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Speech inhibition with utterance length and complexity

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SPEECH INHIBITION WITH UTTERANCE

LENGTH AND COMPLEXITY

A Thesis Submitted

in Partial Fulfillment

of the Requirements for the Designation

University Honors

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Chapter I
Introduction

For many individuals, speech is a nearly automatic behavior which requires little in the way of thinking about each step in the process. In addition, speech is variable and flexible both across and within situations (Netsell, 1982). Despite the fact that this is true for many individuals, speech is an extremely complex motor behavior that requires many different systems and structures to be functioning with one another. These three major systems that must work efficiently and effortlessly include the articulatory/resonatory, phonatory, and respiratory systems. This interaction relies on the theory of motor equivalence; where the capacity of the motor control system to accomplish the same goal or end product with considerable variation among the individual components that contribute to that output (Hebb, 1949; in Barlow, 1999).

To begin to describe speech, one must understand motor planning and this motor equivalence theory. A motor plan is simply what tells an individual's body what to do and how to do it. These plans are endless and necessary for all possible voluntary movements, which includes speech. Numerous theories have attempted to explain the complexity of the number of components within motor programs for speech and how these programs function in an individual. There have been many studies done examining these theories and more specifically, the refractory period of a motor program. This term is used to describe the amount of time an individual has to inhibit a motor movement. It is important to examine this period because it can give researchers insight into motor speech disorders, specifically apraxia of speech.

Although there have been studies done looking at the refractory period of a motor program in speech, these studies come with some controversy. In some of the studies done, researchers had the subjects hold his or her breath prior to a speech task. This action is very

artificial and it is effective to ask whether or not the results from these studies are valid. These studies have also been limited to solely manipulating utterance length and not the complexity of the speech task. Due to these limitations and validity questions regarding speech inhibition, this study was designed to determine the influence of inclusion of the respiratory system and increasing utterance complexity on speech inhibition.

Chapter II

Review of Literature

The articulatory system is comprised of anatomic structures within the vocal tract (larynx, oral and nasal cavities, pharynx) that move in order to produce speech sounds. Major articulators include (from anterior to posterior): lips, teeth, alveolar ridge, hard palate, tongue, mandible, velum, pharyngeal constrictors, and vocal folds. The phonatory system includes the larynx and is crucial to speech production because it is responsible for producing voice. The extrinsic and intrinsic muscles of the larynx work with the vocal folds to produce vibration and sound, which is then articulated in the pharynx, nasal cavity, and oral cavity. Lastly, the respiratory system plays an essential role in speech production because it is made up of the structures (e.g., lungs, trachea, bronchi, diaphragm and abdominal muscles) that help an individual breathe, and produce the airflows and pressures responsible for speech production. These three systems must work together flawlessly in order to produce speech by coupling these structures to shape the vocal tract and each of these systems are closely linked to input information available to them (Barlow, 1999).

The systems mentioned above are interconnected by higher-level neural systems. This highly complex system must also be operating efficiently for an individual to produce speech. For voluntary movement, a motor plan (a number of commands) for speech originates in the

outermost and most complex layer of the brain, known as the cerebral cortex, specifically in the areas of the inferior precentral gyrus and the supplementary motor area (Behrman, 2007). Highly complex and variable voluntary motor movements such as speech require global input from areas across the cortex as well as subcortical structures. Eventually, nerve tracts comprised of many individual neurons descend pathways that carry the information to the appropriate cranial nerve or spinal nerve within the brainstem or spinal cord and eventually out to the muscles for coordinated movement. Each component of the pathway must be functioning faultlessly in order for the motor plan to be carried out as it is intended.

Motor planning. A motor plan, depending upon the theory, is comprised of a number of commands originating within the central nervous system, specifically and most importantly within the cerebral cortex. These plans are endless and are necessary for all of the possible voluntary movements available to the human body. More generally, it is a prestructured set of central commands capable of carrying out a movement (Behrman, 2007). Numerous theories have attempted to explain the complexity of the number of components within motor programs for speech and how these programs function in an individual. For an individual to simply produce a single word, each one of the components and structures mentioned above must be functioning flawlessly and be capable of making adjustments within milliseconds. If there is an insult to any one of these areas, a motor speech disorder may result.

Motor programming and gross movements-nonspeech. Slater-Hammel (1959) examined the refractory period of a motor program by using a finger lift gesture to stop a sweep hand. This gesture was used in order to estimate the length of a motor program. The study determined the refractory period, which is the amount of time an individual has to inhibit an action (a motor program) before the action is initiated. Slater-Hammel (1959) concluded that the

refractory period is approximately equal to the length of the motor program for the action. A

motor program is based on acquiring neural representations of the targeted movement (Matter &

Gribble, 2005). According to Matter and Gribble (2005) the most crucial feature of the motor

system is based on this acquisition of neural representation, which can be interpreted as the

development of the motor program.

Information processing. Motor programs can only be understood if the processing

stages are understood as well. There are three stages that when combined form the reaction time

of a certain task (Schmidt & Wrisberg, 2008). The first stage consists of identifying a stimulus

from the environment using sensory information. The second stage is response-selection where

an individual decides how to respond to the stimulus he or she identified in stage one. The third

and final stage of information processing is response-programming. During this stage, the

individual prepares the necessary muscles needed for the action that will complete the intended

task.

Previous studies have investigated the refractory period of a motor program. The

refractory period, which is the amount of time an individual has to inhibit an action (a motor

program) before the action is initiated. For example, if an individual is playing defense in the

game of volleyball, during a rally he or she is mentally prepared to pass the ball after the

opposing team has taken a strong swing at the ball. He or she is down low, with a strong base

planted in order to pass the ball. However, if the opposing team decides to tip the ball over the

next instead, the ball is going to come at the defense a lot slower and not travel as far. The

defensive player has to inhibit his or her defensive stance after a mental program has already

been planned, in order to switch positions and prepare to defend the tip. The amount of time the

individual had to inhibit the first action before it was initiated is known as the refractory period.

Open loop control and closed loop control are the two systems that control information processing. The open loop control system is responsible for controlling fast and discrete types of movements. In this system though, once the action has been initiated and is in progress, the individual cannot make any sort of modification to the action (Schmidt & Wrisberg, 2008). This control system does not use any feedback from the environment, but does rely upon online feedback available just prior to initiating the action (Barlow, 1999). Schmidt and Wrisberg (2008) compared this to traffic lights that regulate the flow of traffic. The light continuously changes between green, yellow and red. If there is a motor vehicle accident, the light continues to change through the three colors. So despite the fact something has changed in the environment, the system continues to operate as nothing happened. Therefore, open loop control is best for situations that are predictable and do not require much attention from the individual (Schmidt & Wrisberg, 2008). Open-loop control allows for speed, but does require an internal calibration and exchanges accuracy based on feedback with speed and stability (Barlow, 1999).

