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THE EFFECT OF AAC STIMULATION ON THE DORSOLATERAL PREFRONTAL CORTEX

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ABSTRACT

This study examined the effect of Augmentative and Alternative Communication on the dorsolateral prefrontal cortex (DLPFC). The question being researched was, "In what ways is the DLPFC involved in AAC display processing and access?" It was hypothesized that different conditions would elicit different levels of DLPFC activation, depending on the memory demands. To test this hypothesis, 18 right-handed adults without disabilities with a mean age range of 20 – 35 took part in this study. Participants were required to take part in a training session where they learned the location of half of the symbols used in the experiment. After the training sessions, participants were screened and asked to enter the fMRI magnet. During this session, DLPFC activation under the two experimental conditions was recorded and analyzed. Results showed that there was equal DLPFC stimulation across both conditions, but both showed higher levels of activation than when no task was being presented. This study was the first of its kind as no previous studies have shown or proved what happens to the DLPFC when it is tasked with using an AAC system. Future research might present participants with more difficult tasks, to determine if task difficulty makes a difference in the success of using or teaching an AAC system.

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Chapter 1

Introduction

Part of being human is our larynx, “voice box,” that allows us to express all of our wants, needs, and intentions via speech. Without this voice, it becomes much harder to communicate with others. It is the goal of speech-language pathologists to help every client learn to communicate effectively and to help provide an alternative mode of communication to those whose oral speech does not meet all of their expressive communication needs.

The goal of this study was to study brain responses to one particular form of clinical materials. In order for therapy to be successful for clients, basic science examining different interventions is of the utmost importance (cf. Light & McNaughton, 2014). This understanding of the brain provides clinicians with scientific evidence to support their choice of interventions for their clients.

The materials of interest in this study were visual communication supports used in augmentative and alternative communication. AAC is used to facilitate communication and comprehension for those who may have difficulties with spoken language (Drager, 2009). A typical AAC system uses symbols, aids, strategies, and techniques to support speech or provide an alternative to speech (Justice, 2010). This project was part of a larger study on brain imaging that has examined how different areas of the brain react to specific tasks such as using an AAC system. The area of interest in this study is called the dorsolateral prefrontal cortex (DLPFC) and deals with working, short-term memory. Suzanne Miller explains how this area of the brain and working memory is responsible for remembering and holding images in one's memory while performing other tasks (as cited in Miller, 2013).

In order to have effective communication of any kind, memory is required. It is needed to help remember the topic of conversation, prepare upcoming responses, and to revise any message during the conversation (Thistle & Wilkinson, 2013). Short-term memory (STM) is utilized during the time a message is thought out and can only be held for a short time period. Long-term memory (LTM) is almost unlimited in duration and capacity, but working memory rehearsal is required to get information into LTM. Working memory can be defined as the limited capacity system that allows for temporary storage of information while simultaneously performing other cognitive tasks (Miller, 2013).

According to Baddeley & Hitch (1974), there are three components of working memory: the phonological loop, responsible for auditory and phonological verbal information, visuospatial sketchpad, responsible for visual and spatial information, and the central executive, which coordinates performance among these areas (cf. Thistle & Wilkinson, 2013). An individual uses their working memory in every day tasks. For example, when an individual decides to read a book, they elicit the visuospatial sketchpad. The brain must work to maintain orientation on the page while simultaneously working to decode and understand the print on the page (Miller, 2013).

Augmentative and Alternative Communication (AAC)

An AAC system also requires use of the visuospatial sketchpad in working memory. When an individual sees a picture and must find it on a board comprised of many images, they must hold the image in their working memory while simultaneously remembering and searching for a matching image on a board (Thistle & Wilkinson, 2013). This specific task is one part of Augmentative and Alternative Communication (AAC), which is a form of communication relying on visual communication.

Visual Graphic Language System

For those with difficultly with spoken language, manual sign, gestures, or even AAC pictorial representations are used to facilitate expressive language (Shane, O'Brien, & Sorce, 2009). These AAC pictorial representations are static symbols, which mean they do not require any movement, while gestures are dynamic symbols and thus require movement to understand the meaning (Justice, 2010). Justice explains that dynamic symbols are often gestures or manual signs that help supplement oral language or help deliver a message to a listener (2010). AAC systems are comprised of many different types of symbols and these may be either aided or unaided. Beukelman and Mirenda explain symbols as "something that stands for or represents something else" (2013). As these authors note, an aided symbol requires external assistance, such as any form of technology, such as an iPad or smartphone, or even something as simple as a picture. Unaided symbols come from gestures or even facial expressions, both aided and unaided symbols supplement oral speech and help deliver messages.

