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Voice Onset Time Production In Individuals Wth Alzheimer's Disease

Julie M. Baker

University of Central Florida

VOICE ONSET TIME PRODUCTION
IN INDIVIDUALS WTH ALZHEIMER'S DISEASE

By

JULIE M. BAKER
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ABSTRACT

In the present study, voice onset time (VOT) measurements were compared between a group of individuals with moderate Alzheimer's disease (AD) and a group of healthy age- and gender-matched peers. Participants read a list of consonant-vowel-consonant (CVC) words, which included the six stop consonants. Recordings were gathered and digitized. The VOT measurements were made from oscillographic displays obtained from the Brown Laboratory Interactive Speech System (BLISS) implemented on an IBM-compatible computer. VOT measures for the participants' six stop consonant productions were subjected to statistical analysis. The results of the study indicated that differences in VOT values were not statistically significant in the speakers with Alzheimer's disease from the normal control speakers.

To those individuals living with Alzheimer's disease.

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CHAPTER ONE

INTRODUCTION

Dementia causes a progressive decline in intellectual functioning, communicative abilities, and personality traits (Payne, 1997). Alzheimer's disease is the most prevalent form of dementia amongst older individuals, which is the result of structural and biochemical changes in the brain (Johnson, 1997). According to Davis (2000), “Alzheimer’s disease is one of several progressive and irreversible neuropathologies with a gradual onset and relentless deterioration” (p. 27). It is characterized by short- and long-term memory deficits, personality changes, and impaired abstract thinking and judgment (Payne, 1997).

Currently, it is approximated that four million Americans carry the diagnosis of Alzheimer’s disease, and the number is expected to rise to fourteen million by the year 2040. Given that Alzheimer’s disease primarily occurs in individuals older than 65-years of age, the fastest growing population, its prevalence will vastly increase in the upcoming decades. Individuals with Alzheimer’s disease live an average of ten-years following the diagnosis and often require assistance; hence, Alzheimer’s disease is expensive. Health planners have estimated the combined cost of caring for individuals with Alzheimer’s disease to be 100 billion dollars per year, which is why the disease is being referred to as the “disease of the 21st century” (Bayles, 2001).

Early diagnosis offers the best opportunity to treat symptoms of the disease. Presently, the only definite way to diagnose Alzheimer’s disease is to determine whether neuritic plaques and neurofibrillary tangles exist in brain tissue. Neuritic plaques are defined by Davis (1993, p. 142) as “granular deposits and remains of degenerated nerve fibers.” Davis defines neurofibrillary tangles as “unusual triangular and looped fibers in the cytoplasm or nerve cells.” To examine brain tissue, however, medical professionals must wait until an autopsy can be performed. Consequently, only a diagnosis of “possible” or “probable” Alzheimer’s disease can be made while the person is still alive. Several clinical criteria may be employed to diagnose possible or probable Alzheimer’s disease, including: (1) questions about the person's general health, current living environment, previous medical problems, and the history of any difficulties the person has carrying out daily activities, (2) tests of memory, attention, language, problem solving, and counting, (e.g. *Mini-Mental State Examination, Functional Linguistic Communication Inventory, and Arizona Battery for Communication Disorders of Dementia)*, (3) medical tests, such as tests of urine, blood, or spinal fluid, and (4) brain scans (para. 20, "Alzheimer's Disease Education & Referral Center," n.d.).

The purpose of this study was to investigate whether there were subtle early signs of Alzheimer’s disease in the speech signal, which were not apparent to the human ear. It was believed that individuals with moderate Alzheimer’s disease might reveal a change in voice onset time (VOT) production. The long-term goal of this study and additional studies to follow is to assist in the finding of a new and cost-effective way to detect Alzheimer's disease in its earliest stage. An explanation of VOT measurements follows.

Voice Onset Time Measurements

Previously conducted studies have established the use of voice-onset time (VOT) in the production of normal and disordered speech, because it is a discrete temporal measure. VOT can be defined as the distance between the release of an oral constriction and the onset of glottal pulsing (Lisker and Abramson, 1964). Baken (1987) states, "many facts point to VOT as a measure that is likely to be of use in describing or categorizing a range of developmental, neuromotor, or linguistic disorders" (p. 375).

VOT directly relates to the linguistic difference between voiced and voiceless stop consonants. The terms "voiced" or "voiceless" pertains to whether or not the vocal folds are vibrating. Many words in the English language are differentiated only by the presence or absence of voicing in the initial or final stop consonant. The production of a stop consonant depends on a vowel, and given that all vowels are voiced, the vocal folds will ultimately begin to vibrate. In voiced stop consonants, the voicing begins nearly concurrently when the intra-oral air pressure is released. The voicing may even begin before the release of the stop (i.e. pre-voicing). In voiceless stop consonants, however, there is a delay in the onset of vocal fold vibration after the occlusion is released. This delay in timing is referred to as VOT lag (Ryalls, 1996). A review of several studies utilizing VOT in geriatric and aphasic populations follows.

Voice Onset Time among Geriatric Speakers

The process of aging is becoming increasingly relevant, as the average age of the world's population increases; therefore, research into normal aging is speech production is warranted. Ryalls, Simon, and Thomason (2002) conducted a study to broaden findings for VOT productions in normally aging speakers. Normal older individuals participated in the study that (1) had no known speech or language disorders, (2) were generally in good health, and (3) were non-smokers. Twenty individuals participated, including ten males with an average age of 57-years and ten females with an average age of 69-years. Stimuli included eighteen consonant-vowel-consonant (CVC) real words used to elicit speech productions, which included the six stop consonants (/p/, /t/, /k/, /b/, /d/, /g/), combined with the three extreme vowels (/i/, /a/, /u/). Each participant produced each target word in randomized order at least five times, while his or her speech productions were recorded. The Brown Laboratory Interactive System (BLISS; Mertus, 1999) was used to perform the acoustic measures of VOT and an analysis of variance (ANOVA) was performed on the VOT measures for each speaker.

Results from this study revealed a strong, significant effect on age when compared to a study based on the VOT production in younger speakers by Ryalls, Baldauff, and Zipprer (1997). It was found that older speakers had larger negative values for voiced stops (for instance, average VOT measures for /b/ in older speakers was –87 milliseconds, as compared to –11 milliseconds in younger speakers). Furthermore, older speakers had shorter VOT values for voiceless stops (for instance, average VOT measures for /p/ in older speakers was 59 milliseconds, as compared to 71 milliseconds in younger speakers). Results of this study also revealed that younger female speakers had an overall syllable duration average of 363 milliseconds, while older females had an overall total syllable duration average of 494 milliseconds. Additionally, younger males had an overall syllable duration average of 362 milliseconds, while older males had an overall total syllable duration average of 439 milliseconds. These results demonstrate that older individuals produce longer syllable durations. It can be concluded from this study that the relationship between VOT and speaking rates merit further investigation in the aging process. For instance, additional studies investigating aging and speech production could examine the VOT across monolingual and bilingual populations or include data gathered in other geographic region of the United States.

Voice Onset Time among Aphasic Speakers

Blumstein, Cooper, Goodglass, Statlender, and Gottlieb (1980) examined the speech production of speakers with aphasia by measuring VOT productions in order to determine the extent to which speech errors are associated with phonetic as opposed to phonemic disorders. Phonetic errors represent articulatory distortions of a specific phonemic target and are typically produced by anterior non-fluent aphasics. Conversely, phonemic errors involve the substitution of phonemes and are typically produced by posterior fluent aphasics. Their study was based on the hypothesis that Broca's aphasics have specific phonetic deficits in motor speech planning. Thus, the selective predilection for phonetic errors serves as a means of distinguishing between alternative mechanisms involved in speech deficits in aphasia.

A total of eighteen participants were divided into five groups: five Wernicke's aphasics, four Broca's aphasics, four conduction aphasics, one nonaphasiac dysarthric, and four normal controls. The stimuli consisted of 30 monosyllabic real words, which included an initial stop consonant (/p/, /t/, /k/, /b/, /d/, and /g/), followed by the vowel, /a/, and by either one or two final consonants. Participants produced each target word a minimum of eight times. Utterances were audio-recorded and were measured by computer program. Phonemic transcriptions were made for those target words produced in error.

Broca's aphasics' productions of the target words exhibited abnormal overlapping VOT distributions between voiced and voiceless English stop consonants. In contrast, both the normal controls' and Wernicke's aphasics' productions of the target words exhibited two nonoverlapping distributions between the voiced and voiceless categories. The results of this study revealed that all groups of aphasics demonstrated some deviation in timing of articulation movements. As demonstrated by their percentage of phonetic and phonemic errors, Broca's aphasics showed a severe motor speech outputting disorder, as measured by VOT. An average of 60% of their productions of the target words were correct, 26 % included phonetic errors, and 14% included phonemic errors. Conduction aphasics showed a moderate disorder. An average of 71% of their productions of the target words were correct, 19 % included phonetic errors, and 10% included phonemic errors. In contrast, Wernicke's aphasics displayed minimal impairments. An average of

92% of their productions of the target words were correct, 4% included phonetic errors, and 4% included phonemic errors. Broca's aphasics had statistically more phonetic errors than the two other aphasic speaker groups. Thus, Blumstein et al. (1980) represents the first acoustic data supporting the theory of a selective phonetic-level deficit in Broca's aphasia as measured by overlapping voiced and voiceless VOT productions. A review of several studies including the speech production of individuals with Alzheimer's disease follows.

Speech Production of Individuals with Alzheimer's Disease

Cummings, Benson, Hill, and Read (1985) investigated the characteristics, occurrence, and correlations of aphasic symptoms in dementia of the Alzheimer's type. The study was based on the theory that all Alzheimer's disease patients demonstrate at least some minimal degree of aphasic symptoms, such as anomia. Two groups of participants were studied. The first group included 30 participants (seventeen males and thirteen females) diagnosed with dementia of the Alzheimer's type with a mean age of 71- years. To ensure the accuracy of dementia of the Alzheimer's type diagnosis, the participants were referred to the study following a screening interview, a neurological examination, and a *Mini-Mental State Examination* (MMSE; Folstein, Folstein, & McHugh, 1975) score of less than 24. The control group included 70 healthy participants with a mean age of 42-years. Each control participant exhibited no evidence of dementia or aphasia and scored higher than 24 on the MMSE.

Participants were asked questions derived from the *Boston Diagnostic Aphasia Examination* (Goodglass & Kaplan, 1972), the *Western Aphasia Battery* (Kertesz, 1982), a dysarthria scale, a category-naming test, and a reiterative speech disturbance scale. Thirty-seven subscales measured (1) elements of auditory comprehension, (2) oral reading, (3) spontaneous speech, (4) naming, (5) reading comprehension, (6) repetition, (7) paraphasia, (8) writing, and (9) automatic speech. The participants were assigned a scale value between zero (normal) and six (most abnormal).

The results demonstrated that control participants revealed no clinical evidence of aphasia. In contrast, mean scores for dementia of the Alzheimer's type participants differed from zero on each subtest. "Language abnormalities were present in all dementia of the Alzheimer's type patients in the study, and the language alterations readily distinguished the dementia of the Alzheimer's type patients from control participants" (pg. 396). Dementia of the Alzheimer's type participants' verbal output resembled Wernicke's aphasia in the later stages. In summary, Cummings, Benson, Hill, and Read (1985) suggest that aphasia is a consistent symptom of dementia of the Alzheimer's type. Thus, of importance are the results from the study conducted by Blumstein, Cooper, Goodglass, Statlender, and Gottlieb (1980), which revealed that all groups of aphasics demonstrated some deviation in timing of articulatory movements, as measured by VOT.

A longitudinal study by Romero and Kurz (1996) was conducted to measure the rate and pattern of spontaneous speech decline in participants with Alzheimer's disease during a one-year follow-up. The study was based on the belief that the pattern of speech decline would have "prominent disturbances of communication and semantics, moderate disturbances in automatic speech, but retained phonematic structures" (p. 35). Data and results were recorded for 63 participants between the ages of 56- to 87-years, in which 30 participants had mild dementia severity and 33 participants had moderate dementia severity, as measured by the *Clinical Dementia Rating* (Morris, 1993). Forty-six of the participants were female, while seventeen participants were male. The stimuli consisted of a rating scale section on the *Aachener Aphasic Test* (Huber, Poeck, Weniger, Willmes, 1983), a German language aphasia battery. The participants' speech outputs were rated on a scale ranging from zero (extremely disturbed) to five (undisturbed) in the following six language areas: (1) communication, (2) articulation and prosody, (3) automatic speech, (4) semantic structures, (5) phonematic structures, and (6) syntactic structures.

Romero and Kurz (1996) concluded "all six language scales showed that the spontaneous speech of the patients was more impaired at the follow-up examination than at baseline" (p. 37). In summary, the results demonstrated a general tendency for the spontaneous speech of individuals with dementia to decrease upon a one-year follow-up examination.

Croot, Hodges, Xuereb, and Patterson (2000) investigated the theory that articulatory and phonological impairments may occur in the early course of Alzheimer's disease. The purpose of their study was to augment the limited information concerning the speech production of individuals with Alzheimer's disease. The study involved ten participants, including six participants with pathologically confirmed Alzheimer's disease via an autopsy and four participants with clinically diagnosed dementia of the

Alzheimer's type. Four participants had progressive aphasia diagnosed as dementia of the Alzheimer's type from neuropsychological assessment, three participants had initial amnestic syndrome with prominent phonological errors, one participant had mixed progressive aphasia, one participant had nonfluent progressive aphasia, and one participant had biparietal syndrome.