On the other hand, the closed loop control system controls movements that are slower and is dependent upon feedback (Barlow, 1999). In this system, feedback is given from the sensory information in the environment, and the action can be adjusted. The comparator mechanism uses the sensory information to compare the feedback of the desired state to the feedback of the actual state, which allows for adjustments to be made to the action. This system can modify two or three movements per second (Schmidt & Wrisberg, 2008). The closed loop system requires a lot more attention from the individual than the open loop system because it requires not only feedback, but error detection and error correction as well (Schmidt & Wrisberg, 2008). A favorable example of a closed loop system is driving a vehicle. While driving a vehicle, an individual must obtain feedback from sensory information, such as the vision of the car and

the road. This information is used to make necessary adjustments to the system. Speech is a very complex and rapid task. In fact, the average individual utters four words per second and the closed loop system clearly cannot keep up with this speed. Therefore, spoken language uses an open loop system that allows speech to meet the demand for rapid communication and would argue for a predictable and adaptable programming.

Schema motor theory. A simple motor program theory exists that states each variation of the same general action needs its own unique program (Schmidt & Wrisberg, 2008); however, this is likely not feasible. Following this theory, an individual would have to store an endless amount of programs in his or her long-term memory, each one unique, in order to function. Also, this theory does not explain why an individual can complete a novel movement. The limitations of the simple motor program theory led Schmidt (1975) to propose the Schema Motor Theory, which is based on the idea of a generalized motor program (GMP). Instead of an individual storing a unique, simple motor program for every single action, the GMP allows for generalization of motor programs. Movements that share similar characteristics are grouped together, instead of each action having its own motor program. The Schema Theory allows for an endless amount of variations to every action because as the order of movements and timing stays consistent, the surface features change (Schmidt & Wrisberg, 2008). In the end, however, Barlow (1999) stated that there is no general motor program or schema that can describe the large number of networks needed for speech.

Motor learning. For an individual to build the relationship between the sensory information he or she is receiving, the learning conditions and the particular outcomes, schemas are required (Schmidt, 1975). When an individual wants to produce a particular action he or she must use the sensory information from the environment. Motor learning happens when an

individual compares the actual sensory consequences with the expected sensory consequences, and errors are determined (Maas, Robin, Austerman Hula et al., 2008). For an individual to identify whether or not there is an error, he or she must know what the correct outcome is supposed to be. The only way to know the correct outcome is through feedback; external and internal. This learning process is crucial for motor learning and when the type, frequency, and timing of the feedback are varied, motor learning will be most successful (Maas, Robin, Austerman Hula et al., 2008).

Motor program evidence. In 1960, Franklin Henry and Donald Rodgers used reaction time to measure the length of the motor program (Schmidt & Wrisberg, 2008). Participants in the study were instructed to respond to a stimulus, as fast as possible, by doing one of three things: a finger lift, a finger lift and one rapid hand movement, or a finger lift with multiple, rapid hand movements. In this study, the reaction time of each of these three movements were measured. Henry and Rodgers found that as the movement increased in difficulty, the reaction time also increased.

The concept of GMP has been supported by studies done in the areas of kinesiology and physiology by looking at tasks such as typing, serial key pressing, rotating levers, and handwriting (Shapiro, Zernicke, Gregor & Diestel, 1981). Shapiro, Zernicke, Gregor, and Diestel (1981) studied GMPs by examining walking and running. They altered factors such as speed, force, and muscle selection, but the time given to complete the task stayed constant; which supported the idea of a GMP.

Slater-Hammel (1959) looked at a non-speech task and required participants to view a clock that traveled 360 degrees in one second. These individuals had to stop the sweep hand when it reached exactly 800 milliseconds by removing their finger from the key they were

holding down. Catch trials (i.e. the sweep hand would stop moving before the target of 800 milliseconds) were then randomly introduced throughout the trial to the subjects. The subjects were asked not to remove their finger from the key if a catch trial occurred. During the catch trials, the subjects in the study had to estimate both internal and external conditions. The internal condition being their own ability to stop the hand accurately and the external condition being if the sweep hand stopped before the target. Slater and Hammel (1959) found there was a delay in the responses of the individuals during catch trials due to the anticipation of a possible catch, compared to when there were not any catch trials in the experiment. This supported the notion of anticipation being a factor that influences reaction time. The experiment revealed a transit reaction time which allowed Slater-Hammel (1959) to find the point at which the subjects were unable to inhibit the gesture.

Evidence in speech. Researchers have applied the findings from Slater-Hammel (1959) to speech. Carr (2004) examined syllable length using the word "ladybug" and compared it to its overall duration of the word during three different speeds (i.e., slow, normal, and fast). Carr found that the syllable lengths for the rates of normal and fast were the same, which suggested both rates used the same GMP. On the other hand, the slow rate of the utterance was controlled as it was produced. Therefore, the slow rate was using a closed-loop model.

Backlin, Corbett, Gaughan, Howard, Williamson, and Hageman (2008) replicated the Slater-Hammel experiment with speech as the stopping gestures. The stop targets were "uh," "annul," and "annulment." The first task of the experiment was to stop the sweep hand at 800 milliseconds with the stop target of, "uh." This task was also repeated with "annul" and "annulment." The subjects in the study were then asked to complete a second task in which they were asked to inhibit the production of the speech target when there was a catch trial. So, at

random times, the sweep hand stopped prior to the target of 800 milliseconds. When this occurred, subjects were supposed to inhibit their response. The subjects did this with all three speech targets. Through this study, the authors found that as the length of the utterance increased, the more difficult inhibition became. They stated that longer utterances require a longer motor program.

Howard (2010) used the stop targets of "out," "outdoors," and "outdoorsmen." It is important to note that Howard controlled the variable of respiration by having the subject hold his or her breath prior to the start of each trial. This study compared subjects who had aphasia (i.e., an acquired language disorder) and those who did not. The results of this study revealed individuals with aphasia have a greater difficulty inhibiting the motor speech plan.

Mueting (2011) reported that children have sufficient motor programs and are able to inhibit the motor program just as well as adults. It is important to note that Mueting (2011) also had the subjects hold his or her breath at the beginning of each trial.

These highlighted studies had the subjects hold his or her breath prior to the speech task; this manipulated the intended motor program. By manipulating the motor program and asking the individual to hold his or her breath instead of posturing naturally, a cognitive load has been put on the system, changing the motor program. This is likely to have an effect on the refractory period of the motor program.

Respiration. The respiratory system is a crucial component in speech production. Respiratory drive is responsible for the ability to produce voicing at the larynx for subsequent articulation. Many variables influence the system and include, but are not limited to, physiological demand, linguistic demand and health status of the speaker. Involuntary breathing occurs during typical activities because voluntary, cognitive, control of each inspiration and

expiration would be too taxing for the body. However, speakers must override the involuntary system to produce speech or make other changes in response to their environment. Examples of overriding the system include exercise and speech. Speaking requires inspirations taken at specific locations, the majority of which are linguistically driven versus physiologically driven. Specifically, speakers will inspire to a lung volume that matches or correlates to the length of the utterance (and subsequent expiration) that follows (i.e. the duration of a spoken utterance is associated with the depth of the preceding inspiration).

