THE EFFECTS OF AGING ON COGNITIVE MOTOR CONTROL:

FUNCTIONAL CONNECTIVITY ANALYSIS OF THE BETA FREQUENCY

by

Abigail Pate

A Senior Honors Project Presented to the

Honors College

East Carolina University

In Partial Fulfillment of the

Requirements for

Graduation with Honors

by

Abigail Pate

Greenville, NC

May 2021

Approved by:

Dr. Chris Mizelle

Department of Kinesiology, College of Health and Human Performance

Introduction

This research examines the intersection of two aspects of our everyday life: tool use and aging. Humans have adapted to have a strong understanding of object characteristics and their physical relationship with the world (Johnson-Frey, 2003). This has led to the creation of tools with a designated purpose already in mind. For example, a can opener was created with the intent of being able to open a can. In order to be able to use these tools, humans use a neurological process called praxis. This is the ability to successfully interact with the environment by planning, organizing, and then carrying out a sequence of actions that help the individual achieve what it is they aim to do (Ayers, 1985). As we get older and start to use an array of different tools, we further understand that each tool is associated with a certain task. This ability to understand is often first seen in infancy and grows as we experience everyday life (Spelke, Breinlinger, Macomber, & Jacobson,1992). A neurologically healthy individual would use a knife to cut some object but use a key to open a door. What happens though if the task is to cut open a taped box but there are no knives available? A human's understanding of tools and how they work allow for them to later use the tools outside of their original purpose. If the person just picked up their Amazon box from outside and had their keys out to get in the house, they will have an understanding that they can also use the key to cut through the tape and open the box. Although that is not the key's designated purpose, it still successfully gives the desired outcome of opening the box. As pointed out by the associate deficit hypothesis, processes that involve a high-level of cognitive functioning, such as relational/associative knowledge, are particularly vulnerable to aging (Naveh-Benjamin, 2000).

PURPOSE

The number of individuals in the United States who are over the age of 65 is growing every day. As a result, there is an increasing need for programs that help slow the age-related loss of praxis knowledge. At this time, it is unknown if performance decline in the elderly is due to a change in the anatomy of the brain or if it is related to the changes in functional properties of networks used during regular processing tasks. This research uses a 64-channel electroencephalography (EEG) cap to assess healthy young and older individuals and their dynamic neural responses when presented different tool use scenarios.

HYPOTHESIS

We hypothesize that different connectivity patterns will be seen between the younger and older individuals in response to the different stimulus types.

Background

BETA FREQUENCY

There are many different frequencies that occur in the human brain. The one that will be explored in this study is the beta frequency. It falls within the range of 12-30 Hertz (Hz). The primary focus of this band is motor planning and movement execution. Interestingly enough, we do not have to physically make a movement in order to activate this band. Instead, we can simply think of ourselves making the movement and it produces the same connectivity patterns (Jeannerod, 2001).

APRAXIA

Another important aspect of this research is apraxia. This is the loss of praxis, which I described earlier as the ability to perform learned movements on command. For a healthy individual, identifying normal and abnormal tool usage seems simple. This is not the case for people who have experienced neurological injury or illness that affects praxis. The two most common forms of apraxia that occur as a result of stroke are conceptual and ideomotor apraxia. Strokes often cause deficits in an individual's perception and control of action by damaging a patient's left parietal or posterior frontal lobe. Damage can also occur on the right side, which negatively affects visuospatial processing, but it is a lot less common (Sunderland et al., 1999). The damage that occurs to the left inferior parietal lobe causes individuals to be able to successfully identify an object, but have impairments using it (Johnson-Frey, 2004; Mahone & Caramazza 2005). This is known as ideomotor apraxia and is otherwise described as a patient losing the "how" of a tool but keeping the "what." The other type of apraxia is the inability to select and use tools, even though normal motor function is still intact (Moll, De Oliveira-Souza, De Souaz-Lima, Andreiuolo, 1998). This is called conceptual apraxia and is otherwise described as a patient losing the "what" of a tool but keeping the "how." In either circumstance, how the patient goes about their everyday functioning is changed, which often times causes a decrease in quality of life.