Data on the participants' speech production was collected from three speaking frameworks including: 1) conversation, 2) single-word production in reading, naming, and repetition tasks, and 3) speech series tasks, which included speaking and counting the days of the week, the months of the year, and the alphabet. The three speech frameworks were analyzed for the nature of errors and the overall severity of disturbance. Of particular interest to these researchers were the types of speech production impairments demonstrated in individuals diagnosed as dementia of the Alzheimer's type by previous studies including phonological paraphasias (e.g. /lat/ for /kat/), false-start errors/hesitations, and reduced articulatory ease and fluency.

The results from this study demonstrated that all participants produced phonological paraphasias, false-start errors, and perseverations. Additionally, the participants demonstrated hesitant and effortful speech often seen in nonfluent aphasias. One aspect of speech production found to be impaired included access to phonological forms from semantics, such that the participants were unable to correctly retrieve the full phonological form, following an attempt to the retrieve the initial sound (hence, false start errors). Articulation was another aspect of the participants' speech production found to be impaired. Four out of the ten participants had a nonfluent speech disorder resembling Broca's aphasia. The data collected by these researchers suggests that the "integrity of articulatory processing may on occasions be compromised in dementia of the Alzheimer's type. Thus, although rare as a symptom of Alzheimer's disease, impaired articulatory-motor aspects of speech production appear to be a feature of this disease in some cases" (p. 301). Finally, when the focus is on less typical cases, it may be "revealed that while phonological and articulatory abilities are not consistently disrupted in Alzheimer's disease, they are unmistakably impaired in some cases, even selectively, as a presenting symptom" (p. 304).

Biassou, D'Esposito, Grossman, Hughes, Mickanin, Onishi, and Robinson (1995) conducted a study to test the theory that Alzheimer's disease patients would produce more speech errors than healthy age-matched controls. The purpose of the study was to quantify the frequency and nature of speech errors in patients with mild to moderate Alzheimer's disease. The study consisted of two groups of sixteen right-handed and education-matched monolingual speakers of Standard American English. The first group was diagnosed with mild to moderate Alzheimer's disease according to the National Institute of Neurological and Communicative Disorders and Stroke-Alzheimer's Disease Related Disorders Association (NINCDS-ADRDA) and had a mean age of 69-years, while the control group was neurologically intact and had a mean age of 70-years.

The researchers assessed speech production by asking each participant to repeat 30 sentences, which were presented aurally and with natural prosodic contours. The sentences varied in length and syntactic structure: 36% were right-branching constructions that contained terminal subordinate phrases, 27% were passive constructions, 23% contained center-embedded subordinate phrases, 7% were grammatically simple, and 7% contained pseudowords.

Broad phonetic transcription of the participants' recorded speech was made by a "trained linguist" using the International Phonetic Alphabet (IPA). The recorded data was analyzed for the sentences containing any phonological errors. Speech errors were analyzed for whether they occurred in the initial, medial, or final position of a word, and for whether the participants preserved the words' syllabic structure. Furthermore, in order to determine whether the phonemic errors were environmentally influenced, the authors noted the frequency of phonemic substitutions, phonemic additions, metatheses, and preservations. Random substitution errors and deletions were also tabulated.

The results of this study suggested that sentences containing phonological errors were significantly more frequent in individuals with Alzheimer's disease than in the control participants. The errors of participants with Alzheimer's disease were disproportionately in the word-initial position compared with the controls' errors. Additionally, Alzheimer's disease participants were significantly more susceptible to non-environmentally induced errors than the control group. Finally, the results indicated that errors do occur in the speech production of individuals with Alzheimer's disease.

Although the aforementioned studies demonstrated the presence of speech errors in persons with Alzheimer's disease, to our knowledge, no acoustic analyses of speech production in individuals with Alzheimer's disease have been performed. The presence of subtle acoustic differences, not apparent to the human ear, in the speech production of individuals with Alzheimer's disease may represent a new means of detecting the presence of this disease. Therefore, it is proposed to conduct an acoustic investigation of VOT in the speech production of individuals with Alzheimer's disease, as outlined in the next chapter.

Statement of the Problem

Previously conducted studies have established the importance of the acoustic characteristics of VOT in the production of speech (Baken, 1987). However, there has been no research conducted, to this researcher's knowledge, on the effects of Alzheimer's disease on VOT production measurements. The lack of acoustic data justifies a more careful, in-depth view at the question of how Alzheimer's disease may affect speech production in subtle ways, such as VOT.

Purpose of the Study

To investigate whether there were subtle early signs of Alzheimer's disease in the speech signal, which were not apparent to the human ear. It was believed that individuals with moderate Alzheimer's disease would reveal an overall shift toward smaller VOT values (shorter positive VOT values for voiceless stops and longer negative VOT values for voiced stops) based on the results of voice onset production measures in older speakers (Ryalls, Simon, and Thomason, 2002).

Hypothesis

It was hypothesized that there would be a progression in the changes of VOT measures in individuals diagnosed with moderate Alzheimer's disease aged 75- to 95-years to those healthy older individuals aged 75- to 95-years, following the analysis of VOT production/measurements. VOT measurements were taken from the production of 18 CVC monosyllabic words containing the three-voiceless stop consonants of English, (/p/, /t/, /k/), the three-voiced stop consonants of English, (/b/, /d/, /g/), and the peripheral vowels, (/i/, /a/, /u/), and were measured by the Brown Laboratory Interactive Speech System (BLISS) software package.

CHAPTER TWO

METHOD

Participants

Two groups of participants, totaling ten individuals in each group, participated in this study. Participants were recruited from an Alzheimer's disease assisted living facility and an elderly assisted living facility located in Central Florida. The first group of participants consisted of ten individuals diagnosed with at least Stage 5 dementia, according to the diagnostic criteria gathered from the stages for primary degenerative dementia, per the Global Deterioration Scale (GDS; Reisberg, et al., 1982). The second group of participants consisted of ten healthy age- and gender-matched individuals. Both groups met the following criteria for participation: (1) between the ages of 75- and 95-years-old, (2) monolingual speaker of American English, (3) nonsmoking, (4) produced an infrequent number of paraphasic errors, as judged by the researcher, in which the participant produced less than five errors in a two-minute conversation, (5) able to attend for an hour with minimal redirection, (6) have no respiratory difficulties, (7) have no history of psychiatric or neurological disorder, other than Alzheimer's disease, (8) not taking antidepressant psychoactive medication, and (9) not demonstrate resistive behaviors to the testing environment.

The ages of the participants can be found in Table 1. The mean age of the participants with Alzheimer's disease was 86-years of age, with a standard deviation of 4.6-years. The youngest participant was 81-years of age and the oldest participant was 90-years of age. The mean age of the control participants was 85-years of age, with a standard deviation of 5.1-years. The youngest participant was 77-years of age and the oldest participant was 94-years of age. The participants were recruited throughout the greater-Orlando area.

Table 1: Age of Participants (in years)

Participant Number	1	2	3	4	5	Average
AD Male	88	93	82	81	78	84
AD Female	83	87	85	88	90	87
Control Male	85	77	81	90	82	83
Control Female	86	94	87	80	82	86

Mini-Mental State Examination

The *Mini-Mental State Examination* (MMSE; Folstein, Folstein, & McHugh, 1975) is a concise, quantitative measure of cognitive status in adults. It can be used to screen for cognitive impairment, approximate the severity of cognitive impairment at a given point in time, track the course of cognitive changes in an individual over time, and record an individual's response to treatment. The *MMSE* includes tasks to measure the participant's abilities in the following areas: 1) orientation, 2) registration, 3) attention and calculation, 4) recall, 5) naming, 6) repetition, 7) three-stage command, 8) reading, 9) writing, and 10) copying. Participants in the Alzheimer's disease experimental group were limited to those who scored a 20 (out of 30) or below, while participants in the control group were limited to those who scored a 25 or above.

Functional Linguistic Communication Inventory

To ensure Stage 5 dementia, the *Functional Linguistic Communication Inventory* (*FLCI*; Bayles & Tomoeda, 1994) assessment battery was administered to participants with Alzheimer's disease. The *FLCI* is a standardized battery designed to quantify the functional linguistic communication skills of moderately and severely demented individuals. Acquiring knowledge about functional communication abilities is important in order to obtain baseline information about the participants' functional ability. The *FLCI* is comprised of components used to evaluate the following ten functions: (1) greeting and naming, (2) question and answering, (3) writing, (4) sign comprehension and object-to-picture matching, (5) word reading and comprehension, (6) ability to reminisce, (7) following commands, (8) pantomime, (9) gesture, and (10) conversation. An individual's performance on the *FLCI* can be used to identify preserved functions and predict functionally communication abilities at risk in the near future (Tomoeda, 2001). The *FLCI* utilizes the diagnostic criteria gathered from the stages for primary degenerative dementia, per the *Global Deterioration Scale*.

Global Deterioration Scale

The *Global Deterioration Scale* (GDS) was developed to provide caregivers with an overview of the stages of cognitive function for individuals living with a primary degenerative dementia, such as Alzheimer's disease. It is divided into seven different stages. Stages 1-3 are the pre-dementia stages, while Stages 4-7 are the dementia stages. Beginning in Stage 5, an individual can no longer survive without assistance. Within the GDS, each stage is numbered (1-7), given a short title, and followed by a brief listing of clinical characteristics. By examining an individual's behavioral characteristics and comparing them to the GDS, caregivers can obtain an approximation of where an individual is situated in the disease process (Reisberg, et al., 1982).

Stage 1 is titled “No Cognitive Decline” and has the clinical characteristic of no evident memory deficit. Stage 2 is titled “Very Mild Cognitive Decline” and has the clinical characteristics of forgetting where one has placed familiar objects and forgetting names of loved ones and friends. Stage 3 is titled “Mild Cognitive Decline” or “Mild Cognitive Impairment” and has the following clinical characteristics: a) co-workers’ awareness of an individual’s poor performance; b) name and word finding deficits be; c) loss of direction when traveling in unfamiliar location; and (d) misplacement of valuable objects. Stage 4 is titled “Mild Cognitive Decline” or “Mild Dementia” and is defined by the following clinical characteristics: (a) decreased knowledge of current and recent events; (b) deficit in memory of one’s personal history; (c) flattened of affect and withdrawal from challenging situations; and (d) decreased ability to travel, handle finances, etc. Denial is a hallmark characteristic of Stage 4. Stage 5 is titled “Moderately Severe Cognitive Decline” or “Moderate Dementia” and is defined by the following clinical characteristics: (a) inability to recall a major relevant aspect in one’s current life, e.g., an address or telephone number of many years; (b) disorientation to time (date, day of week, season, etc.) or to place; and (c) difficulty choosing the proper attire. Stage 6 is titled “Severe Cognitive Decline” or “Moderately Severe Dementia” and is defined by the following clinical characteristics: (a) intermittent forgetfulness of the name of the person upon whom they are dependent for survival; (b) unawareness of all recent events and experiences in their life; (c) retains vague knowledge of their past life; (d) unawareness of their surroundings, the year, and the season; and (e) requires assistance with activities of daily living. Personality and emotional changes occur in this stage including delusional behavior, obsessive symptoms, anxiety symptoms, and loss of willpower. Stage 7 is titled “Very Severe Cognitive Decline” or “Severe Dementia.” All verbal abilities are lost over the course of this stage. Clinical characteristics include: (a) unintelligible utterances and infrequent emergence of seemingly forgotten words and phrases; (b) requires assistance during toileting and feeding; (c) loss of basic psychomotor skills; and (d) widespread rigidity and developmental neurological reflexes are often present (Reisberg, et al., 1982).

Consent

All participants voluntarily signed an informed consent form in the presence of a witness. Caregivers of those participants with Alzheimer’s disease also signed the consent form. Consent forms had been approved by the University of Central Florida’s Institutional Review Board (IRB). The IRB is a committee mandated by the National Research Act, Public Law 93-348; to be established within each university or other institution that performs research involving human participants. The purpose of the IRB is to determine whether a research plan involving human participants has adequately included the ethical dimensions of the project by evaluating all proposals for human research prior to the start of the research. All participants were assured of complete confidentiality during his or her participation in the study.

Instrumentation

The participants' speech was recorded in a quiet room on a Tascam DA-P1 portable Digital Audio Tape (DAT) recorder. An AKG Acoustics C420 headset with miniature condenser microphone was used, which was positioned close to the corner of the participants' mouth. The participants' recorded speech was digitized onto a hard drive and measured acoustically using the Brown Laboratory Interactive Speech System (BLISS) software package (Mertus, 1999).

Stimuli

The speech stimuli included eighteen isolated monosyllabic consonant-vowel-consonant (CVC) real words containing the three voiceless stop consonants of American English, (/p/, /t/, /k/), or the three voiced stop consonants of American English, (/b/, /d/, /g/), the peripheral vowels, (/i/, /a/, /u/), and ending in a voiceless stop consonant. The vowels represent maximum differences in the relationship of tongue placement in production (from /i/, the highest front vowel, to /u/, the highest back vowel, and /a/, the lowest vowel). These three vowels are among the most common vowels occurring in a variety of languages around the world (Kent, 1997).

The eighteen CVC monosyllabic real words were presented in random order and printed in a large and easy-to-read font. To ensure good quality and reliability of each participant's speech production, all eighteen CVC syllables were recorded seven times. Upon completion of the recording, the first three repetitions of each stimuli list were used for acoustic analysis. Thus, four backup samples of each word were available for analysis in the case of a phonemic substitution or acoustic interference.