Linguistic units of meaning (e.g., at word or sentence level) can modify respiratory behavior by influencing aspects of upcoming breaths (Goldman-Eisler, 1961).   This is particularly true in spontaneous speech, where the speaker likely preplans their utterance and inspires to a depth that will allow them to accomplish the utterance in a single expiration. In contrast, reading requires speakers to inspire to a less variable (and deeper) depth that ensures they can complete the upcoming utterance; however, reading allows the speakers to rely on sentence boundaries, clause boundaries, and grammatically-appropriate inspiratory locations. In other words, they cannot predict how long the upcoming utterance might be. Imaging studies have reported that, approximately 200ms prior to speech production, the left primary motor strip on the neocortex (e.g., location for motor control of speech) becomes active, followed by the right side. This might be indicative of the neural system's consideration of utterance demands.

These respiratory behaviors start early in development. Parham, Buder, Oller, Boliek (2011) reported that two year-olds produce speech-like respiratory behaviors, indicating the coupling of the respiratory system and planning. They demonstrated longer expiratory times during canonical and unarticulated productions than during normal resting breathing. This also might indicate that they are likely to be able to manipulate the respiratory system as utterances

become longer and more complex

There have been many studies which have researched the chest wall dynamics and the abdominal muscles underlying phonation. These studies have indicated that there is a consistent and predictable pre-phonatory posturing of the chest wall for speech breathing. Baken, Cavallo and Weissman (1979) studied prephonatory chest wall movement and found that the chest wall has a preferred "set up" maneuver prior to phonation. The research revealed that during this posturing stage, the abdominal muscles contract before the chest wall muscles to prepare the diaphragm for inspiration (Baken, Cavallo, & Weissman 1979).

Motor speech disorders. Motor speech disorders encompass a variety of disorders that can be due to damage to neural control, motor planning, and muscle weakness or paralysis (e.g., dysarthria) due to a cerebrovascular accident (stroke), degenerative disease (e.g., dementia) or injury (e.g., traumatic brain injury). Specifically, there are numerous different apraxia that effect structures of the body with one specific to communication, apraxia of speech. Apraxia of speech is characterized as the difficulty with the sequencing motor programs necessary for speech production (Duffy, 1995). For example, an individual may know exactly what he or she wants to say, but simply cannot appropriately sequence the necessary movements due to an inability to correctly build a motor program. No muscle weakness is present in apraxia of speech; it is simply a problem of not being able to plan, coordinate and execute the needed structures to produce speech.

In contrast to apraxia of speech, the array of dysarthrias are motor speech disorders that are not due to the inability to build motor programs, but rather the inability to complete a task due to weakness or paralysis. The type and severity of the dysarthria is dependent upon the damaged areas involved. Each of the dysarthrias share some type of muscle paresis or paralysis

that results in difficulty moving and coordinating the muscles of the mouth, face and/or respiratory system due to weakness or paralysis.

Previous studies have investigated the refractory period of a motor program in speech, however the respiratory component has often been controlled by having the individual hold his or her breath before the speech task. To ask an individual to hold his or her breath before preparing to phonate is extremely artificial. It also leads to the assumption that a larger cognitive load is being placed on the individual because he or she not only has to think about the speech task, but has to think about holding his or her breath as well. Future studies need to examine the refractory period with speech breathing incorporated in order to obtain more sensible results.

Studies also need to explore the idea of refractory periods being affected by the complexity of the motor program. For example, considering the different structures of the articulatory system (lips, teeth, tongue, etc.), it may seem intuitive that producing a word that requires transitioning from structures in the front of the oral cavity to structures in the back of the oral cavity would be more difficult than a word that only requires structures from the front of the oral cavity. Though this seems to be logical, speech scientists have spent the better part of the last century trying to determine the relationships between articulatory movements and the intuitively appealing idea of speech production (Hixon, Weismer, & Hoit 2008). Though this relationship seems quite straight-forward, Hixon, Weismer and Hoit (2008) explain that it is much more complex than a series of positions and movements strung together like beads on a string.

Another large consideration speech scientists must take into account is speaker variability. As Behrman (2007) suggests, speaking tasks are designed quite narrowly, or so is thought. The word chosen for the study is selected because the researcher hopes it will reveal a

specific feature. This though, is an unknown factor that can influence results of the study. Behrman (2007) explains that even within a narrowly defined speech task, there is an issue of speaker variability because every individual used in a research study can vary considerably in his or her motor behavior when phonating the exact same word.

Given these points, examining a motor program and its refractory period is much more complex than intuitively thought. Despite this complexity, further research must be done in order to examine the refractory period of a motor program. It is crucial to determine the effects of normal speech breathing on the program and to examine whether or not the complexity of the program makes a difference in the study. For many individuals, producing speech is done effortlessly, or so he or she believes. In all actuality, many different, complex systems are working flawlessly in-sync to build, transport and execute a motor program in a normal developing individual.

Research questions. As stated above, previous studies have investigated the refractory period of a motor program in speech. However, the respiratory component has often been controlled by having the individual hold his or her breath before the speech task, which is extremely artificial.

The purpose of the present study is to remove this artificial constraint and investigate how inclusion of the respiratory system, by allowing for typical speech breathing, affects the refractory period of a speech motor program. In addition, how is inhibition influenced by the complexity of the motor program?

Chapter III

Methodology

The present study extended the previous research of Howard (2010) and Mueting (2011) by eliminating the artificial constraint of asking subjects to hold their breath. Five female subjects ranging in age from 21 to 30, who were free of any history of neurological disorders, respiratory disorders, and speech-language or hearing difficulties, were included in this study. Subjects in this study were in good health and decided voluntarily whether or not to participate in the study. All procedures were approved by the University of Northern Iowa Institutional Review Board for the Protection of Human Subjects (14-0095).

To present both the time sweep hand to the subject and to allow for manipulation of times for the trials, the Speech Therapy Timer #1 software was used (Hageman & Riess, 2008; see Figure 1). The computer program provided the visual stimulus to the subjects in the study and recorded the responses. The custom program is split visually across two computer monitors facing in opposite directions. The subject's monitor displayed a time display similar to clock; this was the same clock face used in Howard's (2010) study. On the time display, a sweep hand traverses 360° in 1000ms, whereas the investigator's monitor displayed the data log and time variables. This study used the set of words, "ee", emotion, and eagerly. The word eagerly was selected to determine whether inhibition is influenced by a more complex motor program. It was intuitively thought that by moving from a high front vowel to a velar consonant in the word eagerly, it would be more complex than emotion.