AGING

It is expected for the brain to experience anatomical and functional changes as we age, especially in areas involved with praxis (Shen et al., 2009). Older individuals often have slower processing and begin to show errors that are similar to patient's who have brain injury and disease when neither of these are actually present (Zahr, Rohlfing, Pfefferbaum, & Sullivan, 2008; Old, Naveh-Benjamin, 2008). The functional changes can be seen in many different tasks such as motor preparation and execution and visual memory. Apraxia is often a symptom of diseases like dementia and corticobasal degeration that most commonly affect older individuals. When these deficits are present, research shows that older individuals have to recruit more brain regions than younger individuals (Park et al., 2001). Sometimes, they lose this functioning altogether (apraxia). As with apraxia, aging has a negative effect on quality of life. When the two are combined, significant neurological challenges arise that we aim to begin to resolve with this study.

Methods

PARTICIPANTS

For this study, healthy young and older adults were recruited to participate. Healthy is defined by having no current or previous neurological pathology that would interfere. There were 21 young and 12 older participants that were all right-handed. The young participants' ages ranged from 18 to 26 years old. The older participants' ages ranged from 66 to 84 years old.

TASK

A stimulus was presented of high resolution black and white photographs that fell into one of two categories. The first one was a normal stimulus (e.g., a hammer hitting a nail into a piece of wood) and the second one was an abnormal stimulus (e.g., using a pair of pliers to screw the nail into wood). Before beginning the experiment, the participants were told that they would be presented an image and were instructed to decide the stimulus type and select the corresponding button on the response pad. Each trial will start with a prompt that explains the goal of the stimulus to the viewer. With these two images, the prompt read "insert nail into wood." The participant then viewed the stimulus and selected the type that they thought it was. The response pad sent the stimulus type that was selected and the time in which it was chosen it to a computer that stored the data.

DATA COLLECTION AND ANALYSIS

Data were collected using a 64-channel EEG electrode cap and SynampsRT amplifier with Curry 7 software interface. The data were marked in Curry for both even onset and category. Unprocessed files were imported into MATLAB. They were then processed and analyzed within the MATLAB computing environment using a proprietary processing script with EEGLAB. The particular frequency of interest in this paper is the beta band. It is responsible for motor control and is within the range of 13-30 Hz. Epochs were made up of information from 1000 ms before the onset of the stimulus through 3000 ms after. Each epoch was baseline corrected with an interval that went from -1000 ms to -500 ms. After this was done, the trials were averaged for each participant and then averaged again across the category types. From these data, the cross spectrum was extracted in the beta band for all channel pairs and functional connectivity was calculated from the complex valued cross spectral data using the debiased squared weighted phase lag index. Finally, degree centrality was calculated on these connectivity data.

Results

The results for the study are shown below in Figure 1 and Figure 2. Figure 1 shows the first condition that was deemed "normal." On the left side, you will see four images that make up the first time bin that was significant to our data, which was 50-200 ms. The young brain is on the left side and the old brain is on the right side. The same applies for the four images on the right side, except this is 350-500 ms, the second time bin of importance. The top row of images was produced as the result of the functional connectivity analysis, while the second row is the degree centrality that was created by using graph theory. The same format applies to Figure 2, except these are the images for the "abnormal" stimulus.

Figure 1:

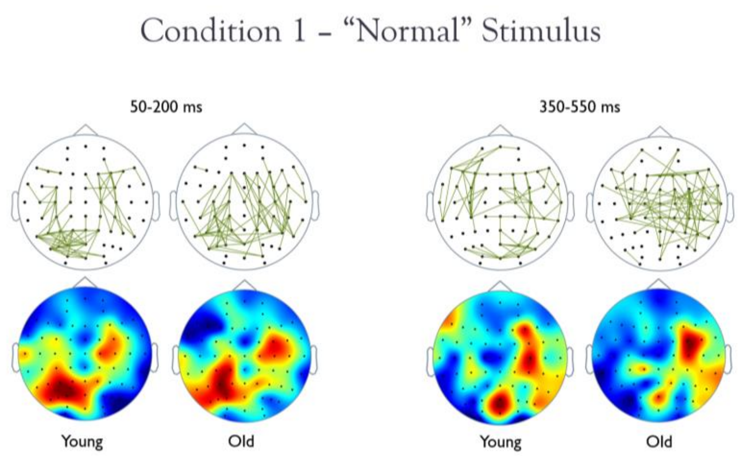
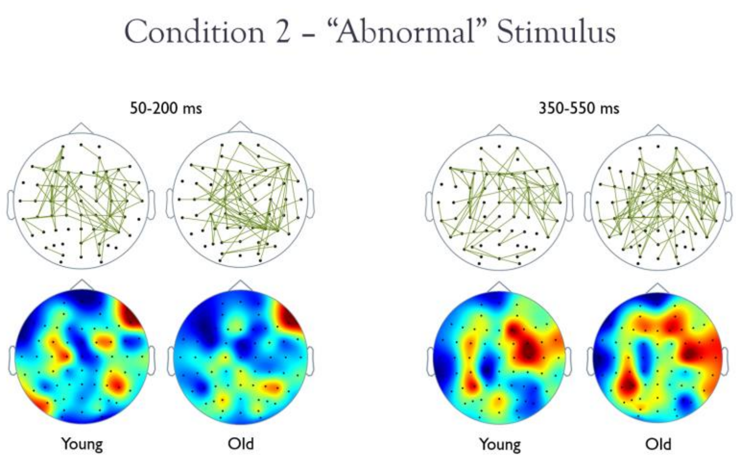


Figure 2:



Discussion

For this study, we hypothesized that there would be different connectivity patterns between the young and old population, as well as between the two stimulus types. The was a correct assumption and can be seen in my results. For Condition 1 Time 1, there is a lot of activity occurring in the back left of the brain and the front right area. The back left area is the part of the brain that is responsible for tool-recognition and use and the front area is a part of the sensory motor strip that is responsible for motor control. This occurs in both the young and the old in a similar pattern. Both of these areas having connectivity makes a lot of sense, seeing as how the participants are mentally putting themselves through that motion and thinking of the tool that they are using. If you look at Condition 1 Time 2, you can see that continued activity in the sensory motor strip region. You also start to see a shift of connectivity to the occipital lobe, which most likely means that they have finished processing the stimuli and are taking new visual information in (perhaps they are looking around the room or at something else that caught their attention). The younger population has a higher degree of centrality there because they most likely processed the information faster. Another thing we hypothesized is that it would take the older individuals longer to process the stimuli than the younger individuals. Although this did prove to be true, it was not to the degree that was expected. A reasoning for this could be that the older individuals have more experience with tool-use and that makes up for the time lost to processing.

For my frequency, the “abnormal” stimulus yielded the most interesting results. If you look at Condition 2, Time 1, you see the largest amount of activity in the very front right of the brain. This is a good sign because that is the area responsible for spatial processing. Since they are viewing an unusual stimulus, they have to spend more time putting themselves into that space to understand and process what is happening. If you look at Condition 2, Time 2, you once again see a heavy amount of connectivity in that back left area that is for tool-use and on the sensory motor strip. The area that is of the most interest is the prefrontal cortex in the older individuals and the amount of activity seen there. That part of the brain is responsible for cognitive processing, so they are most likely spending more time extracting information from the stimulus. Older individuals are known to have a harder time understanding the relationships between things, so perhaps that is the reason for this cognitive activity.

The point of this research was to better understand what functional changes occur in healthy aging. Although there needs to be more research done, this is a step toward being able to take better care of the elderly’s neurological challenges. This can lead to better methods of rehabilitation for stroke patients. If research on this topic continues, we will be able to create a baseline for the affects of aging on cognitive motor control.

References

Ayres, A. (1985). Developmental dyspraxia and adult-onset apraxia. Torrance, CA: Sensory Integration International.