Table 2: CVC Stimuli Word List-Voiceless Consonants

	/p/	/t/	/k/
/i/	peat	teak	keep
/a/	pot	tot	cot
/u/	poop	toot	coup

Table 3: CVC Stimuli Word List-Voiced Consonants

	/b/	/d/	/g/
/i/	beat	deep	geek
/a/	bop	dot	got
/u/	boot	dupe	goop

Procedure

The participants diagnosed with dementia were administered the *FLCI* and *MMSE*, while control participants were only administered the *MMSE*. Each participant was read the instructions and became familiarized with the procedure. The participants were seated and fitted with a headset microphone. Each participant read a practice set to ensure no phonemic substitutions occurred. The audio signal was monitored by headphones to ensure that the instrumentation was working properly. The participants then produced seven repetitions of the word list at a comfortable rate.

Acoustic Analyses

The recorded data of the participants' production of the eighteen CVC syllables were digitized onto a hard drive at the sampling rate of 20 kHz (set by BLISS), with a 12-bit quantization factor. Data were measured acoustically using the BLISS software package that has been implemented on a Dell 486 (IBM-compatible) computer equipped with a Zafiro digital sound card.

Voice Onset Time Measurements

VOT measurements were performed using both auditory and visual cues obtained from the oscillographic display of speech in BLISS. The parameters used to identify the VOT interval were as follows: (1) placement of the first cursor was at the onset of the burst (the point at which the stop consonant was released) and (2) placement of the second cursor was at the highest point of the first cycle of the voiced portion of the speech signal. Since there are typically many baseline crossings in the complex waveform of a vowel, the highest point of the first periodic cycle for the VOT measure was used, as there is usually only a single and unique highest point in any particular cycle (Ryalls, 1996). The time interval, measured in milliseconds, between the two cursors represented the VOT interval for the stop consonant production.

In addition to the visual measurement, the researcher listened to the marked portion to ensure that the burst was properly isolated. Any prevoicing observed was measured by placing the first cursor at the onset of periodic voicing and the second cursor just before the burst. Figures 1, 2, and 3 are examples of how the first and second cursors were placed depending on the type of VOT present. However, it should be noted that the following figures do not represent the entire duration of a word, but rather the onset portion of the production in order to demonstrate the VOT measure more clearly.

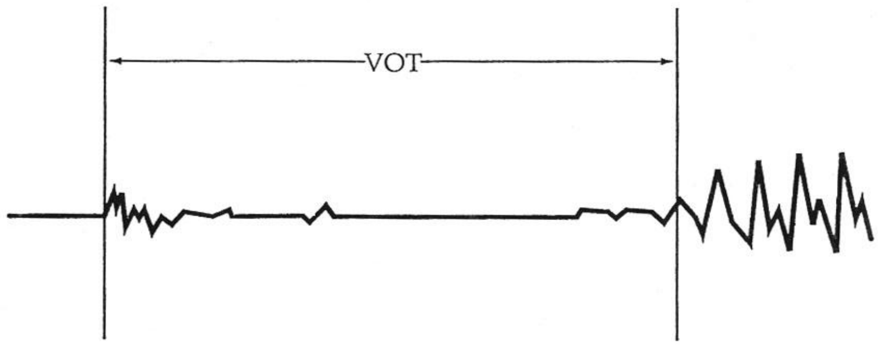

Figure 1: Positive Voice Onset Time (VOT) for a voiceless stop consonant (long lag).

Figure 1 is a depiction of the onset portion of a voiceless stop consonant, such as /p/, /t/, or /k/ when viewed on an oscillographic display produced by BLISS. The left cursor, represented by the first vertical line, was placed at the onset of the burst, while the right cursor, represented by the second vertical line, was then placed at the highest point of the first periodic cycle of the vowel portion of the speech signal. The time interval between the two cursors was then displayed in milliseconds.

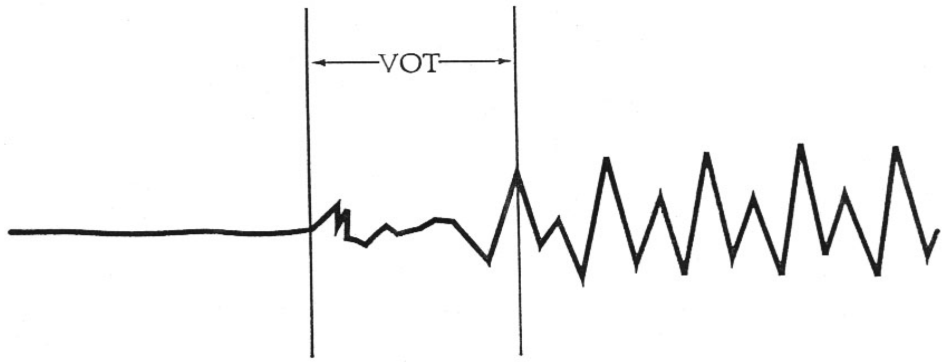

Figure 2: Positive Voice Onset Time (VOT) for a voiced stop consonant (short lag).

Figure 2 is a depiction of the onset portion of a voiced stop consonant, such as /b/, /d/, or /g/ when viewed on an oscillographic display produced BLISS. The left cursor, represented by the first vertical line, was placed at the onset of the burst, while the right cursor, represented by the second vertical line, was then placed at the highest point of the first periodic cycle of the vowel portion of the speech signal. The time interval between the two cursors was then displayed in milliseconds.

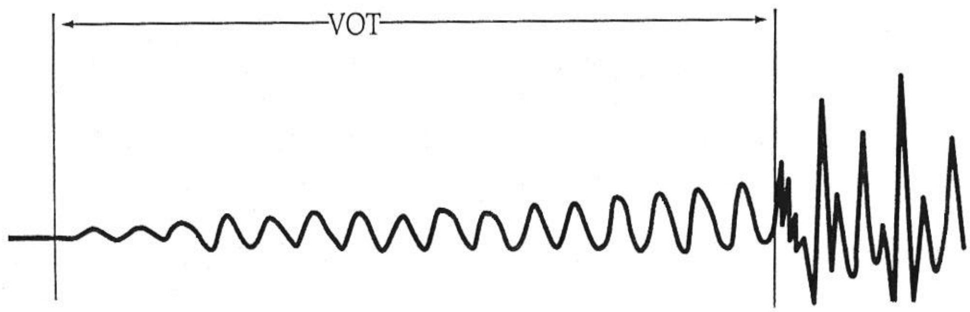

Figure 3: Negative Voice Onset Time (VOT) for a prevoiced stop consonant.

Figure 3 is a depiction of the onset portion of a prevoiced stop consonant, such as /b/, /d/, or /g/ when viewed on an oscillographic display produced by BLISS. To complete the measurements, the left cursor, represented by the first vertical line, was placed at the onset of the prevoicing, while the right cursor, represented by the second vertical line, was then placed at the burst. This is the only measurement that does not include the burst. The time interval between the two cursors was then displayed in milliseconds. However, unlike the voiceless and voiced measurements, which were measured in terms of positive numbers, negative VOT would be represented by negative numbers. Prevoicing is represented by negative numbers, because the vocal folds have begun to vibrate before the burst associated with the release.

Statistical Analysis of Data

Measures of central tendency (means and standard deviations) were calculated for each individual participant for the VOT for each stop consonant in the VOT stimuli. VOT averages were then calculated for each of the six stop consonants. A repeated measures Multivariate Analysis of Variance (MANOVA) and a Two-way Analysis of Variance (ANOVA) was used to compare the two groups of participants' VOT measurements. The between-group factor was individuals moderate Alzheimer's disease versus healthy older individuals. The within-group factors were voicing (voiced versus voiceless), place of articulation (bilabial, alveolar, or velar), and gender.

Reliability

To establish intrajudge reliability, the main investigator reanalyzed the data of one randomly selected participant from each group (i.e. 10% of the population), and a Pearson product-moment correlation was calculated between the two sets of VOT measures.

To establish interjudge reliability, a second investigator measured the VOT data of one different randomly selected participant from each group (i.e. 10% of the population), and a Pearson product-moment correlation was calculated between the two sets of VOT measures.

Expected Results

It was expected that individuals with moderate Alzheimer's disease would demonstrate more signs of aging in VOT production than has been found in the group of healthy older individuals. Specifically, it was anticipated that individuals with moderate Alzheimer's disease patients would produce shorter average VOT values for voiceless stops and larger negative average values for voiced stops (Ryalls, Simon, and Thomason, 2003). It was hoped that the VOT measurements could then be used as an early noninvasive behavioral indicator of those individuals most at risk for Alzheimer's disease.

CHAPTER THREE

RESULTS

Individual duration and VOT measures for each participant are listed in Appendix F. There were a total of 108 measurements for each person, for a total of 2,160 individual measures of word duration and VOT. The average word duration, VOT for place of articulation (bilabial, alveolar, and velar), and overall average (X) of each voiceless stop (/p/, /t/, and /k/) was calculated for each of the participants and are listed in Table 4. The total word duration measurements and VOT values are in milliseconds.

Table 4: Average Word Duration and VOT Measurements of Voiceless Stops (in ms)

AD Males	/p/		/t/		/k/	
	Duration	VOT	Duration	VOT	Duration	VOT
1	429	56	433	80	431	91
2	597	79	806	79	752	92
3	780	115	817	113	761	97
4	639	61	507	57	557	84
5	600	71	656	71	586	80
X	609	76	644	80	617	89
AD Females	/p/		/t/		/k/	
	Duration	VOT	Duration	VOT	Duration	VOT
1	683	101	660	136	693	156
2	562	52	611	51	540	60
3	790	67	1018	71	821	104
4	550	67	537	82	510	96
5	478	58	541	77	459	83
X	613	69	673	84	605	100
Control Males	/p/		/t/		/k/	
	Duration	VOT	Duration	VOT	Duration	VOT
1	291	56	328	57	401	68
2	610	74	612	68	642	90
3	477	62	444	70	458	70
4	409	67	428	67	428	93
5	500	70	488	82	559	82
X	457	66	460	69	498	81
Control Females	/p/		/t/		/k/	
	Duration	VOT	Duration	VOT	Duration	VOT
1	587	86	564	86	659	136
2	573	69	597	78	612	97
3	507	55	478	55	477	66
4	552	88	556	79	563	94
5	605	78	514	68	532	76
X	565	75	542	73	569	94

According to Lisker and Abramson (1964), a voiceless stop would typically have a long VOT, ranging from +60 to +100 milliseconds in American English. In the current study, the range of VOT productions for voiceless stops ranged from was between +51 to

+136 milliseconds.

The average word duration, VOT for place of articulation (bilabial, alveolar, and velar), and the overall average (X) of each voiced stop (/b/, /d/, and /g/) were calculated for each of the participants and are listed in Table 6. As previously mentioned, the duration measurements and VOT values are in milliseconds.

Table 5: Average Word Duration and VOT Measurements of Voiced Stops (in ms)

AD Males	/b/ Duration	/b/ VOT	/d/ Duration	/d/ VOT	/g/ Duration	/g/ VOT
1	544	-133	480	-106	484	-61
2	617	-16	627	-71	752	5
3	948	-77	865	-17	669	-5
4	611	-38	386	-21	465	-20
5	655	17	594	23	744	18
X	675	-49	590	-38	623	-13
AD Females	/b/ Duration	/b/ VOT	/d/ Duration	/d/ VOT	/g/ Duration	/g/ VOT
1	587	29	631	-20	755	35
2	707	-76	602	-25	817	-95
3	914	-6	710	-11	907	-6
4	623	-72	660	-70	630	-48
5	587	-51	767	-184	513	-24
X	684	-35	674	-62	724	-28
Control Males	/b/ Duration	/b/ VOT	/d/ Duration	/d/ VOT	/g/ Duration	/g/ VOT
1	385	-97	398	-109	454	-82
2	729	-99	734	-101	719	-109
3	554	-42	459	19	418	9
4	452	-110	523	-141	494	-97
5	573	-86	582	-54	575	-35
X	539	-87	539	-77	532	-63
Control Females	/b/ Duration	/b/ VOT	/d/ Duration	/d/ VOT	/g/ Duration	/g/ VOT

1	623	-71	634	-106	699	-112
2	649	-126	655	-82	685	-94
3	499	-26	466	25	499	-9
4	583	17	616	-3	549	25
5	647	-68	649	-46	644	-60
X	600	-55	604	-42	615	-50

According to Lisker and Abramson (1964), a voiced stop would have a short VOT, ranging from 0 to +25 milliseconds. In the current study, the range of VOT productions for voiced stops was between +5 and +35 milliseconds. Table 5 also demonstrates the third type of VOT that could occur, which is negative VOT or prevoicing. The range of prevoicing that is demonstrated in Table 5 was between –3 and –133 milliseconds.

The averages of all VOT measures for place of articulation for participants with Alzheimer's disease (male and female) and control participants (male and female) were calculated and can be found in Table 6. These averages indicate that the individuals with Alzheimer's disease produced longer VOTs for the voiceless stop consonants for each place of articulation than the control participants. Additionally, these results reveal that the individuals with Alzheimer's disease produced smaller negative VOTs for the voiced stop consonants for each place of articulation than the control participants.

Table 6: Average VOT Measurements for AD and Control Participants (in ms)

	/p/	/t/	/k/	/b/	/d/	/g/
AD	73	82	95	-42	-50	-21
Control	71	71	88	-71	-60	-57

Average VOT measurements for individuals with Alzheimer's disease revealed that the range of VOT productions for voiced stops ranged from +5 and +35 ms, while the range of VOT productions for voiceless stops ranged from +51 to +136 ms. These results indicate that individuals with Alzheimer's disease exhibited two nonoverlapping distributions between voiced and voiceless categories. Additionally, average VOT measurements for the control speakers revealed that the range of VOT productions for voiced stops ranged from +9 and +25 ms, while the range of VOT productions for voiceless stops ranged from +55 to +136 ms. These results indicate that the control speakers also exhibited two nonoverlapping distributions between voiced and voiceless categories.