The subjects were trained to produce each utterance type and stop the sweep hand at 800 milliseconds (±30msec). The subjects completed 50 practice trials for each of the four speech tasks ("ee", emotion, emotional and eagerly) in order to learn the motor program and become

familiar with stopping the sweep hand. The experimental condition required speakers to stop the

sweep hand at 800ms; however, the sweep hand was programmed to stop at random times

between 550ms-750ms prior to the 800ms target, with the task being to inhibit the production of

the speech sound. During these catch trials, subjects were instructed to completely inhibit the

production of the target word if the sweep hand stopped before the 800ms target. The subjects

were not provided with feedback cues or instructions. Subsequently, each condition was subject-

specific.

Analysis. The dependent variables included: the inhibition or non-inhibition of the

speech sound, the temporal value of the catch trial, and the response of the individual; while the

independent variables included the target stop times (-550ms, 600ms, 650ms, 700s). Each of the
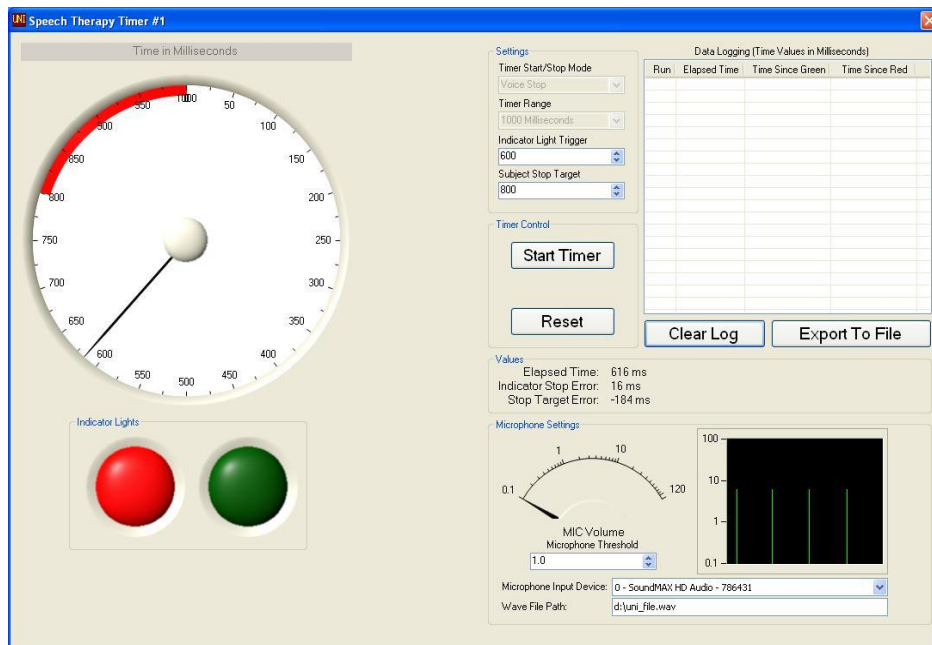
sessions lasted approximately 90 minutes.

Figure 1: Speech Therapy Timer #1 interface

Chapter IV

Results

  Each subject's responses were recorded as inhibited, was unable to inhibit, or postured during the experimental trials. The coding used was (+) for inhibition, P for posturing and PV for prevocalic voicing. The ability of speakers to inhibit decreased as the utterance length increased. Subjects in this study also performed similarly in that they struggled to inhibit as the target stop time got closer to 800ms, even though their respiratory system was not primed by holding her breath. Subjects were able to consistently inhibit when the sweep hand stopped at 550ms, but when the sweep hand stopped at 750ms, it was difficult to inhibit. At 750ms, subjects often produced the word or inhaled to prepare for phonation.

  Figure 2 demonstrates the findings that subjects were better able to inhibit on "ee" but were not as consistent on "emotion" or "eagerly." As a group, as the catch trials became closer to the 800ms target, it was more difficult to inhibit responses.   Data from the first five subjects suggest that it is more difficult to inhibit "eagerly" compared to "e," but not when compared to "emotion."
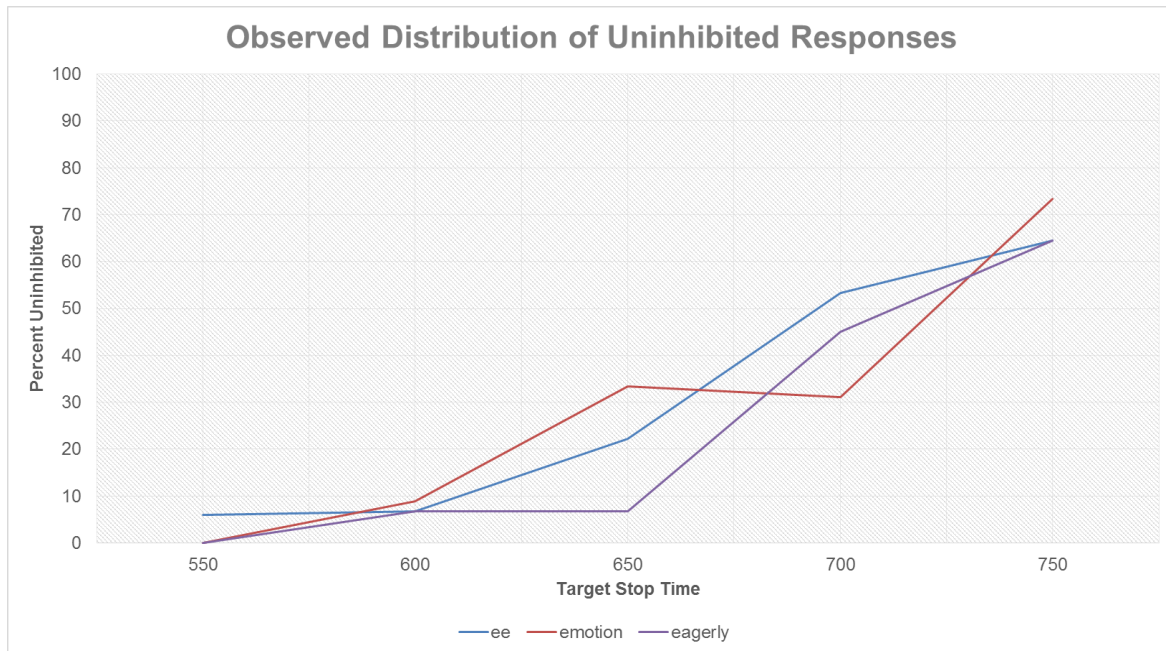
Figure 2: Distribution of responses in which the speakers were unable to inhibit by time

Subject 1 was able to consistently inhibit "ee" when the sweep hand stopped at, or prior to, 600ms. At 650ms, subject 1 was only able to inhibit about 50% of the time. As the sweep hand began to stop closer to 800ms (700ms, 750ms) subject 1 was very inconsistent, inhibiting the speech task less than 20% of the time; see Figure 3 for the distribution of responses.