Graphic symbols are picture representations of symbols that can be photographs, black and white or color line drawings, and even alphabetic letters. When graphic symbols are used, this language system is comprised of picture images and thus is part of visual-graphic language. There are three different types of symbol iconicity used to describe them; transparent, translucent, and opaque. Transparent symbols are those in which the meaning of the symbol can be readily guessed without a referent, translucent are those in which the meaning of the symbol may or may not be obvious, but a relationship can be seen, and an opaque symbol is that in which the relationship between the symbol and referent cannot be seen or thought of (Beukelman & Mirenda, 2013).

In order for a listener and speaker to communicate, they must both process what is being said. Hearing oral speech and processing meaning differs significantly from processing manual sign or picture representations. In this way, it seems likely that learning a language through a visual-graphic system will use different parts of the brain than that of auditory-visual learning. Ideally, both the communicators and their partners are taking part in the system and are using the pictorial representations for two-way communication (Shane et al., 2009). When using these visual systems with a learner who struggles with spoken language, communication partners supplement the pictures with spoken language, modeling the correct syntax and semantics of the spoken language (Drager, 2009). Children learning their language this way will likely process language differently than children who rely on auditory-visual language.

Working Memory

When selecting an image on an AAC board, attention shifts between the items being remembered to some type of processing of those items and thus requires a working memory component (Thistle & Wilkinson, 2013). According to Thistle and Wilkinson, “AAC devices that include word prediction, a similar integrative process is necessary because the individual must maintain the target in mind while considering and specifically rejecting or overriding predicted words that are not actual matches to the target word" (2013, p. 237). Working memory is elicited while using AAC since the individual must not only remember the location and pathway to reach a symbol, but also formulate and hold in mind the intended message to be communicated (Thistle & Wilkinson, 2013).

Thistle and Wilkinson (2013) reviewed literature that suggested that difficulties with working memory could lead to difficulties using aided AAC systems. They argued that while developing a message, an individual has to maintain the message in mind using STM and then must search through multiple symbols and pages while using LTM. This process then also requires split attention between the visual display and the communication partner. Thistle and Wilkinson claim "an individual who is communicating with a partner must attend not only to that partner, but must also shift attention to the communication display to select a symbol or see what symbol is being indicated by the partner" (2013, p. 239). These processes all require working memory.

Dorsolateral Prefrontal Cortex (DLPFC)

By understanding how different areas of the brain respond to different task demands, one can develop the most efficient and successful interventions for clients. Different parts of the brain are responsible for different parts of the communication chain, and one of these parts is the dorsolateral prefrontal cortex (DLPFC). The DLPFC is part of the frontal lobe and is found in Brodmann's Area 8 to 10.

It is believed that the DLPFC is activated when thinking back and selecting items from one's working memory (Nathaniel-James & Frith, 2002). Previous studies have reported that

DLPFC activation was present in working memory tasks such as the maintenance of information in working memory and the manipulation of items held in working memory (Nathaniel-James & Frith, 2002). Duncan and Owens (2000) concluded that many different tasks elicited dorsolateral prefrontal cortex stimulation and as long as the task was new and relatively complex, DLPFC activation is likely to occur (as cited in Nathaniel-James & Frith, 2002).

Nathaniel-James and Frith studied six right-handed volunteers from 32 to 63 years of age, five of whom were male. Participants were required to complete two tasks; one response initiation and one response suppression in which the final word was omitted from a sentence. In the first task, subjects had to think of a word to complete the sentence, while in the second task, subjects had to think of a word that did not fit. Constraints were defined in terms of probability in terms of the most frequent response. For example, a highly constrained sentence would be "He mailed the letter without a…." in which the most common response was "stamp".

Results from Nathaniel-James and Frith (2002) found the largest DLPFC activation under low constraint and the left dorsolateral prefrontal cortex was most elevated when comparing the suppression with initiation under all levels of constraint. Nathaniel-James and Frith looked into brain region interactions between the task and constraint and found that the only region showing this interaction was the left DLPFC. The study concluded that the results show left DLPFC activation more for the suppression tasks at all levels of constraint and for low constraint conditions in the initiation task. This is important to AAC users since AAC pictorial representations require one to select an image from a large set. A person will be thinking of the image they want to choose and must think back on this image in their working memory until they search and find the correct one from their AAC board.