Average duration measurements can be found in Table 7. The average duration measurements revealed that individuals with Alzheimer's disease had an overall syllable duration average of 627 ms for voiceless stops, while control individuals had an overall total syllable duration average of 515 ms for voiceless stops. Additionally, individuals with Alzheimer's disease had an overall syllable duration average of 662 ms for voiced stops, while control individuals had an overall total syllable duration average of 571 ms for voiced stops. These results demonstrate that individuals with Alzheimer's disease produced longer syllable durations than healthy age-matched controls, indicating a slightly slower speaking rate.

Table 7: Average Word Duration Measurements for AD and Control Participants (in ms)

	Voiceless Stops	Voiced Stops
AD	627	662
Control	515	571

Analysis of Data

A repeated measures Multivariate Analysis of Variance (MANOVA) was performed on the repeated trials of VOT data, using SPSS (2005). The F (2, 17) = .322 was not significant (p =.73). Subsequently, a two-way Analysis of Variance (ANOVA) was performed on the averaged VOT data. As expected, there was a highly significant effect of voicing [F (2, 17) = 220.36; p < .0001] indicating that both groups made a significant distinction in VOT between voiceless and voiced stops. However, a two way ANOVA for voiceless stops was not significant [F (1, 17) = .695; p = .42], nor was a two way ANOVA for voiced stops significant [F (1, 17) 1.553; p =.23]; indicating that VOT values were not statistically significantly different among the speakers with Alzheimer's disease from the normal control speakers.

A one-way ANOVA was performed for VOT comparing gender. The ANOVA for voiceless stops did not show statically significant group effect for gender [F (1, 18) = .199; p =.66], nor was there a gender group effect for voiced stops [F (1, 18) = .497; p =.49]. A one-way ANOVA was also performed on average word durations. The results were not statistically significant [F (1, 18) = 4.336; p >.05].

Reliability

To establish intrajudge reliability, the main investigator reanalyzed the data of one randomly selected participant from each group (i.e. 10% of the population), and a Pearson product-moment correlation was calculated between the two sets of VOT measures. Intrajudge reliability was calculated at a correlation of $r = 1.0$ for both groups.

To establish interjudge reliability, a second investigator measured the VOT data of one different randomly selected participant from each group (i.e. 10% of the population), and a Pearson product-moment correlation was calculated between the two sets of VOT measures. Interjudge reliability was calculated at a correlation of $r = .95$ for the control group and .94 for the group of individuals with Alzheimer's disease.

CHAPTER FOUR

DISCUSSION

The purpose of this study was to investigate whether there were subtle early signs of Alzheimer's disease in the acoustic signal of speech, which were not apparent to the human ear. The present study compared VOT measurements between a group of individuals with moderate Alzheimer's disease and a group of healthy age- and gender-matched peers. It was believed that individuals with moderate Alzheimer's disease might reveal an overall change in voice onset time (VOT) production. More specifically, it was expected that individuals with moderate Alzheimer's disease will reveal an overall shift toward smaller VOT values (shorter positive VOT values for voiceless stops and longer negative VOT values for voiced stops) based on the results of voice onset production measures in older speakers (Ryalls, Simon, and Thomason, 2002).

The results of the study indicated that differences in VOT values were not statistically significant in the speakers with Alzheimer's disease from the normal control speakers. Therefore, the hypothesis stating that there would be a progression in the changes of VOT measures in individuals diagnosed with moderate Alzheimer's disease aged 75- to 95-years to those healthy older individuals aged 75- to 95-years following the analysis of VOT production/measurements was not supported by the data. An explanation as to why a shift in VOT measurements were not produced by individuals with Alzheimer's disease is the fact that motor functioning, including speech, is relatively spared throughout most of the disease course (Bayles, 2001).

While the results of the present study were not statistically significant, the large amount of individual VOT measures collected, 1,080, supplements previous research completed on VOT. In addition to the large amount of individual VOT measures, the current study also augmented VOT research by providing VOT measurements of individuals with an average age of 85-years.

Furthermore, to this investigator's knowledge, there are no published studies looking at VOT measurements of individuals with Alzheimer's disease. Therefore, this study is a novel application to the already popular use of VOT measurements when comparing speech characteristics of two or more populations. For instance, studies of VOT measurements have been used in studies comparing younger versus older speakers, female versus male speakers (Ryalls, Simon, and Thomason, 2002), and Caucasian versus African-American speakers (Ryalls, Zipprer, & Baldauff, 1997).

An interesting finding in the present study was the large percentage of prevoicing that occurred during the production of voiced stop consonants. As previously mentioned, the range of prevoicing demonstrated in this study was between -3 and -133 ms. Eighty-two percent (49/60) of the average VOT measurements of voiced stops for both groups were prevoiced in this study. Reasons for the high percentage of prevoicing in this study as compared to that of the popular VOT research completed by Lisker and Abramson (1964), in which no prevoicing measurements were demonstrated in the results include (1) the larger number of participants used in this study (twenty versus four) lead to more variability in the speech signal among speakers, (2) the negative production measurements (prevoicing) were included in the calculations of this study, while those produced in the study by Lisker and Abramson were not, (3) better technology, including computer-based measurements lead to more accurate calculations, and (4) a carrier phrase was not used in the present study, which supports the thought that native American English speakers may typically produce citation-form words with significant prevoicing.

Comparisons between the VOT measurements of individuals with Alzheimer's disease in the current study to those of aphasic speakers from a study completed by Blumstein, Cooper, Goodglass, Statlender, and Gottlieb (1980) were conducted. Blumstein et al. revealed that all groups of aphasics demonstrated some deviation in timing of articulatory movements, as measured by VOT. More specifically, Broca's aphasics' productions of the target words exhibited abnormal overlapping VOT distributions between voiced and voiceless English stop consonants. In contrast, Wernicke's aphasics' productions of the target words exhibited two nonoverlapping distributions between the voiced and voiceless categories. Thus, such a comparison of

VOT measurements between individuals with Alzheimer's disease and individuals with aphasia is warranted, as previous studies have suggested that aphasia is a consistent symptom of dementia of the Alzheimer's type (Cummings, et al., 1985).

The current study revealed that individuals with Alzheimer's disease exhibited two nonoverlapping distributions between voiced and voiceless categories, which were also exhibited in the production of individuals with Wernicke's aphasia. Furthermore, Cummings et al. (1985) demonstrated that dementia of the Alzheimer's type participants' verbal output resembled Wernicke's aphasia in the later stages. Therefore, further research comparing the speech output between individuals with Alzheimer's disease and individuals with Wernicke's aphasia may be warranted.

Additional comparisons of VOT measurements were made between the healthy control speakers used in the present study to those healthy older speakers used in the study by Ryalls, Simon, and Thomason (2002). Ryalls et al. conducted a study to broaden findings for VOT productions in normally aging speakers. The same speech stimuli were used in both studies to elicit speech productions. A comparison between the speakers in the two studies was completed to determine if the VOT measurements would vary depending on the increasing age of the participants. The average age for the males in the present study was 83-years, in comparison to 57-years in the study by Ryalls et al. The difference in age between both groups of males was 26-years. The average age for the females in the present study was 86-years, in comparison to 69-years in the study by

Ryalls et al. The difference in age between both groups of females was 17-years. In total, the average age for the older control speakers in the present study was 84.5-years compared to the average age of 63-years from older speakers in the study by Ryalls et al. The total average difference in age between both sets of groups was 21.5-years.

It was found that older speakers with an average age 84.5-years had smaller negative values for voiced stops (for instance, average VOT measures for /b/ in older speakers was –71 milliseconds, as compared to –87 milliseconds). Furthermore, older speakers with an average age 84.5-years had longer VOT values for voiceless stops (for instance, average VOT measures for /p/ in older speakers was 71 milliseconds, as compared to 59 milliseconds). The results of the comparison does not support previous research stating that older speakers would produce longer negative average VOT values for voiced stops and shorter average VOT values for voiceless stops (Ryalls, Simon, and Thomason, 2002). The averages of all VOT measures for place of articulation for participants for the older control speakers (84.5-years) in the present study and the older speakers (63-years) in the study by Ryalls et al. were calculated and can be found in Table 8.

Table 8: Average VOT Measurements for Older Speakers (in ms)

Participant	/p/	/t/	/k/	/b/	/d/	/g/
Older Speakers (84.5-years)	71	71	88	-71	-60	-57
Younger Speakers (63-years)	59	69	72	-87	-90	-76

The average duration measurements revealed that the older individuals with an average age 84.5-years of had an overall syllable duration average of 543 milliseconds, while the older individuals with an average age 63-years of had an overall syllable duration average of 467 milliseconds. These results demonstrate that older individuals produce longer syllable durations than younger individuals. These results mirror those found by Ryalls et al., in which the older speakers produced longer syllable durations than younger speakers. However, the contrasting VOT measurement results between the two studies merits further investigation in the VOT productions in normal aging speakers.

An additional area warranting further research is the speech production of individuals with Alzheimer's disease. The majority of research completed on individuals with Alzheimer's disease has looked at their language abilities. Aside from the changes in memory and personality, language disturbances represent a major characterizing factor in Alzheimer's disease, such as name and word finding deficits (Reisberg, et al., 1982). For instance, in a study by Cummings, Benson, Hill, and Read (1985), it was found that "Language abnormalities were present in all dementia of the Alzheimer's type patients in the study, and the language alterations readily distinguished the dementia of the Alzheimer's type patients from control participants" (p. 396). In the previously reviewed literature, it was demonstrated that some individuals with Alzheimer's disease experienced speech disturbances following the acquisition of Alzheimer's disease.

A longitudinal study by Romero and Kurz (1996) measured the rate and pattern of spontaneous speech decline in participants with Alzheimer's disease during a one-year follow-up. The results demonstrated a general tendency for the spontaneous speech of individuals with dementia to decrease upon a one-year follow-up examination. Croot, Hodges, Xuereb, and Patterson (2000) measured whether articulatory and phonological impairments occurred in the early course of Alzheimer's disease. The data suggested that articulatory processing may occasionally be compromised in dementia of the Alzheimer's type, and may be a presenting symptom when the focus is on less typical cases. Biassou, D'Esposito, Grossman, Hughes, Mickanin, Onishi, and Robinson (1995) measured the amount of speech errors in Alzheimer's disease patients. The results of this study suggested that sentences containing phonological errors were significantly more frequent in individuals with Alzheimer's disease than in the control participants. In conclusion, the results of these studies indicate that errors do occur in the speech production of individuals with Alzheimer's disease. Therefore, future studies on the speech production of individuals with Alzheimer's disease are warranted since the research in this area is promising, yet sparse.

An unexpected finding that occurred within the study was the discovery of an "audible swallow" immediately preceding the speech production of a stop consonant in some of the participants. This audible swallow was heard during five separate occasions in the speech production of individuals with Alzheimer's disease (occurring one time each in three participants and twice in one participant). Additionally, the audible swallow was heard during two separate occasions in the speech production of one control participant. Table 8 shows the participants who produced the audible swallow and on which word the audible swallow was produced.

Table 9: Participants Who Produced an Audible Swallow

Participant	Speech Stimuli Produced Following the Swallow
AM01	/dat/, /gat/
AF01	/dup/
AF04	/dat/
AF05	/dip/
CF02	/dup/, /dup/

MacNeilage & Davis (2005) theorized that speech evolved from the gestures found in chewing and swallowing; perhaps the audible swallows heard in this study reflect support for this theory. In aging and Alzheimer's disease, we may see the dissolution of speech gestures to earlier stages of their evolutionary development. It appears to be a reflection of aging, in general, as it appeared in one control speaker. It should be noted, however, that the control participant who produced the audible swallow was the oldest participant in the study at 93-years of age. The detection of these audible swallows merits further investigation, as it has never been previously observed in speech production behaviors, to this researcher's knowledge.

In summary, the present study has added to the ever-growing research currently being completed on individuals with Alzheimer's disease and supplemented the groundwork for continuing research on the speech characteristics of individuals with

Alzheimer's disease. Results of this study demonstrated that VOT measurements could not be used as an early investigative tool to detect Alzheimer's disease in its earliest stage. While the results of the present study were not statistically significant, it should not diminish the effort of researchers to continue additional studies on the speech production characteristics of individuals with Alzheimer's disease, nor the search for earlier indicators of Alzheimer's disease.

Future research may include an in-depth look into the amount and types of paraphasic errors individuals with Alzheimer's disease produce during structured, imitative, and spontaneous speech. Additional research efforts may include comparing the speech output between individuals with Alzheimer's disease and individuals with Wernicke's aphasia due to the similarities within the groups' VOT measurements. In conclusion, further research on the speech characteristic of individuals with Alzheimer's disease is imperative to supplement our knowledge of the progressive and deteriorative disease.

APPENDIX A

CAREGIVER CONSENT FORM

Dear Caregiver:

I am a graduate student in the Department of Communicative Disorders at the University of Central Florida. I am investigating whether there are subtle early signs of Alzheimer's disease in the speech signal, which are not apparent to the human ear. Your family member's participation will increase the knowledge of the early signs of Alzheimer's disease and contribute to better understanding and care for persons with this debilitating disease.

As part of the project, the *Functional Linguistic Communication Inventory* (FLCI) will be administered to assess your family member's functional communication abilities in order to verify the level of severity. The FLCI takes approximately 15-25 minutes to administer. Secondly, your family member will be administered the *Mini-Mental State Examination* (MMSE) to measure his or her cognitive status. The MMSE takes approximately 5-10 minutes to administer. Next, your family member will be asked to read aloud a reading passage and a list words into a microphone. His or speech will be recorded on an audiotape, and then measured acoustically. This portion of testing is about 25-30 minutes and can be done following the administration of the FLCI or during a separate session.