Johnson-Frey, S. H. (2003, July 17). What's so special about human tool use? *Neuron*. Cell Press. https://doi.org/10.1016/S0896-6273(03)00424-0

Johnson-Frey, S. H. (2004, February 1). The neural bases of complex tool use in humans. *Trends in Cognitive Sciences*. Elsevier Current Trends. https://doi.org/10.1016/j.tics.2003.12.002

Liu, A. K., Dale, A. M., & Belliveau, J. W. (2002). Monte Carlo simulation studies of EEG and MEG localization accuracy. *Human brain mapping*, *16*(1), 47-62.

Mahon, B. Z., & Caramazza, A. (2005). The orchestration of the sensory-motor systems: Clues from neuropsychology. *Cognitive Neuropsychology*, *22*(3–4), 480–494. https://doi.org/10.1080/02643290442000446

Jeannerod, M. (2001). Neural Simulation of Action: A Unifying Mechanism for Motor Cognition. NeuroImage 14(1): S103-S109.

Mizelle, J. C., & Wheaton, L. A. (2010). Neural activation for conceptual identification of correct versus incorrect tool-object pairs. *Brain Research*, *1354*, 100–112. https://doi.org/10.1016/j.brainres.2010.07.059

Mizelle, J. C., & Wheaton, L. A. (2010). Why is that Hammer in My Coffee? A Multimodal Imaging Investigation of Contextually Based Tool Understanding. *Frontiers in Human Neuroscience*, *4*(December), 233. https://doi.org/10.3389/fnhum.2010.00233

Mizelle, J. C., & Wheaton, L. A. (2010). Neural activation for conceptual identification of correct versus incorrect tool-object pairs. *Brain Research*, *1354*, 100–112. https://doi.org/10.1016/j.brainres.2010.07.059

Moll, J., De Oliveira-Souza, R., De Souza-Lima, F., & Andreiuolo, P. A. (1998). Activation of left intraparietal sulcus using a fMRI conceptual praxis paradigm. *Arquivos de Neuro-Psiquiatria*, *56*(4), 808–811. https://doi.org/10.1590/S0004-282X1998000500017

Naveh-Benjamin, M. (2000). Adult Age Differences in Memory Performance: Tests of an Associative Deficit Hypothesis. *Journal of Experimental Psychology: Learning Memory and Cognition*, *26*(5), 1170–1187. https://doi.org/10.1037/0278-7393.26.5.1170

Old, S. R., & Naveh-Benjamin, M. (2008). Memory for People and Their Actions: Further Evidence for an Age-Related Associative Deficit. *Psychology and Aging*, *23*(2), 467–472. https://doi.org/10.1037/0882-7974.23.2.467

Park, D. C., Polk, T. A., Mikels, J. A., Taylor, S. F., & Marshuetz, C. (2001). Cerebral aging: integration of brain and behavioral models of cognitive function. *Dialogues in Clinical Neuroscience*, *3*(3), 151–65. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/22034448

Shen, D., Resnick, S. M., Kraut, M., Davatzikos, C., An, Y., Driscoll, I., & Wu, X. (2009). Longitudinal pattern of regional brain volume change differentiates normal aging from MCI. *Neurology*, *72*(22), 1906–1913. https://doi.org/10.1212/wnl.0b013e3181a82634

Spelke, E. S., Breinlinger, K., Macomber, J., & Jacobson, K. (1992). Origins of Knowledge. *Psychological Review*, *99*(4), 605–632. https://doi.org/10.1037/0033-295X.99.4.605

Sunderland, A., Bowers, M. P., Sluman, S. M., Wilcock, D. J., & Ardron, M. E. (1999). Impaired dexterity of the ipsilateral hand after stroke and the relationship to cognitive deficit. *Stroke*, *30*(5), 949–955. https://doi.org/10.1161/01.STR.30.5.949

Zahr, N. M., Rohlfing, T., Pfefferbaum, A., & Sullivan, E. V. (2009). Problem solving, working memory, and motor correlates of association and commissural fiber bundles in normal aging: A quantitative fiber tracking study. *NeuroImage*, *44*(3), 1050–1062. https://doi.org/10.1016/j.neuroimage.2008.09.046