Mars and Grol (2007) reviewed literature on DLPFC activation. Consistent with a proposal by Rowe et al (2000, as cited in Mars & Grol, 2007), they argued that the role of the DLPFC is for “selection of representations, rather than the retention of sensory information” (p. 1801). This is another component of the DLPFC that relates back to AAC usage. When people are using an aided, graphic, static (physical device, pictorial representations, and unmoving) AAC system, they must compare multiple symbols and select the best one in order to portray and communicate their meaning. A previous FMRI study done by Pochon, et al. found that the DLPFC was activated when subjects needed to mentally prepare for an upcoming action based on information in their working memory (Pochon, et al., 2011).

Eight right-handed volunteers with no history of neurological or psychiatric disease were required to complete two tasks: visuospatial matching and visuospatial reproduction (Pochon, et al., 2011). In the matching task, participants were required to fixate on a pattern on the board and after a delay period, participants had to identify if the new pattern on the screen was identical or a new one. In the reproduction task, participants saw a pattern and then had to recreate it after a fixation period. The fact that the DLPFC was activated in the reproduction task meant that the DLPFC was not activated when simply thinking of a visual stimulus in one’s working memory; it was only activated when a forthcoming action was going to arise from a visual stimulus, such as recreating a specific pattern.

Nathaniel-James and Frith (2002) concluded that the DLPFC is more involved in manipulation and not maintenance of stimuli in working memory. This supports the conclusion by Pochon, et al. (2011) that the DLPFC is activated when one must think about something in their working memory and change it. Knowing this helps AAC users since many times they will be preparing in their working memory what they want to say and must quickly change this based on what the speaker has to say. Speakers and listeners manipulate their language and speech incredibly often, so seeing how the brain responds to this manipulation will help explain language processing. AAC users must be constantly thinking about how they want to communicate their intention through pictures or gestures. While they search for a sign or a picture to portray this intention, they must maintain exactly what they want to say in their working memory.

Research Question and Hypothesis

My study aimed to evaluate the role of the dorsolateral prefrontal cortex in access to augmentative and alternative communication. The question being researched was, “In what ways is the DLPFC involved in AAC display processing and access?”

Because of the sequential picture matching task in AAC and the comparison of multiple events, I expected that the dorsolateral prefrontal cortex would be activated to help retrieve information from short-term memory and to correctly identify the matching picture from the graphic system. In my study, I was examining how the brain responds to transparent symbols. Participants were required to select one of these transparent symbols from an AAC display and DLPFC activation occurs when an individual is required to make decisions, especially matching. Because of the nature of the methods, I hypothesized that DLPFC activation would be seen.

Chapter 2

Method

Participants

Eighteen right handed adults without disabilities volunteered to take part in this study. Prior to participation, all provided written informed consent. All procedures were reviewed and approved by the Institutional Review Board (IRB). Seven of the participants were male, eleven female, with a mean age of 24;5 (years; months; range = 20 – 35). All participants were screened for implanted metal prior to participation, as required by fMRI safety procedure.

Stimuli and Experimental Conditions

The stimuli in this study consisted of line drawings obtained from the Boardmaker Picture Symbol Dictionary and taken from Google images. Three overarching categories of drawings were used in the stable condition; farm animals, jungle animals, and insects (Table 1). Twenty animals from the categories of ocean dwellers, forest creatures, and birds were used in the unpredictable condition (Table 2).

Table 1

Stable Condition		
Farm animals	**African Mammals**	**Insects**
Cow	**Elephant**	**Butterfly**

Donkey	**Zebra**	**Grasshopper**
Horse	**Cheetah**	**Fly**
Lamb	**Giraffe**	**Ants**
Pig	**Lion**	**Wasp**
Goat	**Monkey**	**Cockroach**
Rooster		**Spider**

Table 2

Unpredictable Condition		
Ocean Dwellers	**Forest Creatures**	**Birds**
Starfish	**Snake**	**Swan**
Shark	**Squirrel**	**Chick**
Jellyfish	**Raccoon**	**Parrot**
Octopus	**Rabbit**	**Hummingbird**
Orca	**Skunk**	**Crow**
Seahorse	**Mouse**	**Owl**
Crab		**Gull**

The symbols were arranged into three rows containing seven, six, and seven animals in the top, middle, and bottom rows. The middle row only consisted of six line drawings so that the center could remain blank. This center was where the photograph appeared in the sample period of the study.