The entire project will take approximately 1 hour. It will take place over one to two sessions. If you or your family member with Alzheimer's disease does not wish to participate in the tasks at any time, you can withdraw at any time. There are no risks anticipated of any kind. You will not be compensated for your participation.

All activities will be completed at the Arden Courts. You and your family member's names will never be associated with the project. A number will code any information obtained, and all tapes will be erased following the project's completion.

If you have any questions regarding this project, please feel free to contact Julie Baker or Dr. Jack Ryalls

Whom to contact about your rights in this study: UCFIRB Office, Office of Research, University of Central Florida, Orlando Tech Center, 12443 Research Parkway, Suite 207, Orlando, FL (407) 823-2901.

If you agree to participate in this project, please sign and return the attached consent form to Julie Baker. Upon your request, a photocopy of this form will be given to you for your records. By signing the consent form, you give us permission to report your family member's responses anonymously in the final manuscript of Julie Baker's Master's thesis and to professional publications. I appreciate your time and cooperation.

Sincerely yours,

Julie Baker, B.S., SLP Jack Ryalls, Ph.D.

Informed Consent

Please read this consent document carefully before you decide to participate in this study.
Project title: Speech Production Measures in Individuals with Alzheimer's disease
Purpose of the study:

The purpose of this research study is to examine the speech production of individuals with Alzheimer's disease. The hypothesis of this study is that those individuals with Alzheimer's disease will show greater indicators of aging in their speech than their peers without Alzheimer's disease.

What you will be asked to do in this study:

You will be asked to perform a session of two separate standardized memory tests by answering questions and performing short memory tasks. You will be asked to read aloud a list of short words and a short paragraph. Your voice will be recorded. You will not be compensated for your participation.

Time required: approximately 50 to 60 minutes

Risks: There are no known risks to reading words and being tape-recorded.

Confidentiality:

Your identity will be kept confidential. Your data will be assigned a confidential code number and your name will not be used in any report of the data. Only Julie Baker and Dr. Ryalls will have access to the tape recordings. The audiotapes will be erased following the completion of the project.

Voluntary participation:

Your participation is voluntary. There is no penalty for not participating.

Right to withdraw from the study:

You have the right to withdraw from the study at any time without consequence.

Whom to contact if you have questions about the study:

Julie Baker, student in Communicative Disorders, University of Central Florida, Orlando, FL.

Jack Ryalls, Ph.D. Department of Communicative Disorders, University of Central Florida, Orlando, FL.

Whom to contact about your rights in the study:

UCFIRB Office, Office of Research, University of Central Florida, Orlando Tech Center, 12443 Research Parkway, Suite 207, Orlando, FL (407) 823-2901

_______I have read the procedure described above.

_______I voluntarily agree to participate in this study, and if requested, I have received a copy of this description.

____/___ ___ ___
Caregiver /Guardian Date

____/___ ___ ___
Student Investigator Date

____/___ ___ ____

Supervisor/ Principal Investigator Date

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APPENDIX B

CONTROL CONSENT FORM

Informed Consent

Please read this consent document carefully before you decide to participate in this study.
Project title: Speech Production Measures in Individuals with Alzheimer's disease
Purpose of the study:

The purpose of this research study is to examine the speech production of individuals with Alzheimer's disease. The hypothesis of this study is that those individuals with Alzheimer's disease will show greater indicators of aging in their speech than their peers without Alzheimer's disease.

What you will be asked to do in this study:

You will be asked to perform a session standardized memory tests by answering questions and performing short memory tasks. You will be asked to read aloud a list of short words and a short paragraph. Your voice will be recorded. You will not be compensated for your participation.

Time required: approximately 30 minutes

Risks: There are no known risks to reading words and being tape-recorded.

Confidentiality:

Your identity will be kept confidential. Your data will be assigned a confidential code number and your name will not be used in any report of the data. Only Julie Baker and Dr. Ryalls will have access to the tape recordings. The audiotapes will be erased following the completion of the project.

Voluntary participation:

Your participation is voluntary. There is no penalty for not participating.

Right to withdraw from the study:

You have the right to withdraw from the study at any time without consequence.

Whom to contact if you have questions about the study:

Julie Baker, student in Communicative Disorders, University of Central Florida, Orlando, FL.

Jack Ryalls, Ph.D. Department of Communicative Disorders, University of Central Florida, Orlando, FL.

Whom to contact about your rights in the study:

UCFIRB Office, Office of Research, University of Central Florida, Orlando Tech Center, 12443 Research Parkway, Suite 207, Orlando, FL (407) 823-2901

_______I have read the procedure described above.

_______I voluntarily agree to participate in this study, and if requested, I have received a copy of this description.

____/___ ___ ___
Participant Date

____/___ ___ ___
Student Investigator Date

____/___ ___ ____
Supervisor/ Principal Investigator Date

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APPENDIX C

INSTRUCTIONS TO SUBJECTS

Instructions

You are about to read some lists of words. First, you will be asked to read the words aloud once to make sure you are reading them correctly. Next, you will read the words aloud and be recorded. Please say your identification number clearly into the microphone. Then, please read the words naturally into the microphone, as if you are speaking with someone. Please read the repetition number at the top of every page and then read all of the words listed on the page. This is not a race! Please do not go too fast, but rather at a steady, natural pace. Thank you for your cooperation.

APPENDIX D

STIMULUS WORDS

Word Lists

List 1	List 2	List 3	List 4	List 5	List 6	List 7
dot	geek	beat	keep	dot	goop	coop
keep	teak	bop	tot	cot	peat	pot
pot	dot	peat	toot	goop	teak	got
boot	tot	keep	dupe	deep	geek	peat
bop	toot	boot	dot	peat	beat	keep
toot	deep	tot	poop	teak	tot	teak
dupe	coop	dupe	bop	beat	boot	boot
peat	boot	dot	goop	geek	got	bop
tot	goop	poop	teak	keep	keep	goop
poop	peat	coop	cot	tot	coop	beat
deep	cot	geek	deep	dupe	toot	poop
got	bop	deep	boot	pot	dot	cot
coop	pot	teak	peat	toot	bop	deep
geek	poop	got	beat	got	deep	dot
beat	beat	goop	geek	coop	poop	dupe
cot	got	cot	coop	poop	cot	tot
teak	keep	toot	got	bop	pot	geek
goop	dupe	pot	pot	boot	dupe	toot

APPENDIX E

INDIVIDUAL DATA SHEETS

Table 10: AD Participant #AM01

	/p/		/t/		/k/	
	Duration	VOT	Duration	VOT	Duration	VOT
/i/	1. 444	1. 56	1. 388	1. 51	1. 402	1. 80
	2. 438	2. 69	2. 533	2. 64	2. 417	2. 91
	3. 417	3. 81	3. 438	3. 54	3. 452	3. 66
	X 433	X 69	X 453	X 56	X 424	X 79
/a/	1. 427	1. 63	1. 425	1. 89	1. 474	1. 96
	2. 644	2. 54	2. 484	2. 96	2. 500	2. 113
	3. 395	3. 56	3. 448	3. 96	3. 431	3. 99
	X 489	X 58	X 452	X 94	X 468	X 103
/u/	1. 352	1. 28	1. 350	1. 78	1. 387	1. 55
	2. 359	2. 58	2. 438	2. 109	2. 430	2. 121
	3. 382	3. 40	3. 394	3. 81	3. 388	3. 98
	X 364	X 42	X 394	X 89	X 402	X 91
Total	X 429	X 56	X 433	X 80	X 431	X 91
		SD 15		SD 20		SD 21

	/b/		/d/		/g/	
	Duration	VOT	Duration	VOT	Duration	VOT
/i/	1. 418	1. -67	1. 726	1. -277	1. 421	1. 28
	2. 679	2. -277	2. 577	2. -181	2. 441	2. 28
	3. 740	3. -177	3. 522	3. -116	3. 339	3. 22
	X 612	X -174	X 608	X -191	X 400	X 26
/a/	1. 563	1. -171	1. 337	1. -70	1. 409	1. -39
	2. 398	2. -86	2. 693	2. -228	2. 603	2. -122
	3. 731	3. -294	3. 269	3. 23	3. 699	3. -181
	X 564	X -184	X 433	X -93	X 570	X -114
/u/	1. 434	1. -87	1. 336	1. 14	1. 412	1. 22
	2. 460	2. 21	2. 373	2. 16	2. 509	2. -128
	3. 472	3. -67	3. 486	3. -133	3. 525	3. -177
	X 455	X -44	X 398	X -34	X 482	X -94
Total	X 544	X -134	X 480	X -106	X 484	X -61

		SD 105		SD 111		SD 91

Table 11: AD Participant #AM02

	/p/		/t/		/k/	
	Duration	VOT	Duration	VOT	Duration	VOT
/i/	1. 617	1. 121	1. 987	1. 61	1. 519	1. 152
	2. 679	2. 67	2. 599	2. 57	2. 688	2. 104
	3. 691	3. 58	3. 895	3. 83	3. 773	3. 88
	X 662	X 82	X 827	X 67	X 660	X 115
/a/	1. 525	1. 72	1. 877	1. 87	1. 853	1. 93
	2. 468	2. 83	2. 856	2. 108	2. 818	2. 80
	3. 449	3. 137	3. 783	3. 75	3. 953	3. 90
	X 481	X 97	X 839	X 90	X 875	X 88
/u/	1. 460	1. 56	1. 957	1. 77	1. 1036	1. 81
	2. 772	2. 67	2. 492	2. 81	2. 391	2. 58
	3. 714	3. 51	3. 807	3. 85	3. 738	3. 81
	X 649	X 58	X 752	X 81	X 722	X 73
Total	X 597	X 79	X 806	X 79	X 752	X 92
		SD 20		SD 15		SD 26

	/b/		/d/		/g/	
	Duration	VOT	Duration	VOT	Duration	VOT
/i/	1. 598	1. -51	1. 651	1. -101	1. 976	1. 21
	2. 630	2. -56	2. 512	2. 38	2. 957	2. 42
	3. 607	3. 45	3. 601	3. 32	3. 790	3. -54
	X 612	X -21	X 588	X -10	X 908	X 3
/a/	1. 720	1. -50	1. 653	1. 24	1. 783	1. 39
	2. 590	2. 14	2. 581	2. -59	2. 437	2. -39
	3. 563	3. 11	3. 721	3. -100	3. 818	3. 37
	X 624	X -8	X 652	X -45	X 679	X 12
/u/	1. 450	1. -55	1. 593	1. -121	1. 699	1. 12
	2. 817	2. -31	2. 728	2. -296	2. 533	2. 38
	3. 578	3. 27	3. 598	3. -55	3. 777	3. -54

	X 615	X -20	X 640	X -157	X 670	X -1
Total	X 617	X -16	X 627	X -71	X 752	X 5
		SD 40		SD 104		SD 42

Table 12: AD Participant #AM03

	/p/		**/t/**		**/k/**	
	Duration	VOT	Duration	VOT	Duration	VOT
/i/	1. 946	1. 195	1. 621	1. 76	1. 555	1. 120
	2. 721	2. 109	2. 814	2. 200	2. 849	2. 172
	3. 1019	3. 181	3. 988	3. 77	3. 921	3. 95
	X 895	X 162	X 808	X 118	X 775	X 129
/a/	1. 684	1. 180	1. 1025	1. 157	1. 705	1. 66
	2. 863	2. 77	2. 780	2. 160	2. 606	2. 86
	3. 797	3. 71	3. 842	3. 93	3. 926	3. 82
	X 781	X 109	X 882	X 137	X 746	X 78
/u/	1. 428	1. 51	1. 794	1. 86	1. 842	1. 44
	2. 743	2. 100	2. 776	2. 70	2. 707	2. 180
	3. 821	3. 67	3. 716	3. 97	3. 736	3. 31
	X 664	X 73	X 762	X 84	X 762	X 85
Total	X 780	X 115	X 817	X 113	X 761	X 97
		SD 56		SD 47		SD 52

	/b/		**/d/**		**/g/**	
	Duration	VOT	Duration	VOT	Duration	VOT
/i/	1. 1261	1. -165	1. 1032	1. -50	1. 436	1. 18
	2. 769	2. 29	2. 882	2. 20	2. 533	2. 18
	3. 812	3. 29	3. 646	3. -53	3. 726	3. -123
	X 947	X -36	X 853	X -28	X 565	X -29
/a/	1. 794	1. 19	1. 935	1. -126	1. 640	1. 38
	2. 1424	2. -240	2. 752	2. -54	2. 690	2. 30
	3. 1157	3. -231	3. 967	3. 33	3. 973	3. -104
	X 1125	X -151	X 885	X -49	X 768	X -12

/u/	1. 802	1. -234	1. 938	1. 20	1. 636	1. 26
	2. 845	2. 73	2. 879	2. 27	2. 735	2. 35
	3. 666	3. 24	3. 750	3. 32	3. 655	3. 13
	X 771	X -46	X 856	X 26	X 675	X 25
Total	X 948	X -78	X 865	X -17	X 869	X -5
		SD 136		SD 56		SD 62

Table 13: AD Participant #AM04

	/p/		**/t/**		**/k/**	
	Duration	VOT	Duration	VOT	Duration	VOT
/i/	1. 1160	1. 66	1. 466	1. 74	1. 540	1. 70
	2. 862	2. 49	2. 451	2. 40	2. 413	2. 96
	3. 277	3. 70	3. 745	3. 35	3. 873	3. 73
	X 766	X 62	X 554	X 50	X 609	X 80
/a/	1. 322	1. 65	1. 445	1. 64	1. 337	1. 99
	2. 749	2. 69	2. 282	2. 53	2. 304	2. 84
	3. 345	3. 48	3. 315	3. 71	3. 323	3. 68
	X 472	X 61	X 347	X 63	X 321	X 84
/u/	1. 1064	1. 65	1. 845	1. 57	1. 901	1. 72
	2. 564	2. 38	2. 735	2. 61	2. 625	2. 82
	3. 413	3. 80	3. 278	3. 53	3. 695	3. 112
	X 680	X 61	X 619	X 57	X 740	X 89
Total	X 639	X 61	X 507	X 57	X 557	X 84
		SD 13		SD 13		SD 15