As seen in Figure 4, when the speech task was changed to "emotion," subject 1 was able to inhibit more than 50% of the opportunities when the sweep hand stopped at or prior to 600ms. Past 600ms (650ms, 700ms, 750ms), subject 1 inhibited inconsistently, less than 50% of opportunities.

For the speech task of "eagerly," subject 1 inhibited more than 80% of opportunities when the sweep hand stopped at or prior to 600ms. Inhibition abilities dropped to 50% at 650ms and continued to lower at 700ms and 750ms. These results are shown in Figure 5.
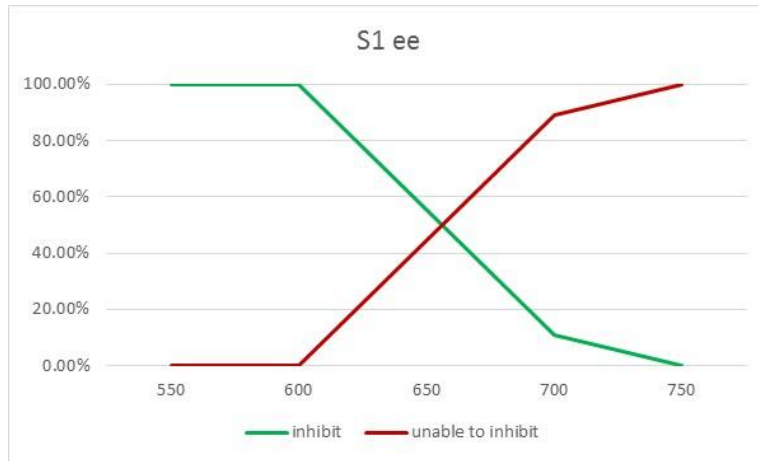
Figure 3: Distribution of responses for Subject 1 on the production of "ee"

Figure 4: Distribution of responses for Subject 1 on the production of "emotion"
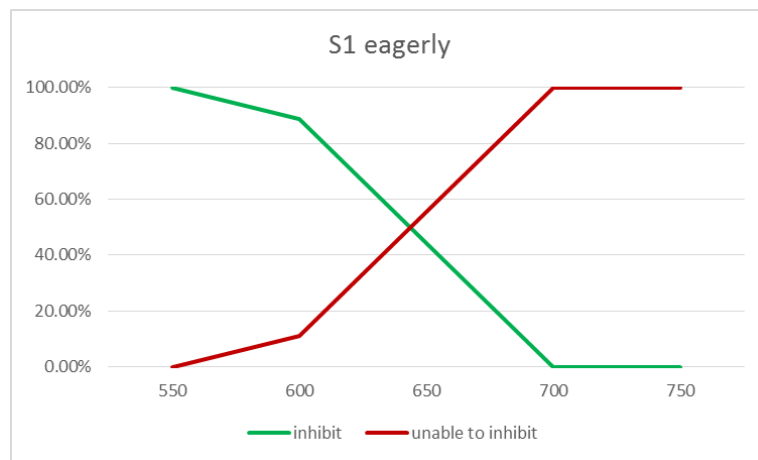

Figure 5: Distribution of responses for Subject 1 on the production of "eagerly"

Subject 3 was able to consistently inhibit "ee" with 100% accuracy when the sweep hand stopped at, or prior to, 650ms. Their ability to inhibit dropped to 70% consistency when the sweep hand stopped at 750ms and is shown in Figure 6.

Figure 7 shows that for the speech task of "emotion," subject 3 inhibited without error when the sweep hand stopped at or prior to 600ms. Accuracy dropped slightly through 700ms. The ability to inhibit were non-in-existent for subject 3 when the sweep hand stopped at 750ms.

Subject 3 was able to inhibit "eagerly" with complete accuracy while the sweep hand stopped at or prior to 650ms. Inhibition accuracy dropped slightly through 700ms and fell to about 30% at 750ms. See Figure 8 for these results.

Figure 6: Distribution of responses for Subject 3 on the production of "ee"

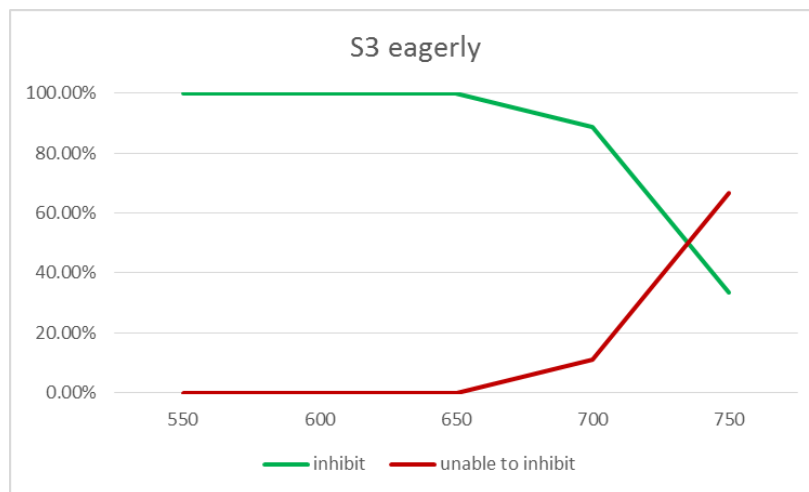*Figure 7*: Distribution of responses for Subject 3 on the production of "emotion"

Figure 8: Distribution of responses for Subject 3 on the production of "eagerly"

Figure 9 shows that subject 4 was not as accurate inhibiting "ee" as other subjects, but could still inhibit the sweep hand with at least 50% accuracy through 650ms. At 750ms, subject 4 could not inhibit "ee."

For the speech task of "emotion," subject 4 was able to inhibit and stop the sweep hand with more than 50% accuracy prior to 650ms. Subject 4's ability to inhibit dropped greatly after the 650ms stopping point; see Figure 10.

For the word "eagerly," subject 4 was able to inhibit with 100% accuracy when the sweep hand stopped at or prior to 600ms. Then at 650ms, the subject's inhibition ability significantly dropped to 30%. As the stop target approached 750ms, the inhibition ability decreased even more. These results can be seen in Figure 11.
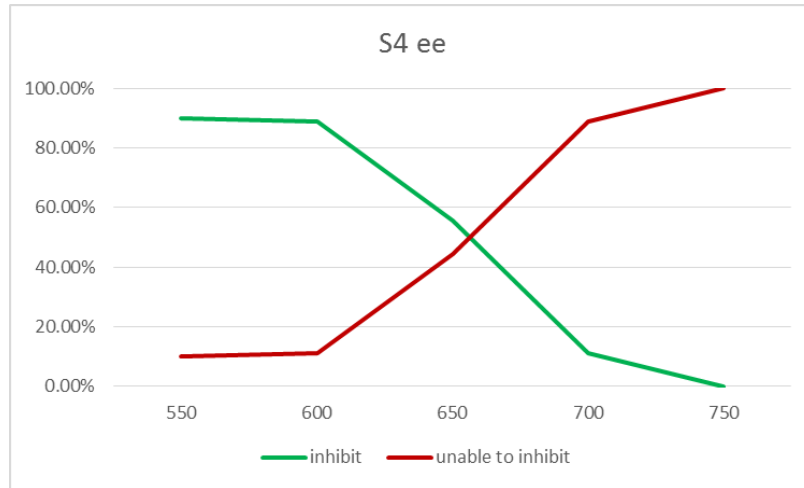