There were two conditions in the study; stable and unpredictable. In the stable condition, the position of the symbols in the array remained in the same location and were grouped within their animal category, as seen in Figure 1. Farm animals were in the top row, jungle animals in the middle, and insects on the bottom. The stable condition was meant to allow participants to learn the locations of the twenty symbols.

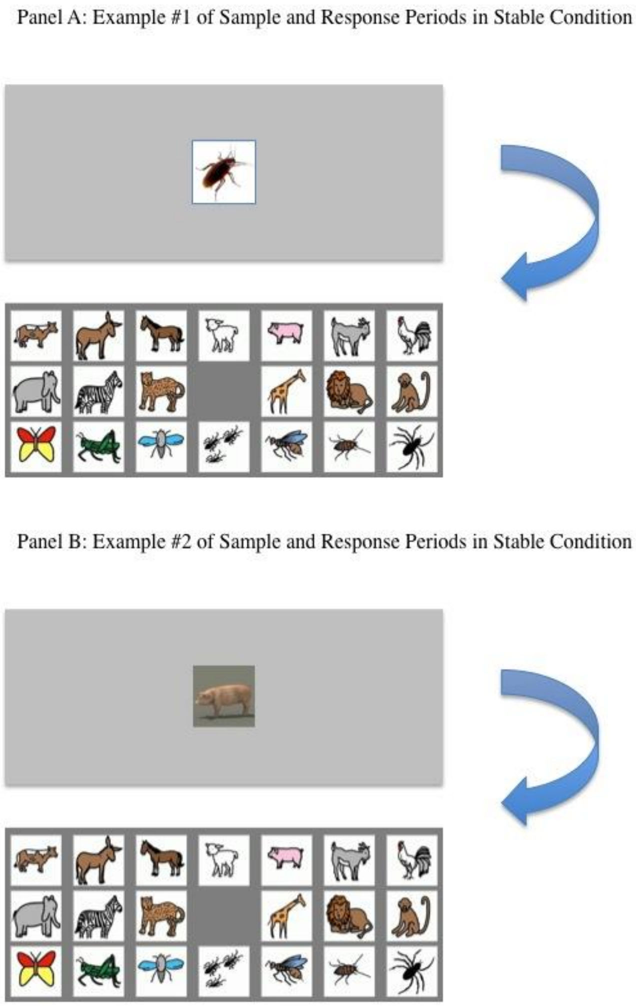

Figure 1: Examples of Two Trials from the Stable Experimental Condition

In the unpredictable condition, the location of the symbols and distractors differed from each trial, as seen in Figure 2. This was intended to prevent the participants from learning the conditions of the symbols so that they could not rely on the memorized locations. It is the unpredictable condition that was expected to elicit stimulation from the dorsolateral prefrontal cortex, as participants were required to hold an image in their working memory and find the match within the array of symbols.