	/b/		**/d/**		**/g/**	
	Duration	VOT	Duration	VOT	Duration	VOT
/i/	1. 497	1. 32	1. 442	1. 23	1. 445	1. -41
	2. 845	2. 25	2. 376	2. 22	2. 507	2. -45
	3. 605	3. -97	3. 472	3. -266	3. 348	3. 26
	X 649	X -13	X 430	X -74	X 433	X -20
/a/	1. 824	1. 20	1. 363	1. -64	1. 702	1. -258
	2. 332	2. -109	2. 249	2. 24	2. 278	2. 22

	3. 770	3. -212	3. 286	3. 16	3. 323	3. 25
	X 642	X -100	X 299	X -8	X 434	X -70
/u/	1. 790	1. 25	1. 536	1. 20	1. 375	1. 30
	2. 411	2. -51	2. 533	2. 13	2. 574	2. 35
	3. 425	3. 25	3. 218	3. 21	3. 632	3. 28
	X 542	X 0	X 429	X 18	X 527	X 31
Total	X 611	X -38	X 386	X -21	X 465	X -20
		SD 86		SD 96		SD 95

Table 14: AD Participant #AM05

	/p/		**/t/**		**/k/**	
	Duration	VOT	Duration	VOT	Duration	VOT
/i/	1. 586	1. 73	1. 560	1. 81	1. 643	1. 121
	2. 513	2. 39	2. 566	2. 72	2. 666	2. 93
	3. 593	3. 90	3. 675	3. 66	3. 699	3. 87
	X 564	X 67	X 600	X 73	X 669	X 100
/a/	1. 743	1. 61	1. 835	1. 62	1. 436	1. 31
	2. 717	2. 83	2. 548	2. 86	2. 466	2. 44
	3. 456	3. 78	3. 603	3. 56	3. 460	3. 89
	X 639	X 74	X 662	X 68	X 454	X 55
/u/	1. 593	1. 91	1. 614	1. 72	1. 771	1. 79
	2. 588	2. 61	2. 895	2. 86	2. 482	2. 90
	3. 611	3. 61	3. 613	3. 56	3. 650	3. 86
	X 597	X 71	X 707	X 71	X 634	X 85
Total	X 600	X 71	X 656	X 71	X 586	X 80
		SD 17		SD 12		SD 27

	/b/		**/d/**		**/g/**	
	Duration	VOT	Duration	VOT	Duration	VOT
/i/	1. 603	1. 20	1. 605	1. 23	1. 700	1. -32
	2. 488	2. 9	2. 507	2. 22	2. 656	2. -36
	3. 856	3. 15	3. 578	3. 14	3. 617	3. -52
	X 649	X 15	X 563	X 20	X 658	X -40

/a/	1. 763	1. 20	1. 435	1. 39	1. 704	1. 32
	2. 491	2. 15	2. 726	2. 14	2. 774	2. 40
	3. 673	3. 9	3. 509	3. 26	3. 661	3. 34
	X 642	X 15	X 557	X 26	X 713	X 35
/u/	1. 667	1. 20	1. 686	1. 20	1. 978	1. 66
	2. 675	2. 17	2. 694	2. 23	2. 850	2. 60
	3. 681	3. 28	3. 605	3. 25	3. 754	3. 53
	X 674	X 22	X 662	X 23	X 861	X 60
Total	X 655	X 17	X 594	X 23	X 744	X 18
		SD 6		SD 7		SD 45

Table 15: AD Participant #AF01

	/p/		**/t/**		**/k/**	
	Duration	VOT	Duration	VOT	Duration	VOT
/i/	1. 641	1. 131	1. 578	1. 124	1. 731	1. 136
	2. 571	2. 80	2. 649	2. 121	2. 722	2. 236
	3. 658	3. 117	3. 668	3. 145	3. 752	3. 191
	X 623	X 109	X 632	X 130	X 735	X 188
/a/	1. 631	1. 103	1. 576	1. 92	1. 662	1. 156
	2. 547	2. 74	2. 801	2. 221	2. 522	2. 111
	3. 1135	3. 87	3. 793	3. 161	3. 721	3. 147
	X 771	X 88	X 723	X 158	X 635	X 138
/u/	1. 524	1. 86	1. 614	1. 106	1. 744	1. 128
	2. 890	2. 143	2. 620	2. 120	2. 746	2. 176
	3. 547	3. 84	3. 643	3. 132	3. 635	3. 125
	X 654	X 104	X 626	X 119	X 708	X 143
Total	X 683	X 100	X 660	X 136	X 693	X 156
		SD 25		SD 38		SD 39

	/b/		**/d/**		**/g/**	
	Duration	VOT	Duration	VOT	Duration	VOT
/i/	1. 748	1. 29	1. 588	1. 21	1. 601	1. 51

	2. 522	2. 35	2. 617	2. 21	2. 740	2. 56
	3. 570	3. 23	3. 569	3. 32	3. 619	3. 54
	X 613	X 29	X 591	X 25	X 653	X 54
/a/	1. 568	1. 38	1. 775	1. 14	1. 960	1. 38
	2. 631	2. 28	2. 476	2. 13	2. 839	2. 21
	3. 650	3. 32	3. 533	3. 16	3. 954	3. 23
	X 616	X 33	X 595	X 14	X 918	X 27
/u/	1. 532	1. 34	1. 714	1. -153	1. 873	1. 14
	2. 550	2. 20	2. 880	2. -166	2. 607	2. 28
	3. 516	3. 19	3. 523	3. 21	3. 604	3. 27
	X 533	X 24	X 706	X -99	X 695	X 23
Total	X 587	X 29	X 631	X -20	X 755	X 35
		SD 7		SD 79		SD 16

Table 16: AD Participant #AF02

	/p/		**/t/**		**/k/**	
	Duration	VOT	Duration	VOT	Duration	VOT
/i/	1. 672	1. 42	1. 636	1. 55	1. 501	1. 66
	2. 479	2. 44	2. 533	2. 84	2. 491	2. 63
	3. 407	3. 31	3. 603	3. 44	3. 464	3. 52
	X 519	X 39	X 591	X 61	X 485	X 60
/a/	1. 479	1. 65	1. 650	1. 58	1. 529	1. 61
	2. 726	2. 43	2. 554	2. 65	2. 517	2. 63
	3. 564	3. 123	3. 670	3. 32	3. 461	3. 53
	X 590	X 77	X 625	X 52	X 502	X 59
/u/	1. 698	1. 33	1. 599	1. 66	1. 517	1. 62
	2. 477	2. 52	2. 610	2. 35	2. 653	2. 63
	3. 559	3. 34	3. 641	3. 22	3. 730	3. 57
	X 578	X 40	X 617	X 41	X 633	X 61
Total	X 562	X 52	X 611	X 51	X 540	X 60
		SD 29		SD 20		SD 5

	/b/		/d/		/g/	
	Duration	VOT	Duration	VOT	Duration	VOT
/i/	1. 755	1. -281	1. 423	1. -43	1. 548	1. -91
	2. 916	2. -274	2. 638	2. 17	2. 890	2. -97
	3. 899	3. -250	3. 582	3. -84	3. 646	3. -40
	X 857	X -268	X 548	X -37	X 695	X -76
/a/	1. 674	1. 21	1. 595	1. 16	1. 775	1. 27
	2. 656	2. 28	2. 542	2. -33	2. 1100	2. -317
	3. 672	3. 29	3. 868	3. -65	3. 928	3. -228
	X 667	X 26	X 666	X -27	X 934	X -173
/u/	1. 440	1. 20	1. 472	1. 20	1. 655	1. 23
	2. 717	2. 11	2. 633	2. -73	2. 1040	2. 25
	3. 634	3. 10	3. 674	3. 19	3. 767	3. -160
	X 597	X 14	X 593	X -11	X 821	X -37
Total	X 707	X -76	X 602	X -25	X 817	X -95
		SD 144		SD 44		SD 121

Table 17: AD Participant #AF03

	/p/		/t/		/k/	
	Duration	VOT	Duration	VOT	Duration	VOT
/i/	1. 769	1. 91	1. 1058	1. 24	1. 709	1. 114
	2. 819	2. 101	2. 1354	2. 104	2. 770	2. 115
	3. 724	3. 77	3. 1202	3. 103	3. 909	3. 144
	X 771	X 90	X 1205	X 77	X 796	X 124
/a/	1. 787	1. 85	1. 771	1. 99	1. 1031	1. 147
	2. 980	2. 34	2. 933	2. 85	2. 726	2. 97
	3. 929	3. 86	3. 794	3. 70	3. 728	3. 91
	X 899	X 68	X 833	X 85	X 828	X 112
/u/	1. 744	1. 71	1. 807	1. 48	1. 1440	1. 73
	2. 587	2. 36	2. 888	2. 38	2. 475	2. 109
	3. 772	3. 23	3. 1351	3. 72	3. 605	3. 43
	X 701	X 43	X 1015	X 53	X 840	X 75
Total	X 790	X 67	X 1018	X 72	X 821	X 104
		SD 29		SD 29		SD 33

	/b/		/d/		/g/	
	Duration	VOT	Duration	VOT	Duration	VOT
/i/	1. 1088	1. 42	1. 852	1. -100	1. 936	1. 17
	2. 1114	2. -134	2. 1012	2. -177	2. 1139	2. -134
	3. 819	3. 18	3. 506	3. 23	3. 828	3. 33
	X 1007	X -25	X 790	X -85	X 968	X -28
/a/	1. 729	1. 47	1. 568	1. 21	1. 966	1. 24
	2. 825	2. -23	2. 922	2. 32	2. 791	2. 14
	3. 1024	3. 42	3. 763	3. 31	3. 873	3. 21
	X 859	X 22	X 751	X 28	X 877	X 20
/u/	1. 602	1. 52	1. 526	1. 11	1. 950	1. 20
	2. 1063	2. -127	2. 576	2. 24	2. 460	2. 20
	3. 961	3. 25	3. 668	3. 39	3. 1220	3. -73
	X 875	X -17	X 590	X 25	X 877	X -11
Total	X 914	X -7	X 710	X -11	X 907	X -6
		SD 74		SD 75		SD 57

Table 18: AD Participant #AF04

	/p/		/t/		/k/	
	Duration	VOT	Duration	VOT	Duration	VOT
/i/	1. 646	1. 52	1. 570	1. 36	1. 577	1. 107
	2. 522	2. 67	2. 547	2. 86	2. 348	2. 79
	3. 521	3. 73	3. 500	3. 84	3. 426	3. 88
	X 563	X 64	X 539	X 69	X 450	X 91
/a/	1. 342	1. 62	1. 678	1. 91	1. 663	1. 82
	2. 541	2. 67	2. 307	2. 58	2. 469	2. 100
	3. 641	3. 86	3. 581	3. 99	3. 557	3. 83
	X 508	X 72	X 522	X 83	X 563	X 88
/u/	1. 481	1. 72	1. 504	1. 97	1. 624	1. 130
	2. 725	2. 79	2. 575	2. 106	2. 429	2. 86
	3. 529	3. 49	3. 572	3. 80	3. 493	3. 107
	X 578	X 67	X 550	X 94	X 516	X 108

Total	X 550	X 68	X 537	X 82	X 510	X 96
		SD 12		SD 22		SD 17

	/b/		/d/		/g/	
	Duration	VOT	Duration	VOT	Duration	VOT
/i/	1. 623	1. -128	1. 773	1. -115	1. 633	1. -74
	2. 804	2. -285	2. 546	2. -105	2. 720	2. 23
	3. 1069	3. -76	3. 657	3. -84	3. 800	3. -207
	X 832	X -163	X 659	X -101	X 718	X -86
/a/	1. 366	1. 11	1. 715	1. 38	1. 628	1. 44
	2. 483	2. 17	2. 386	2. -94	2. 624	2. -28
	3. 385	3. 22	3. 965	3. 17	3. 515	3. -48
	X 411	X 17	X 689	X -13	X 589	X -11
/u/	1. 587	1. -98	1. 655	1. 15	1. 627	1. -130
	2. 802	2. -154	2. 491	2. -112	2. 566	2. 25
	3. 492	3. 40	3. 753	3 .-186	3. 558	3. -38
	X 627	X -71	X 633	X -94	X 584	X -48
Total	X 623	X -72	X 660	X -69	X 630	X -48
		SD 107		SD 76		SD 81

Table 19: AD Participant #AF05

	/p/		/t/		/k/	
	Duration	VOT	Duration	VOT	Duration	VOT
/i/	1. 565	1. 64	1. 603	1. 85	1. 517	1. 89
	2. 461	2. 45	2. 510	2. 75	2. 472	2. 103
	3. 468	3. 50	3. 666	3. 76	3. 491	3. 103
	X 461	X 53	X 593	X 79	X 493	X 98
/a/	1. 296	1. 77	1. 276	1. 88	1. 284	1. 77
	2. 707	2. 37	2. 467	2. 64	2. 559	2. 32
	3. 435	3. 63	3. 567	3. 50	3. 318	3. 58
	X 479	X 59	X 437	X 67	X 387	X 56
/u/	1. 471	1. 43	1. 521	1. 82	1. 592	1. 114

