623	2546	2510	2478	2504	2497
2	F1	351	297	274	307	275	265	282	272	272
	F2	1474	1386	1307	1825	1855	1779	1316	1262	1123
	F3	2554	2520	2521	2599	2507	2496	2480	2500	2504
3	F1	288	273	261	311	285	277	273	260	289
	F2	1259	1202	1166	1844	1835	1750	1213	1157	1007
	F3	2532	2488	2455	2582	2516	2450	2435	2355	2415
4	F1	322	297	279	306	316	285	277	270	273
	F2	1393	1309	1268	1838	1849	1780	1332	1257	1094
	F3	2475	2487	2423	2598	2491	2467	2532	2556	2567
5	F1	288	290	291	329	327	311	275	267	272
	F2	1025	1101	1048	1787	1820	1793	1193	1260	1041
	F3	2647	2620	2553	2620	2562	2551	2504	2499	2584

Repetition		but 20%	but 50%	but 80%	dup 20%	dup 50%	dup 80%	gup 20%	gup 50%	gup 80%
1	F1	335	315	257	275	280	281	253	277	255
	F2	1310	1424	1457	1852	1876	1638	1593	1444	1285
	F3	2517	2498	2506	2570	2499	2422	2372	2445	2543
2	F1	350	322	277	285	306	272	276	297	274
	F2	1386	1486	1566	1843	1865	1697	1542	1465	1266
	F3	2439	2535	2561	2595	2567	2504	2389	2457	2518
3	F1	353	313	272	299	296	254	261	283	264
	F2	1418	1497	1517	1865	1859	1586	1499	1489	1345
	F3	2584	2596	2654	2630	2579	2535	2228	2354	2464
4	F1	338	333	283	293	294	290	283	307	270
	F2	1465	1608	1598	1814	1886	1694	1601	1520	1309
	F3	2528	2560	2538	2510	2501	2417	2310	2365	2410
5	F1	341	288	269	285	308	252	266	298	275
	F2	1254	1281	1286	1767	1766	1563	1339	1351	1214
	F3	2494	2653	2572	2568	2478	2393	2340	2414	2494

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