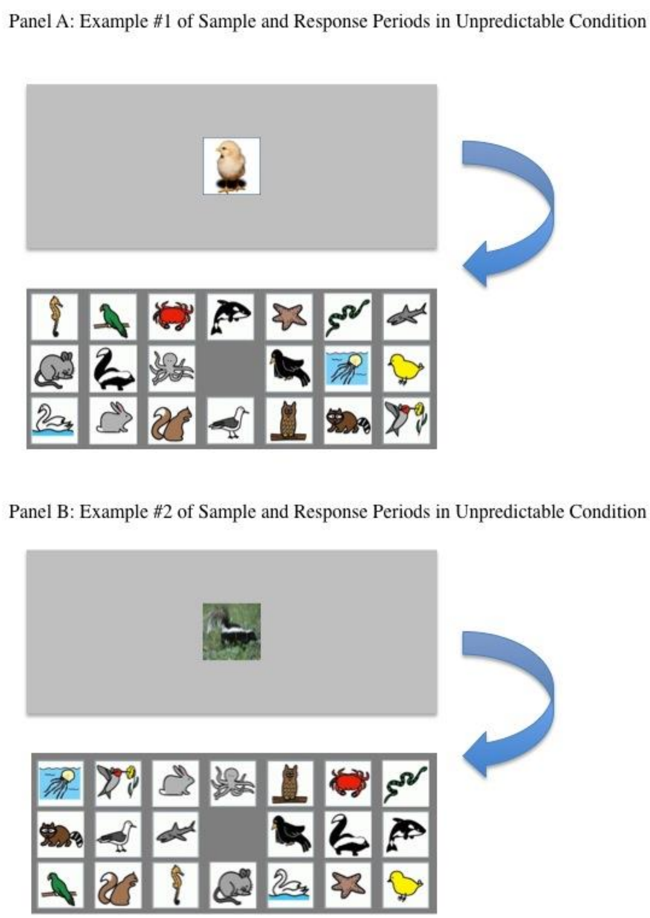

Figure 2: Examples of Two Trials from the Unpredictable Experimental Condition

General Task and Response

Every trial consisted of three periods: fixation, sample, and response period. During the fixation period, a simple fixation cross was presented on a white background. It was intended to give participants a brief break and was about 1000 and 12000 ms, in order to provide greater accuracy of measurement. In the sample period, a single color photograph was presented on the center of the screen, where the fixation cross was previously presented. This was a cue to which line drawing would be targeted in the response period. During the response period, the sample disappeared and was replaced with an array of twenty line drawings. It was in this period that the participant was tasked with finding the item to match that of the sample.

In order for participants to make their responses, a joystick with a response button was used during the sample and response period. Participants lay prone and held the joystick in their left hand and controlled it with their right. They were able to self-pace themselves and clicked on a stimulus at their own rate, so the sample and response periods were often different lengths for each trial. Pre-processing was done to ensure that the joystick did not introduce undue motion artifact. The pre-processing showed that no participants moved more than 3 mm.

Study Structure

Before entering the fMRI, participants completed 40 trials of pre-training. This training contained twenty trials of stable and twenty trials of unpredictable conditions. The purpose of the training was to give participants a chance to experience both conditions and learn the stable array. After this training session, participants entered the magnet, either the same day or within a few days of training. Once in the magnet, participants completed a set of trials to familiarize themselves with the joystick and refresh those participants who had not recently done the pre-training. These trials were not used for data.

After the familiarization, two experimental blocks were run. Each block contained 40 trials; twenty stable conditions and twenty unpredictable. Imaging data was acquired for all of these trials. At the end of each session, 80 trials of data were obtained per participant; 40 stable and 40 unpredictable.

Balancing Within and Across Conditions

Trials order was counterbalanced such that the order of stable and unpredictable trials was randomly shuffled and the location of the correct item also randomly determined. For greater details on the shuffling procedures, see Wilkinson et al. (2015)

Image Acquisition and Processing

Image acquisition and processing were described in Wilkinson et al., 2015, as follows:

> Images were obtained using a Siemens 3 T Magnetom Trio MRI scanner equipped with a 12-channel head coil. Responses were recorded using an MRI safe joystick. The potential for participant head movement was reduced using foam pads and scanner noise was minimized using earplugs.
>
> **Technical Specifications.** Consistent with recommended practice (see, e.g., Huettel et al., 2008, and http://fmri.ucsd.edu/Research/whatisfmri.html) a T1 weighted sagittal localizer was acquired to align scans to the anterior and posterior (AC-PC) commissures. A high resolution anatomical image (MPRAGE) was acquired with a 1400ms TR, 2.03ms TE, 256mm field of view (FOV), 256^2 matrix, 160 axial slices, and 1mm slice thickness for each participant. Echoplanar functional images were obtained using a descending acquisition, 3000ms TR, 30 ms TE, and 200mm FOV. Fifty-three axial slices were acquired per TR with a 2.0mm

slice thickness and 0.5mm gap, resulting in 2.5mm isotropic voxels, and an 80 x 80 image matrix.

Preprocessing and statistical analysis of the fMRI data was performed using SPM8 (Statistical Parametric Mapping) software. Time-series data were corrected to account for differences in slice acquisition times and were spatially realigned. Functional images were coregistered to (e.g., placed into alignment with) the anatomical MR images and spatially normalized to the standard Montreal Neurological Institute (MNI) space by resampling at 3mm isotropic resolution, with the coordinates later converted into Talairach space (Talairach and Tournoux, 1988) for reporting. Lastly, the data were spatially smoothed using an 8mm Gaussian smoothing kernel.