	2. 404	2. 74	2. 692	2. 80	2. 458	2. 75
	3. 603	3. 66	3. 562	3. 89	3. 445	3. 93
	X 493	X 61	X 592	X 84	X 498	X 94
Total	X 478	X 58	X 541	X 77	X 459	X 83
		SD 14		SD 13		SD 26

	/b/		/d/		/g/	
	Duration	VOT	Duration	VOT	Duration	VOT
/i/	1. 444	1. 20	1. 716	1. -242	1. 570	1. -32
	2 462	2. 29	2. 546	2. -80	2. 823	2. -63
	3. 833	3. -180	3. 826	3. -293	3. 547	3. -60
	X 580	X -44	X 696	X -205	X 647	X -52
/a/	1. 631	1. -54	1. 1371	1. -688	1. 272	1. 32
	2. 495	2. 27	2. 939	2. -226	2. 507	2. -28
	3. 721	3. 28	3. 629	3. 44	3. 494	3. -25
	X 616	X 0	X 980	X -290	X 424	X -7
/u/	1. 618	1. -304	1. 627	1. -160	1. 437	1. 15
	2. 499	2. 30	2. 564	2. 22	2. 440	2. 13
	3. 576	3. -62	3. 685	3. -36	3. 527	3. -71
	X 564	X -111	X 625	X -58	X 468	X -14
Total	X 587	X -52	X 767	X -184	X 513	X -24
		SD 117		SD 223		SD 37

Table 20: Control Participant #CM01

	/p/		/t/		/k/	
	Duration	VOT	Duration	VOT	Duration	VOT
/i/	1. 519	1. 66	1. 500	1. 66	1. 471	1. 56
	2. 463	2. 51	2. 534	2. 70	2. 242	2. 67
	3. 268	3. 46	3. 398	3. 40	3. 464	3. 92
	X 417	X 54	X 477	X 59	X 392	X 72
/a/	1. 279	1. 91	1. 279	1. 79	1. 505	1. 63
	2. 247	2. 39	2. 340	2. 58	2. 271	2. 58

	3. 235	3. 43	3. 258	3. 56	3. 247	3. 49
	X 254	X 58	X 292	X 64	X 341	X 57
/u/	1. 212	1. 62	1. 237	1. 45	1. 520	1. 99
	2. 202	2. 48	2. 241	2. 68	2. 437	2. 75
	3. 194	3. 56	3. 166	3. 30	3. 451	3. 55
	X 203	X 55	X 215	X 48	X 469	X 76
Total	X 291	X 56	X 328	X 57	X 401	X 68
		SD 16		SD 16		SD 17

	/b/		**/d/**		**/g/**	
	Duration	VOT	Duration	VOT	Duration	VOT
/i/	1. 489	1. -81	1. 568	1. -180	1. 690	1. -94
	2. 355	2. -126	2. 315	2. -112	2. 683	2. -119
	3. 447	3. -70	3. 217	3. -42	3. 585	3. -90
	X 430	X -92	X 367	X -111	X 653	X -70
/a/	1. 337	1. -60	1. 379	1. -120	1. 306	1. -32
	2. 360	2. -128	2. 354	2. -78	2. 319	2. -60
	3. 305	3. -92	3. 378	3. -122	3. 301	3. -97
	X 334	X -93	X 370	X -107	X 309	X -63
/u/	1. 536	1. -127	1. 532	1. -100	1. 621	1. -79
	2. 331	2. -104	2. 519	2. -98	2. 304	2. -74
	3. 304	3. -89	3. 323	3. -131	3. 279	3. -89
	X 390	X -107	X 458	X -110	X 401	X -81
Total	X 385	X -97	X 398	X -109	X 454	X -71
		SD 25		SD 38		SD 25

Table 21: Control Participant #CM02

	/p/		**/t/**		**/k/**	
	Duration	VOT	Duration	VOT	Duration	VOT
/i/	1. 452	1. 77	1. 524	1. 59	1. 594	1. 101
	2. 619	2. 89	2. 675	2. 75	2. 667	2. 92
	3. 642	3. 71	3. 583	3. 70	3. 643	3. 103
	X 571	X 79	X 594	X 68	X 635	X 99

/a/	1. 626	1. 81	1. 634	1. 63	1. 757	1. 65
	2. 577	2. 83	2. 693	2. 61	2. 726	2. 80
	3. 626	3. 63	3. 604	3. 70	3. 625	3. 83
	X 610	X 76	X 644	X 65	X 703	X 76
/u/	1. 761	1. 52	1. 635	1. 73	1. 601	1. 80
	2. 679	2. 79	2. 578	2. 67	2. 610	2. 112
	3. 503	3. 66	3. 582	3. 72	3. 549	3. 91
	X 648	X 66	X 598	X 71	X 587	X 94
Total	X 610	X 74	X 612	X 68	X 642	X 90
		SD 12		SD 6		SD 14

	/b/		/d/		/g/	
	Duration	VOT	Duration	VOT	Duration	VOT
/i/	1. 656	1. 17	1. 671	1. -80	1. 811	1. -98
	2. 726	2. -125	2. 777	2. -142	2. 651	2. -97
	3. 886	3. -211	3. 865	3. -118	3. 725	3. -147
	X 756	X -106	X 771	X -113	X 729	X -114
/a/	1. 583	1. 18	1. 903	1. -169	1. 877	1. -96
	2. 758	2. -156	2. 874	2. -131	2. 819	2. -119
	3. 674	3. -44	3. 629	3. 23	3. 691	3. -111
	X 672	X -61	X 802	X -92	X 796	X -109
/u/	1. 775	1. -96	1. 681	1. -122	1. 587	1. -84
	2. 710	2. -130	2. 612	2. -86	2. 672	2. -126
	3. 791	3. -166	3. 593	3. -90	3. 637	3. -102
	X 759	X -131	X 629	X -99	X 632	X -104
Total	X 729	X -99	X 734	X -101	X 719	X -109
		SD 81		SD 55		SD 19

Table 22: Control Participant #CM03

	/p/		/t/		/k/	
	Duration	VOT	Duration	VOT	Duration	VOT
/i/	1. 458	1. 75	1. 456	1. 81	1. 489	1. 83

	2. 500	2. 64	2. 478	2. 66	2. 461	2. 81
	3. 527	3. 54	3. 451	3. 52	3. 405	3. 69
	X 495	X 64	X 462	X 66	X 452	X 78
/a/	1. 451	1. 61	1. 438	1. 86	1. 469	1. 87
	2. 517	2. 67	2. 390	2. 86	2. 485	2. 83
	3. 473	3. 48	3. 497	3. 73	3. 524	3. 81
	X 480	X 59	X 442	X 82	X 493	X 84
/u/	1. 525	1. 64	1. 478	1. 61	1. 441	1. 59
	2. 398	2. 54	2. 402	2. 52	2. 423	2. 30
	3. 441	3. 70	3. 400	3. 75	3. 425	3. 60
	X 455	X 63	X 427	X 63	X 430	X 50
Total	X 477	X 62	X 444	X 70	X 458	X 71
		SD 9		SD 13		SD 18

	/b/		**/d/**		**/g/**	
	Duration	VOT	Duration	VOT	Duration	VOT
/i/	1. 576	1. -90	1. 484	1. -46	1. 425	1. 28
	2. 596	2. -141	2. 486	2. 39	2. 482	2. -62
	3. 605	3. -92	3. 500	3. 29	3. 448	3. 37
	X 592	X -108	X 490	X 7	X 452	X 1
/a/	1. 485	1. -96	1. 415	1. 21	1. 426	1. -21
	2. 719	2. 34	2. 396	2. 22	2. 418	2. 37
	3. 439	3. 28	3. 391	3. 14	3. 434	3. 19
	X 548	X -11	X 401	X 19	X 426	X 12
/u/	1. 536	1. 35	1. 365	1. 17	1. 391	1. 46
	2. 404	2. 33	2. 623	2. 41	2. 357	2. -26
	3. 629	3. -93	3. 474	3. 34	3. 383	3. 23
	X 523	X -8	X 487	X 31	X 377	X 14
Total	X 554	X -42	X 459	X 19	X 418	X 9
		SD 73		SD 26		SD 37

Table 23: Control Participant #CM04

	/p/		/t/		/k/	
	Duration	VOT	Duration	VOT	Duration	VOT
/i/	1. 362	1. 66	1. 405	1. 23	1. 448	1. 92
	2. 419	2. 80	2. 525	2. 88	2. 463	2. 91
	3. 401	3. 85	3. 437	3. 40	3. 438	3. 94
	X 394	X 77	X 456	X 50	X 450	X 92
/a/	1. 431	1. 79	1. 395	1. 73	1. 415	1. 92
	2. 422	2. 65	2. 407	2. 79	2. 369	2. 72
	3. 445	3. 31	3. 444	3. 87	3. 399	3. 80
	X 433	X 58	X 415	X 80	X 394	X 81
/u/	1. 419	1. 70	1. 443	1. 76	1. 482	1. 105
	2. 376	2. 57	2. 415	2. 66	2. 401	2. 101
	3. 404	3. 71	3. 379	3. 69	3. 439	3. 109
	X 400	X 66	X 412	X 70	X 441	X 105
Total	X 409	X 67	X 428	X 67	X 428	X 93
		SD 16		SD 22		SD 12

	/b/		/d/		/g/	
	Duration	VOT	Duration	VOT	Duration	VOT
/i/	1. 483	1. -117	1. 513	1. -145	1. 565	1. -172
	2. 486	2. -61	2. 531	2. -123	2. 562	2. -88
	3. 496	3. -159	3. 504	3. -112	3. 567	3. -187
	X 488	X -112	X 516	X -127	X 565	X -149
/a/	1. 541	1. -187	1. 600	1. -218	1. 348	1. -94
	2. 521	2. -118	2. 496	2. -95	2. 471	2. -114
	3. 514	3. -102	3. 452	3. -100	3. 460	3. -111
	X 525	X -135	X 516	X -138	X 426	X -106
/u/	1. 486	1. 23	1. 548	1. -168	1. 498	1. 22
	2. 533	2. -154	2. 521	2. -115	2. 504	2. 15
	3. 497	3. -116	3. 539	3. -195	3. 469	3. -147
	X 343	X -82	X 536	X -159	X 490	X -37
Total	X 452	X -110	X 523	X -141	X 494	X -97
		SD 61		SD 44		SD 74

Table 24: Control Participant #CM05

	/p/		/t/		/k/	
	Duration	VOT	Duration	VOT	Duration	VOT
/i/	1. 420	1. 44	1. 472	1. 95	1. 578	1. 102
	2. 565	2. 46	2. 487	2. 90	2. 488	2. 67
	3. 458	3. 60	3. 634	3. 73	3. 607	3. 72
	X 481	X 50	X 531	X 86	X 538	X 80
/a/	1. 484	1. 98	1. 483	1. 98	1. 731	1. 86
	2. 643	2. 108	2. 486	2. 101	2. 455	2. 78
	3. 547	3. 91	3. 487	3. 79	3. 618	3. 75
	X 558	X 99	X 485	X 93	X 538	X 80
/u/	1. 433	1. 72	1. 379	1. 65	1. 518	1. 77
	2. 551	2. 57	2. 423	2. 58	2. 540	2. 95
	3. 397	3. 50	3. 539	3. 75	3. 558	3. 85
	X 460	X 60	X 447	X 66	X 539	X 86
Total	X 500	X 70	X 488	X 82	X 559	X 82
		SD 24		SD 15		SD 11

	/b/		/d/		/g/	
	Duration	VOT	Duration	VOT	Duration	VOT
/i/	1. 623	1. -78	1. 472	1. -111	1. 686	1. -131
	2. 618	2. -98	2. 494	2. -90	2. 713	2. -117
	3. 497	3. -52	3. 634	3. 24	3. 443	3. -50
	X 579	X -76	X 533	X -59	X 614	X -99
/a/	1. 598	1. -129	1. 625	1. -47	1. 486	1. 18
	2. 820	2. -103	2. 678	2. -43	2. 620	2. 21
	3. 596	3. -54	3. 708	3. -78	3. 594	3. 19
	X 671	X -95	X 670	X -56	X 567	X 19
/u/	1. 470	1. -103	1. 549	1. -55	1. 496	1. 21
	2. 483	2. -108	2. 436	2. 12	2. 622	2. -116
	3. 450	3. -47	3. 642	3. -94	3. 513	3. 23
	X 468	X -86	X 542	X -46	X 544	X -24

Total	X 573	X -86	X 582	X -54	X 575	X -35
		SD 29		SD 47		SD 69

Table 25: Control Participant #CF01

	/p/		/t/		/k/	
	Duration	VOT	Duration	VOT	Duration	VOT
/i/	1. 522	1. 81	1. 534	1. 77	1. 668	1. 186
	2. 533	2. 96	2. 516	2. 93	2. 586	2. 122
	3. 549	3. 98	3. 863	3. 101	3. 613	3. 149
	X 535	X 92	X 638	X 90	X 622	X 152
/a/	1. 720	1. 61	1. 476	1. 82	1. 444	1. 107
	2. 678	2. 122	2. 553	2. 85	2. 613	2. 133
	3. 560	3. 70	3. 505	3. 103	3. 551	3. 96
	X 653	X 84	X 511	X 90	X 536	X 112
/u/	1. 579	1. 89	1. 596	1. 101	1. 808	1. 149
	2. 594	2. 71	2. 550	2. 55	2. 994	2. 133
	3. 543	3. 85	3. 480	3. 80	3. 653	3. 147
	X 572	X 82	X 542	X 79	X 818	X 143
Total	X 587	X 86	X 564	X 86	X 659	X 136
		SD 18		SD 15		SD 26