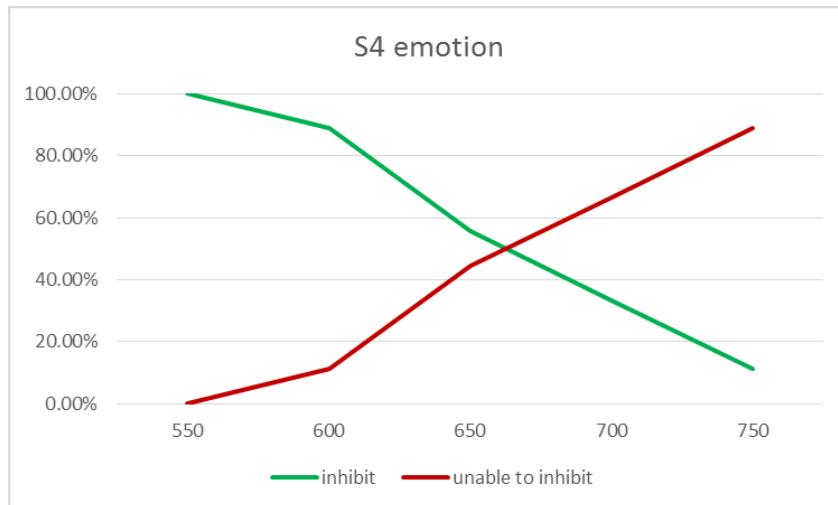*Figure 9:* Distribution of responses for Subject 4 on the production of "ee"

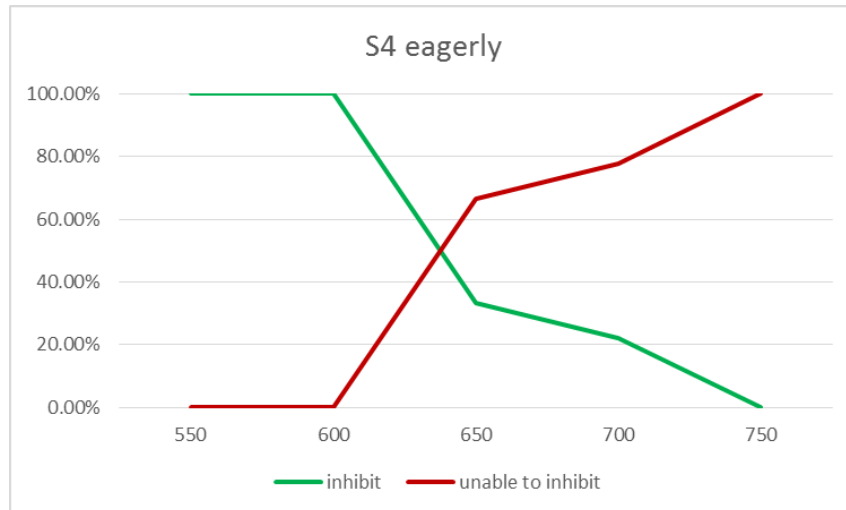*Figure 10*: Distribution of responses for Subject 4 on the production of "emotion"

Figure 11: Distribution of responses for Subject 4 on the production of "eagerly"

Subject 5 was able to inhibit "ee" with 80% accuracy consistently from 550ms to 650ms. Inhibition accuracy fell to about 40% when the stop target was 700ms and to 10% at 750ms; see Figure 12.

Figure 13 shows that subject 5 was able to inhibit with 100% accuracy through the stop target of 600ms on emotion. Her accuracy fell slightly after that, but still remained above 60% through the stop target of 700ms. At 750ms, she was still able to inhibit about 20% of the opportunities.

For the production of "eagerly," subject 5 was remarkably good at inhibition and this can be seen in Figure 14. She was able to inhibit with more than 80% accuracy through the stop target or 700ms. At 750ms, her accuracy did fall, but only to about 50%.
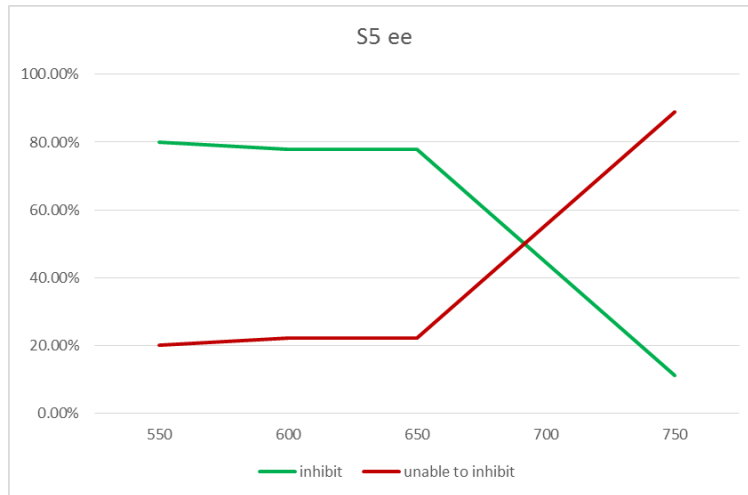
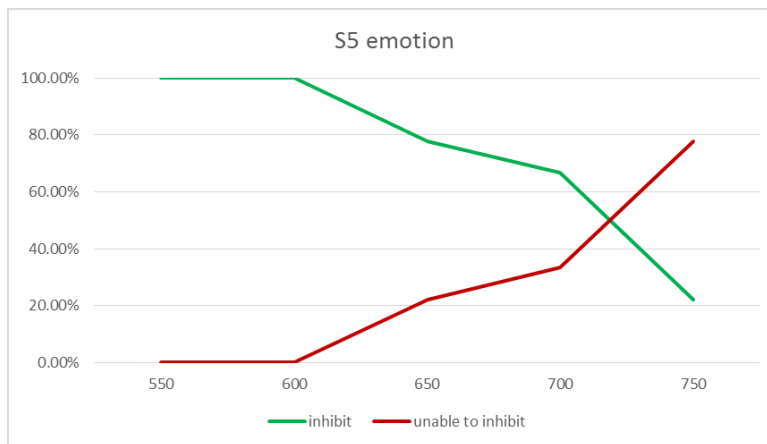*Figure 12*: Distribution of responses for Subject 5 on the production of "ee"

Figure 13: Distribution of responses for Subject 45 on the production of "emotion"

Figure 14: Distribution of responses for Subject 5 on the production of "eagerly"

Subject 2 in this study was considered to be a special case due to her ability to inhibit the motor program. As seen in Figure 15, her ability to inhibit "ee" was 100% accurate at every stop target but 700ms. Even then, she still had 90% accuracy.