Data Analysis: Behavioral Responding in Visual Search

Behavioral data were used as a gateway for determining which trials would be entered for fMRI analysis. Trials on which participants selected incorrectly were treated as a regressor of no interest. Mean accuracy was 38 of 40 trials (95%) for the stable condition and 39.7 of 40 trials (99.1%) for the unpredictable condition. In addition, trials on which participants correctly selected but took a very long time to do so were also treated in the same regressor of no interest. This is because the initial trial procedures in the MRI demonstrated that the participant was able to correctly locate the target, but had issues controlling the joystick. This resulted in occasional correct trials that had long latencies, which were later found to be outliers, and self-reported frustration from the pilot participants. These outliers were identified as any trial with a latency period greater than one standard deviation above the median length of the session. About 5.5 of the 40 trials in the stable condition and 6.8 in the unpredictable condition were flagged as outliers. To account for these outliers, approximately 7.4 out of 40 stable conditions and 7.1

from the unpredictable conditions were removed from analysis. Paired t-tests confirmed that there were no differences between conditions in the number of trials removed. (Wilkinson et al., 2015)

Data Analysis: fMRI analysis

Analysis of the fMIR data was described in Wilkinson et al., 2015, as follows:

> We contrasted BOLD activity associated with a correct response in the stable condition with activity associated with a correct response in the unpredictable condition. This contrast allowed us to see what regions were more active during the stable condition, which we had predicted would involve the memory systems, the dorsal visual pathway, and motor areas. We also examined the reverse contrast to compare activity associated with a correct response in the unpredictable condition to that associated with a correct response in the stable condition. This contrast allowed us to evaluate whether the ventral pathway was more active in the unpredictable condition, when the participant was required to search based on object identity alone.
>
> **Technical Specifications.** Trial-related activity was modeled in the General Linear Model (GLM) with a stick function corresponding to the trial onsets (i.e., onset of the sample period) convolved with a canonical hemodynamic response function (hrf) and its temporal (first) derivative. The temporal derivative was included to account for latency differences in hemodynamic delays due to the self-paced nature of the task (Calhoun, Stevens, Pearlson, & Kiehl, 2004). Statistical parametric maps (SPMs) were identified by applying linear contrasts to the parameter estimates (beta weights) for the events of interest. Regressors associated with correct responses in unpredictable and stable trials were used in defining contrasts of interest. Incorrect trials and correct trials that had a response

time of greater than 1 standard deviation above the participant-specific median latency time were also modeled, yet treated as a regressor of no interest.

In order to obtain results that were corrected for multiple comparisons, we used followed standard procedures in using Monte Carlo simulations (https://www2.bc.edu/sd-slotnick/scripts.htm) to define individual voxel and cluster extent thresholds across all contrasts (e.g., Forman, Cohen, Fitzgerald, Eddy, Mintun, et al., 1995; Garoff-Eaton, Kensinger, & Schacter, 2007; Quadflieg, Turk, Waiter, Mitchell, Jenkins, et al., 2008; Slotnick & Schacter, 2004). This procedure takes into account the acquisition matrix (80x80), number of slices (53), voxel dimensions (2.5 mm^3), intrinsic smoothness (13 mm), and resampling of voxels (resampled to 3mm) in order to simulate data and estimate the rate of Type I error given the protocol parameters. In this study, an individual voxel threshold of $p < 0.01$ was used in combination with a cluster extent threshold of 18 resampled voxels (486 mm^3) in order to identify results corrected for multiple comparisons at $p < 0.05$.

Chapter 3

Results

Behavioral Responses: Accuracy and Latency to Select the Target

Data analysis above demonstrated that the participants' selections were highly accurate under both conditions, as the mean correct for unpredictable was 39.7 of 40 trials and 38 of 40 in stable. The reaction times for the accurate trials were evaluated to determine the speed of responding, as the stable condition promoted learning and is expected to have faster response latencies. Figure 3 illustrates the difference in response latencies and proves that the stable trials promoted a faster response than the unpredictable ones. Repeated measures ANOVA indicated that the difference between conditions was of statistical significance with a large effect size, $F(1,17) = 19.98$, $p < .000$, eta = .73 (Wilkinson et al., 2015).