	/b/		/d/		/g/	
	Duration	VOT	Duration	VOT	Duration	VOT
/i/	1. 473	1. 12	1. 482	1. 16	1. 659	1. -134
	2. 545	2. 13	2. 608	2. -117	2. 1078	2. -165
	3. 517	3. 20	3. 638	3. -179	3. 542	3. -106
	X 512	X 15	X 576	X -93	X 760	X -135
/a/	1. 815	1. -106	1. 1017	1. -124	1. 794	1. -200
	2. 559	2. -119	2. 562	2. -84	2. 666	2. -121
	3. 620	3. -112	3. 781	3. -140	3. 667	3. -90
	X 665	X -112	X 787	X -116	X 709	X -137
/u/	1. 832	1. -115	1. 674	1. -133	1. 549	1. -120

	2. 678	2. -144	2. 344	2. -49	2. 765	2. 44
	3. 568	3. -90	3. 601	3. -142	3. 566	3. -113
	X 693	X -116	X 540	X -108	X 627	X -63
Total	X 623	X -71	X 634	X -106	X 699	X -112
		SD 66		SD 59		SD 67

Table 26: Control Participant #CF02

	/p/		**/t/**		**/k/**	
	Duration	VOT	Duration	VOT	Duration	VOT
/i/	1. 597	1. 78	1. 546	1. 63	1. 650	1. 97
	2. 551	2. 50	2. 671	2. 79	2. 546	2. 89
	3. 624	3. 47	3. 824	3. 85	3. 629	3. 111
	X 591	X 58	X 680	X 76	X 608	X 99
/a/	1. 596	1. 74	1. 569	1. 89	1. 638	1. 117
	2. 820	2. 56	2. 601	2. 84	2. 577	2. 92
	3. 270	3. 45	3. 574	3. 80	3. 638	3. 95
	X 562	X 58	X 581	X 84	X 618	X 101
/u/	1. 586	1. 100	1. 535	1. 80	1. 679	1. 98
	2. 530	2. 65	2. 533	2. 69	2. 572	2. 89
	3. 582	3. 109	3. 518	3. 73	3. 575	3. 81
	X 566	X 91	X 529	X 74	X 609	X 89
Total	X 573	X 69	X 597	X 78	X 612	X 96
		SD 23		SD 8		SD 11

	/b/		**/d/**		**/g/**	
	Duration	VOT	Duration	VOT	Duration	VOT
/i/	1. 723	1. -142	1. 586	1. -79	1. 767	1. -106
	2. 617	2. -116	2. 619	2. -109	2. 713	2. -68
	3. 763	3. -152	3. 628	3. -96	3. 658	3. -83
	X 701	X -137	X 611	X -95	X 713	X -86
/a/	1. 639	1. -124	1. 691	1. -85	1. 701	1. -134
	2. 629	2. -113	2. 754	2. -129	2. 634	2. -98
	3. 639	3. -127	3. 679	3. -79	3. 675	3. -65

	X 636	X -121	X 708	X -98	X 670	X -99
/u/	1. 578	1. -108	1. 679	1. -97	1. 681	1. -100
	2. 612	2. -118	2. 585	2. 32	2. 654	2. -87
	3. 638	3. -136	3. 677	3. -100	3. 681	3. -108
	X 609	X -121	X 647	X -55	X 672	X -98
Total	X 649	X -126	X 655	X -83	X 685	X -94
		SD 15		SD 46		SD 21

Table 27: Control Participant #CF03

	/p/		**/t/**		**/k/**	
	Duration	VOT	Duration	VOT	Duration	VOT
/i/	1. 438	1. 33	1. 438	1. 60	1. 472	1. 74
	2. 368	2. 41	2. 526	2. 87	2. 447	2. 56
	3. 483	3. 62	3. 446	3. 52	3. 486	3. 81
	X 430	X 45	X 470	X 66	X 468	X 70
/a/	1. 610	1. 84	1. 472	1. 45	1. 483	1. 104
	2. 658	2. 66	2. 565	2. 47	2. 507	2. 41
	3. 631	3. 73	3. 490	3. 43	3. 438	3. 64
	X 633	X 74	X 509	X 45	X 476	X 70
/u/	1. 378	1. 55	1. 455	1. 53	1. 652	1. 56
	2. 447	2. 45	2. 473	2. 55	2. 400	2. 63
	3. 547	3. 33	3. 433	3. 56	3. 412	3. 53
	X 457	X 44	X 454	X 55	X 488	X 57
Total	X 507	X 54	X 478	X 55	X 477	X 66
		SD 18		SD 13		SD 19

	/b/		**/d/**		**/g/**	
	Duration	VOT	Duration	VOT	Duration	VOT
/i/	1. 483	1. 24	1. 368	1. 26	1. 509	1. 32
	2. 605	2. -101	2. 405	2. 29	2. 533	2. 32
	3. 618	3. -153	3. 508	3. 18	3. 419	3. 28
	X 569	X -77	X 428	X 24	X 487	X 31

/a/	1. 489	1. -97	1. 567	1. 19	1. 516	1. 25
	2. 474	2. 20	2. 498	2. 25	2. 537	2. 26
	3. 490	3. 10	3. 470	3. 21	3. 477	3. 43
	X 484	X -22	X 512	X 22	X 510	X 31
/u/	1. 410	1. 23	1. 455	1. 41	1. 539	1. -137
	2. 473	2. 19	2. 495	2. 32	2. 575	2. -154
	3. 445	3. 24	3. 425	3. 16	3. 388	3. 25
	X 443	X 22	X 458	X 30	X 501	X -89
Total	X 499	X -26	X 466	X 25	X 499	X -9
		SD 70		SD 8		SD 78

Table 28: Control Participant #CF04

	/p/		**/t/**		**/k/**	
	Duration	VOT	Duration	VOT	Duration	VOT
/i/	1. 631	1. 101	1. 585	1. 87	1. 584	1. 84
	2. 478	2. 71	2. 486	2. 88	2. 562	2. 134
	3. 513	3. 104	3. 671	3. 69	3. 572	3. 91
	X 541	X 92	X 581	X 81	X 573	X 103
/a/	1. 457	1. 73	1. 411	1. 49	1. 549	1. 123
	2. 587	2. 99	2. 478	2. 96	2. 477	2. 118
	3. 527	3. 80	3. 479	3. 88	3. 577	3. 82
	X 524	X 84	X 456	X 77	X 534	X 108
/u/	1. 784	1. 134	1. 694	1. 77	1. 598	1. 33
	2. 497	2. 52	2. 605	2. 91	2. 547	2. 100
	3. 490	3. 86	3. 595	3. 70	3. 602	3. 85
	X 590	X 87	X 631	X 79	X 582	X 73
Total	X 552	X 88	X 556	X 79	X 563	X 95
		SD 26		SD 15		SD 30

	/b/		**/d/**		**/g/**	
	Duration	VOT	Duration	VOT	Duration	VOT
/i/	1. 471	1. 29	1. 650	1. 31	1. 485	1. 23
	2. 482	2. 34	2. 607	2. 32	2. 795	2. 31

	3. 475	3. 32	3. 566	3. 24	3. 504	3. 27
	X 476	X 32	X 608	X 29	X 595	X 27
/a/	1. 581	1. -62	1. 564	1. 24	1. 436	1. 19
	2. 794	2. 37	2. 427	2. 19	2. 530	2. 23
	3. 514	3. 31	3. 526	3. 26	3. 594	3. 24
	X 630	X 2	X 506	X 23	X 520	X 22
/u/	1. 840	1. 22	1. 784	1. -244	1. 546	1. 25
	2. 572	2. 15	2. 818	2. 35	2. 524	2. 17
	3. 516	3. 12	3. 591	3. 22	3. 527	3. 33
	X 643	X 16	X 733	X -62	X 532	X 25
Total	X 583	X 17	X 616	X -3	X 549	X 25
		SD 31		SD 90		SD 5

Table 29: Control Participant #CF05

	/p/		**/t/**		**/k/**	
	Duration	VOT	Duration	VOT	Duration	VOT
/i/	1. 496	1. 57	1. 508	1. 70	1. 511	1. 81
	2. 589	2. 90	2. 476	2. 100	2. 579	2. 98
	3. 425	3. 71	3. 708	3. 52	3. 493	3. 77
	X 503	X 73	X 564	X 74	X 528	X 85
/a/	1. 617	1. 90	1. 408	1. 62	1. 555	1. 88
	2. 816	2. 91	2. 470	2. 69	2. 667	2. 81
	3. 425	3. 43	3. 618	3. 57	3. 474	3. 70
	X 619	X 75	X 499	X 63	X 565	X 80
/u/	1. 910	1. 137	1. 456	1. 72	1. 631	1. 42
	2. 627	2. 62	2. 596	2. 80	2. 427	2. 68
	3. 546	3. 57	3. 389	3. 51	3. 452	3. 79
	X 694	X 85	X 480	X 68	X 503	X 63
Total	X 605	X 78	X 514	X 68	X 532	X 76
		SD 28		SD 15		SD 16

	/b/		**/d/**		**/g/**	

	Duration	VOT	Duration	VOT	Duration	VOT
/i/	1. 856	1. -79	1. 805	1. 24	1. 566	1. 36
	2. 680	2. -52	2. 632	2. -88	2. 926	2. -150
	3. 570	3. -114	3. 480	3. -35	3. 648	3. -59
	X 702	X -82	X 639	X -33	X 713	X -58
/a/	1. 583	1. 33	1. 598	1. 23	1. 693	1. -173
	2. 530	2. 15	2. 490	2. 12	2. 705	2. -138
	3. 531	3. -117	3. 438	3. 17	3. 600	3. -48
	X 548	X -23	X 509	X 17	X 666	X -120
/u/	1. 807	1. -123	1. 588	1. -79	1. 438	1. 25
	2. 750	2. -87	2. 1106	2. -109	2. 712	2. -76
	3. 521	3. -92	3. 705	3. -179	3. 511	3. 39
	X 693	X -101	X 800	X -122	X 554	X -4
Total	X 647	X -69	X 649	X -46	X 644	X -61
		SD 57		SD 72		SD 82

LIST OF REFERENCES

Baken, R. (1987). *Clinical Measurement of Speech and Voice*. Boston, MA: College-Hill Press.

Bayles, K. A. (2001). Understanding the Neuropsychological Syndrome of Dementia. *Seminars in Speech and Language, 22*, 251-259.

Bayles, K. A., Boone, D. R., Tomoeda, C. K., Slauson, T. J., & Kaszniak, A. W. (1989). Differentiating Alzheimer's patients from the normal elderly and stroke patients with aphasia. *Journal of Speech and Hearing Disorders, 54,* 74-87.

Bayles, K. A. & Tomoeda, C. K. (1994). *Functional Linguistic Communication Inventory*.

Biassou, N., D'Esposito, M., Grossman, M., Hughes, E., Mickanin, J., Onishi, K., Robinson, K.M. (1995) Phonological processing deficits in Alzheimer's disease. *Neurology*, *45*, 2165-2169.

Blumstein, S., Cooper, W., Goodglass, H., Statlender, S., & Gottlieb, J. (1980). Production deficits in aphasia: A voice-onset time analysis. *Brain and Language, 9,* 153-170.

Croot, K., Hodges, J., Xuereb, J., Patterson, K. (2000). Phonological and Articulatory Impairment in Alzheimer's Disease: A Case Series. *Brain and Language*, *75*, 277-309.

Cummings, J., Benson, F., Hill, M. & Read, S. (1985). Aphasia in dementia of the Alzheimer type. *Neurology*, *35*, 394-397.

Davis, G.A. (1993) *A survey of adult aphasia and related language disorders* (2nd ed.) San Diego: Singular Publishing Group.

Davis, G.A., (2000). *Aphasiology: Disorders and Clinical Practice.* Needham Heights, MA: Allyn &Bacon.

Folstein M.F., Folstein S.E., McHugh (1975). "Mini-mental State." A practical method for grading the cognitive statues of patients for the clinician. *Journal of Psychiatric Research 12*, 189–198.

Johnson, D. J. (1997) Mental status and aging: Cognition and affect. In B. B. Shadden & M. A. Toner (Eds.), *Aging and communication*. Austin, TX: Pro-Ed.

Kent, R.D. (1997). *The Speech Sciences*. San Diego, CA: Singular Publishing Group, Inc.

Lisker, L. & Abramson, A. (1964). A cross-language study of voicing in initial stops: Acoustical measurements. *Word, 20*, 384-422.

MacNeilage, P.F. & Davis, B.L. (2005). Evolution of a language. *Handbook of Evolutionary Psychology*. (698-723) New York: Wiley.

Mertus, J., (1999) Brown Laboratory Interactive Speech System http://www.cog.brown.edu.~mertus/download.html.

Payne, J.C. (1997). *Adult neurogenic language disorders: Assessment and treatment*. San Diego, CA: Singular Publishing Group.

Reisberg, B., Ferris, S.H., & Crook, T. (1982). Alzheimer's disease: A report or progress. *Aging*, *19*, 177-181.

Romero, B. & Kurz, A. (1996). Deterioration of Spontaneous Speech in AD Patients during a 1-Year Follow-Up: Homogeneity of Profiles and Factors Associated with Progression. *Dementia*, *7*, 35-40.

Ryalls, J., (1996). *A Basic Introduction to Speech Perception*. San Diego, CA: Singular Publishing Group, Inc.

Ryalls, J., Simon, M. & Thomason, J. (2002). Voice Onset Time production in older Caucasian- and African Americans. *Journal of Multilingual Communication Disorders*, *2* (*1*) 61-67.

Ryalls, J., Zipprer, A., & Baldauff, P. (1997). A preliminary investigation of the effects of gender and race on Voice Onset Time. *Journal of Speech, Language, and Hearing Research, 40*, 642-645.

SPSS for Windows, Rel. 10.0.0. 2005. Chicago: SPSS Inc.