For "emotion," she was able to inhibit with 100% accuracy through the 650ms stop target. Again, her accuracy only dropped down to 90% at the stop targets of 700ms and 750ms. See Figure 16.

Figure 17 displays the results for "eagerly." Again, her ability to inhibit the motor plan was remarkable. She was able to inhibit with 100% accuracy at every stop target except 650ms and 700ms. Subject 2 is considered an outlier within this data set because she was rarely unable to inhibit.

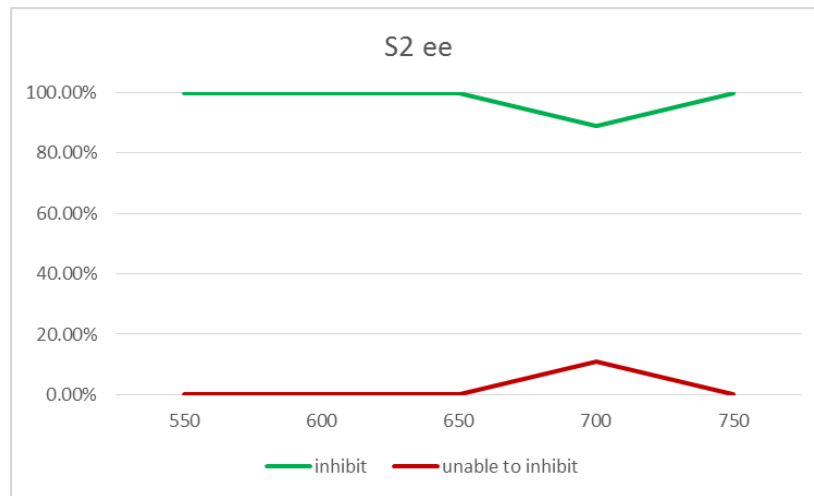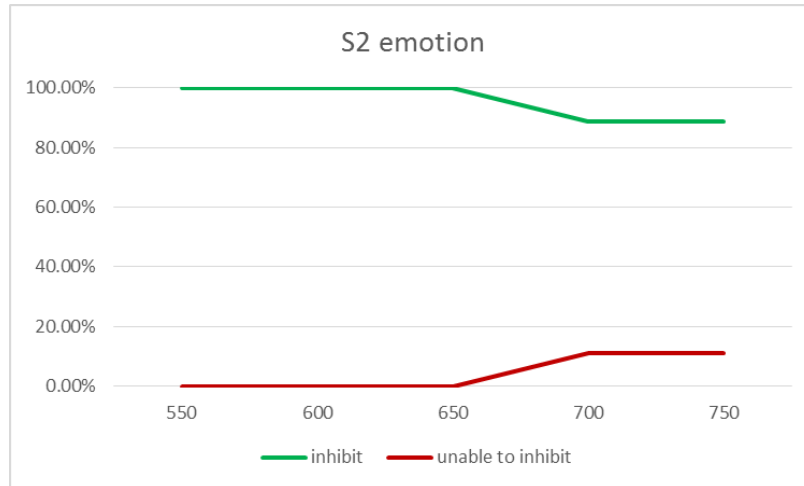*Figure 15*: Distribution of responses for Subject 2 on the production of "ee"

Figure 16: Distribution of responses for Subject 2 on the production of "emotion"
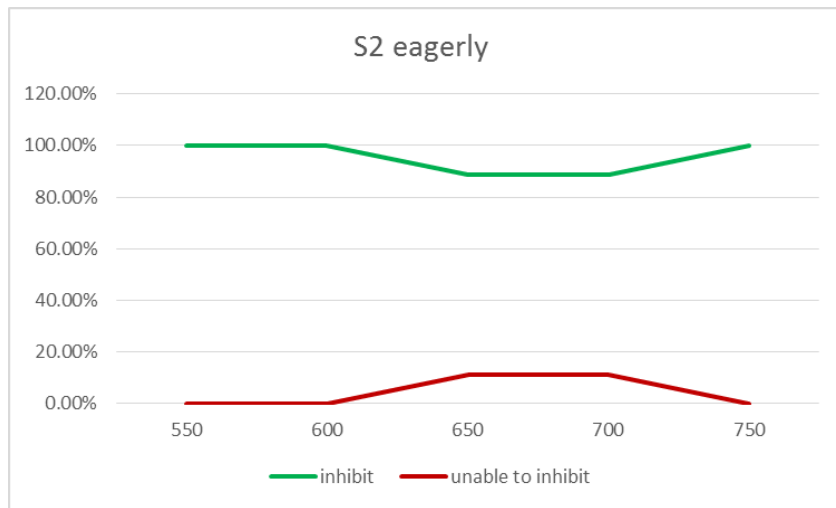

Figure 17: Distribution of responses for Subject 2 on the production of "eagerly"

Chapter V

Discussion

Unlike previous studies, the respiratory system was not primed during this study. By allowing for typical speech breathing prior to the speech task (i.e., not having the individuals hold his or her breath), there was less of a cognitive load on the subject and the motor program was not manipulated. Despite this change, the individuals in this study performed similarly to the previous studies. As the target stop time approached the 800ms marker, individuals struggled to inhibit. In addition, there was no differences the ability to inhibit due to increased utterance complexity.

The findings suggest that allowing for typical speech breathing does not seem to influence one's ability to inhibit and differently than when asked to hold his or her breath. Having the subject hold his or her breath is completely artificial to typical speech breathing. An alteration to the motor program by breath-holding may not be necessary, and perhaps should be avoided. Allowing for typical speech breathing allows the individual to posture naturally before phonation. It is important to recall that the third and final stage of information processing is response-programming, where the individual prepares the necessary muscles needed for the action that will complete the intended task.

The individuals were able to do this without any effect on the refractory period compared to previous studies. Therefore, it is completely arbitrary to have the participant hold his or her breath. More importantly though, this validates all of the results previously found. Even though the studies included this arbitrary task, the results are still valid and can be used as a reference for further research. However, future studies could include kinematic measures of the behaviors of the chest wall during the inhibition trials. This study was unable to determine if the

respiratory system was activated, but the utterance was inhibited at the level of the phonatory

system

        Participants in the study were able to inhibit "ee" consistently, while "emotion" and

"eagerly" were not as consistent. A longer word requires a more complex motor program and

thus inhibition is more difficult. Examining the word "eagerly," the speaker must move the

articulators from a high front vowel to a velar consonant; this is one of the largest amounts of

movement for articulators in the English language. Intuitively, the researchers in this study

predicted that because of the complexity of movement of the articulation, it would be harder to

inhibit. The data suggests, that from the first five subjects in the study, it was harder to inhibit

"eagerly" compared to "ee," but not compared to "emotion."