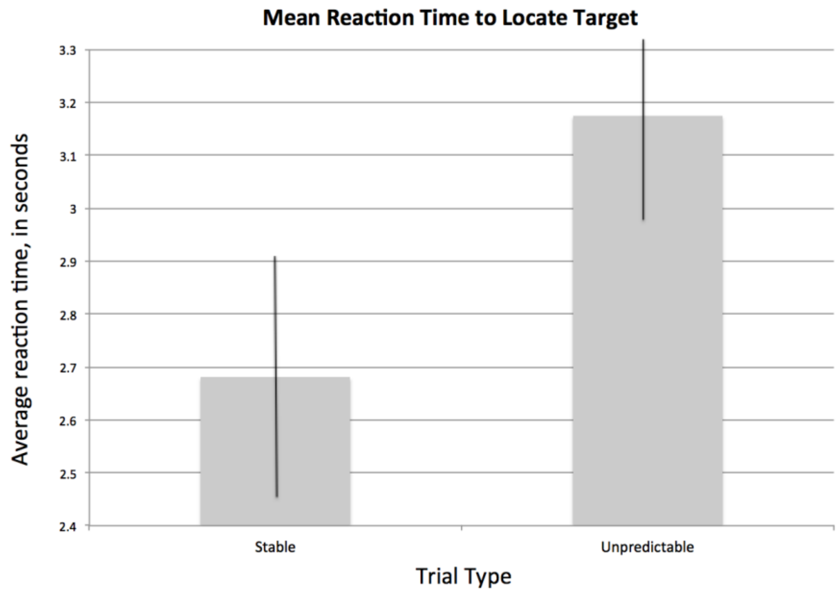

Figure 3: Mean Reaction Time to Locate Target, Across Conditions

fMRI Results

Statistical analysis comparing level of activation under the two conditions indicated that both areas were activated to equal levels under stable and unpredictable conditions. Both conditions showed higher levels of activation than when no task was being presented (baseline, which was the fixation and intertrial epochs); this activation relative to baseline is illustrated in

Figure 4. These results indicate that equal levels of activation were found under both conditions.

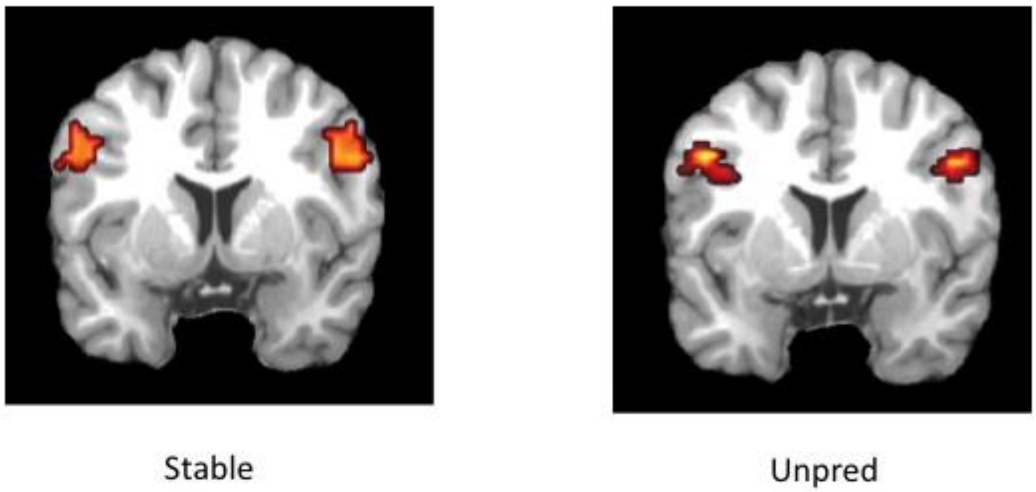

Figure 4: Level of DLPFC activation in stable and unpredictable conditions

Chapter 4

Discussion

This was the first study of its kind to look into the effects of AAC stimulation on the dorsolateral prefrontal cortex. Previous studies have looked into working memory tasks on the DLPFC, but no studies have shown or proved what happens to this part of the brain when it is tasked with using an AAC system. In this study, participants were required to hold the sample, cue image in their working memory and then pick the same image from an array of twenty pictures. DLPFC activation occurred in the task period and not the fixation period, signifying that the DLPFC was required to execute the task and with the help of working memory.

We had anticipated that the task should have elicited stimulation from the DLPFC in the unpredictable condition relative to the stable condition, since participants would have had to recall the image from their working memory while simultaneously picking a different image. This expectation was not upheld. There are two possible explanations. First, the task may not have been challenging enough. If the task was more difficult and required more use of working memory, we would expect to see more DLPFC activation in the unpredictable condition rather than the stable one. Another second explanation for the lack of difference between the stable and unpredictable conditions could be the fact that both tasks required the use of working memory. If this is the case, we might never see a difference across conditions.

If the matching task was too easy, then the DLPFC was not required to find a matching image. To test this theory, more tasks could be added to make the matching component harder.

Participants could see the sample image, count backwards from ten, and then be required to find the image from the array. Harder tasks such as this would require more working memory and thus more activation from the DLPFC. Along with counting backwards from ten, participants could recite the alphabet, be asked a series of questions about themselves, or simply have a longer period of time between the sample and response periods. Another way to increase working memory demands is to include more pictures in the array. Having more options to choose from, especially in the unpredictable array, would require the participant to scan through more images and use more of their working memory to determine which image is a match.

If it were to be found that the more difficult tasks are eliciting a difference in activation levels under the conditions, this will help speech language pathologists understand how critical it is to create an AAC array that is stable and predictable. If memorizing a board results in faster response times and less working memory, proven by less activation in the DLPFC, speech therapists will be able to provide their clients with AAC systems that are stable, predictable, and allow for faster response times and faster communication between partners.

If equal activation under both conditions continues to be found regardless of the difficulty of the tasks, speech language pathologists will use these findings to assist them in the way in which they support the learning of an AAC system with their clients. Working memory is required to successfully hold an image in mind while searching for it on an AAC board. For clients with working memory deficiencies, the way in which AAC systems are taught will differ significantly with other clients because using stable, predictable conditions might not improve speed or faster communication. This will change the way in which AAC systems are taught to clients. This finding would also prove whether or not AAC systems with many pages and symbols are using more working memory and are therefore harder to learn and implement than systems that are predictable with less symbols.

This study was the first of its kind and because of that, only ages 20 – 35 were tested. Results could potentially be different dependent upon older ages and the older population. Testing different ages would provide insight to whether or not the age of a participant results in different levels of DLPFC activation.

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- ***Speech Pathology Shadowing***. Shadow Dr. Barnes, local speech pathologist, September '12 –present
- ***D.E. Lichtenwalner Farms.*** Farmer's Assistant, June '12 – June '12
- ***Camelot For Children.*** Counselor for disabled children, September '08 – June '10

Research Experience

- ***Production and Perception Differences in L1 and L2 German Speakers.*** Selected to conduct independent research in Mannheim, Germany for two months under the supervision of Michael Putnam, Penn State University, September '13 – May '15.
- ***The Role of the Prefrontal Dorsolateral Cortex on Fluency of Alternative Augmentative Forms of Communication.*** Dr. Krista Wilkinson, Penn State University, August '13 – May '15.

Awards/Certificates

- Student Marshal, College of HHD, Communication Sciences and Disorders, May 2015
- Penn State Alumni Recognition for Student Excellence Award, College of HHD, April 2015
- Penn State Evan Pugh Scholar Award, March 2015
- Penn State Spark's Award, April 2014

- Penn State President’s Freshman Award, April 2013
- Penn State Dean’s List, December 2012 – present

Affiliations/Memberships

- Schreyer Honors College, Penn State University, August ’13 – May ‘15
- National Student Speech Language Hearing Association, August ’12 – May ‘14
- Penn State IFC/Panhellenic Dance Marathon, October ’12 – May ‘15

Interests

- ***Speech and Language.*** As a result, I am pursuing a career as a speech language pathologist. I am fascinated how humans are able to communicate to one another.
- ***American Sign Language.*** I find manual language just as interesting as spoken language and I have taken multiple classes inside and out of Penn State University to pursue this interest.
- ***THON.*** I love being able to make a difference in the life of a child.

Skills and Abilities

- ***Goal Driven.*** I set my standards very high in order to reach my goals. As a result, I have maintained a 4.0 GPA over my time at Penn State University.
- ***Time Management.*** From my many leadership opportunities, I have learned how to efficiently manage all my time and am able to accomplish a lot in a small amount of time.
- ***Prompt.*** I am very fast in responses to emails or other forms of contact and I do not procrastinate.
- ***Self-Motivated.*** I am able to drive myself personally towards my own goals without further encouragement.