        Though it seemed logical to choose the word "eagerly," this study has contributed to

what Hixon, Weismer, and Hoit (2008) have explained as the question speech scientists have

spent the better part of the last century trying to determine. The relationships between

articulatory movements and the intuitively appealing idea of speech production may seem

straight forward but it is proven time and time again that this relationship is far more complex

than anyone has hypothesized. Although, the word choice of "eagerly" seemed intuitively

correct, the study revealed there was not any significant complexity associated with this speech

task.

        There were also large variations in inhibition abilities from subject to subject in this

study. For example, Subject 2 was extremely good at inhibiting her response and had very few

instances of production when the sweep had stopped before 800ms. Subject 2 was rarely unable

to inhibit and supports the notion of speaker variability; with her ability being much higher than

the speakers in previous studies. Behrman (2007) explained that even within a narrowly defined

speech task, there is an issue of speaker variability because every individual used in a research study can vary considerably in his or her motor behavior when phonating the exact same word. This speaker variability may also help explain why the assumed complexity of the word eagerly compared to emotional did not stand true. There is so much variability and overlap between productions in the same individual that it may be near impossible to compare subjects. Future studies should be done examining speaker variability and ability levels.

Examining the results and methodology of the study, it is fair to ask whether or not conditions of arousal and anxiety influenced the results. Schmidt and Wrisberg (2008) note that arousal and anxiety are common aspects of many performance situations. The level of arousal imposed by a situation is an important determinant of performance, especially on fast and accurate decision making (Schmidt & Wrisberg 2008). Although it was not formally documented, researchers in this study informally noted what they perceived as differences in arousal and anxiety in the subjects. While some subjects remained relaxed throughout the entire study, others became agitated and aroused when she performed poorly during a catch trial. Heightened arousal can affect the way individual's process information and can even contribute to faulty performance (Schmidt & Wrisberg, 2008). Further research should be done in order to examine these differences in arousal and whether or not they influence the performance of the subject during speech tasks.

Future studies should also be done to examine the effect of individual abilities and differences. Schmidt and Wrisberg (2008) have identified individual-difference factors that can contribute to differences in people's motor performance and many of them can apply to studies such as this one. Factors such as abilities, attitude, emotional makeup, motivational level, and previous movement experiences have all been identified by Schmidt and Wrisberg (2008) and

would be applicable to examine in this study. It would be interesting to examine whether past experiences with electronic games (e.g., iPad applications, computer games) would reveal any difference in the performance of individuals in this study. Individual differences and abilities, along with arousal and anxiety levels, are areas in which further research is needed.

Despite the need for further research, this study provided useful knowledge. The study revealed that incorporating typical speech breathing into the speech task, did not affect the subject's ability to inhibit. Subjects were still able to inhibit the motor program just as well as the previous studies, while eliminating the artificial element of the study, indicating that the results from previous studies, despite including the arbitrary task of holding one's breath, are valid and useful. Authenticating these results allows research to move forward using the past studies as a reference.

Also, having inconclusive results regarding utterance complexity agrees with the thought that the relationship between articulatory movements and the intuitively appealing idea of speech production is far more complex than researchers tend to believe. Despite having one of the largest amounts of movement for articulators in the English language, the word "eagerly" did not show significant difference in regards to the refractory period. Examining this refractory period and complexity changes has clinical importance to the profession of speech-language pathology, because it has the potential to give future speech scientists an insight into motor speech disorders, specifically into apraxia of speech.

References

Backlin, J., Corbett, A., Halbur, T., Gaughan, L., Howard, L., Williamson, C. & Hageman, C.F.

(2008). Reliability, accuracy, & refractoriness of a transit reaction: replication with

speech. Presentation at the Annual Meeting of the American Speech Language-Hearing

Association, Chicago, IL

Baken, R.J., Cavallo, S.A., Weissman, K.L. (1979). Chest wall movements prior to phonation.

Journal of Speech and Hearing Research, 22, 862-872.

Barlow, S.M. (Ed.). (1999). *Handbook of clinical speech physiology.* San Diego, CA: Singular

Publishing.

Behrman, Alison, (2007). *Speech and Voice Science.* San Diego, CA: Plural Publishing.

Carr, L.M. (2004). *Temporal stability of speech motor programs in young children.* Unpublished

manuscript, University of Northern Iowa.

Clark, H. M., Robin, D.A., McCullagh, G., & Schmidt, R.A. (2001). Motor control in children

and adults during a non-speech oral task. *Journal of Speech, Language, and Hearing

Research, 44,* 1015-1025.

Duffy, J. (1995). *Motor speech disorders.* St. Louis: Mosby.

Goldman-Eisler, F., (1961). The distribution of pause duration in speech. *Language and Speech*,

4, 232-237.

Hageman, C. & Riess, J. (2008). Speech Refractory Timer [Computer Software]. University of

Northern Iowa, IA.

Hebb, D. O. (1949). *The organization of behavior: A neuropsychological approach*. John Wiley & Sons.

Hixon, T., Weismer, G., Hoit, J. (2008). *Preclinical Speech Science: Anatomy Physiology,

Acoustics Perception.* San Diego, CA: Plural Publishing.

Howard, L.A. (2010). *Speech Inhibition in Aphasia: A Measure of Motor Speech Programs.*
       Unpublished manuscript, University of Northern Iowa.

Mass, E., Robin, D.A., Austerman Hula, S.N., Wuf, G., Ballard, K.J., & Schmidt, R.A. (2008).

       Principles of motor learning in treatment of motor speech disorders. *American Journal of*

       Speech-Language Pathology, 17, 277-298.

Mattar, A. A. G, & Gribble, P.L. (2005). Motor learning by observing, *Neuron, 46,* 153-160.

Mueting, L. (2011). *Reliability, accuracy, & refractoriness of a transit reaction: replication with*

       speech in children. Unpublished manuscript, University of Northern Iowa.

Netsell, R. (1982). Speech motor control and selected neurologic disorders. *Speech motor*

       control, 247-261.

Parham, D. F., Buder, E. H., Oller, D. K., & Boliek, C. A. (2011). Syllable-related breathing in

       infants in the second year of life. *Journal of Speech, Language, and Hearing Research*,

       54(4), 1039-1050.

Schmidt, R.A. (1975). A schema theory of discrete motor skill learning, *Psychological Review,*

       82(4), 225-260.

Schmidt, R.A., & Wrisberg, C.A. (2008). *Motor learning and performance* (4th ed.).

       Champaign, IL: Human Kinetics.

Shapiro, D.C., Zernicke, R.F., Gregor, R.J., and Diestel, J.D. (1981). Evidence for generalized

       motor programs using gait pattern analysis. *Journal of Motor Behavior, 13*(1), 33-47.

Slater-Hammel, A.T. (1959). Reliability, accuracy, and refractoriness of a transit reaction. *The*

       Research Quarterly, 31 (2), 217-228.

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