THE EFFECTS OF AGING ON COGNITIVE MOTOR CONTROL: FUNCTIONAL CONNECTIVITY ANALYSIS OF ALPHA FREQUENCY

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Introduction

Aging is a natural phenomenon that occurs among humans and can lead to a wide variety of physical and mental changes in individuals. Over 20 percent of the US population is projected to be age 65 and older by the year 2030. By the year 2050 the population of individuals aged 65 and older is projected to be 87.3 million (Ortman, Velkoff, & Hogan, 2014). This will put a lot of pressure on our healthcare system to take care of the wide variety of health challenges that this age group will face.

This age group will not only face disease and injury, but also the challenges that come along with healthy aging. The process of healthy aging creates physical changes in the makeup and function of the brain. Significant declines in the cortical volume and grey matter thickness in the cortex of the brain have been reported with healthy aging (Hutton, Draganski, Ashburner, & Weiskopf, 2009). There is also much evidence of a decrease in the white matter integrity of the aging brain (Davis et al., 2009). The overall decrease in brain matter can have a large effect on brain function and increase in processing difficulty, even in healthy older individuals.

Strokes, typically occurring in individuals 65 years or older, are another cause for brain deterioration and slower processing of older individuals. One common concern for stroke patients is damage to the ventral stream. This can cause problems identifying objects visually but does not seem to affect object-directed action (Goodale & Milner, 1992). This loss of knowledge on object or tool use is known as apraxia. Apraxia is a term used to describe multiple phenomena involving the inability to program one's motor system to comprehend or perform skilled motor-related tasks (Wheaton & Hallett, 2007). Research has shown that both impaired and healthy population can see the effects of apraxia as aging occurs (Donkervoort, Dekker, & Deelman, 2006). Since both healthy and injured populations can be affected by apraxia, it is important to understand to understand the basic workings of praxis in the healthy brain so that effective neurological rehabilitation protocols of apraxia can be properly formed (Buxbaum, Kyle, Grossman, & Coslett, 2007; Wheaton & Hallett, 2007).

Background

To understand how the brain healthily ages we must first understand the general workings of motor control. Praxis is the brains system of planning motor tasks. The occipital, temporal, and parietal lobes are all recruited when praxis takes place. Planning out what tool to use to drive in a nail (such a hammer) and how to use that tool would be a process done by praxis. Apraxia is the diminishing of the ability to plan out these motor tasks (Wheaton & Hallett, 2007). This often occurs when the areas of the brain related to praxis "experience accelerated tissue loss… that increases exponentially with advancing age" (Driscoll et al., 2009). As individuals age, information processing as a whole becomes less efficient such as speed of processing, working memory capacity, long-term memory, and inhibitory function (Park & Reuter-Lorenz, 2001). This involves the diminishing in effectiveness of the system of praxis.

This study uses the lens of the alpha band which is defined as a wavelength between 8 Hz and 12 Hz. The alpha band frequency domains relate to some motor tasks and more specifically visual processing tasks. Alpha ERD is present at many regions during different motor tasks (Crone et al. 1998; Pfurtscheller et al. 1997a; Wheaton et al. 2008) and at the parietal region in visual processing tasks (Pfurtscheller 1989b; Pfurtscheller et al. 1994). This study seeks to find the connection between alpha band frequencies and brain cognition as it relates to aging so that this can be used to further stroke research and rehabilitation.

Purpose of the Study

This study is meant to explore the changes in brain connectivity that occur naturally with healthy aging. The data found in this study can be used in future research to compare brain connectivity changes due to stroke with those changes found in healthy adult aging. By creating a baseline of what healthy aging should look like, we can potentially help improve the recovery process for old individuals facing neurological challenges beyond those of healthy aging.

Hypothesis

We expect to see differenced in the brain patterns and connections of older people compared to younger people when processing information related to object recognition of normal and abnormal object usage.

Methods

Participants

Healthy young and older individuals were recruited to participate in this study. This study included 21 young (age 22 +/- 4 years) and 12 older (age 75 +/- 9 years), right-handed participants. The University and Medical Center Institutional Review Board of East Carolina University approved informed consent and procedures for testing was presented to each participant prior before they participated. Handedness was determined by the Edinburgh

Handedness Inventory (Oldfeild, 1971). Our definition of healthy was having no current or previous neurological pathology which would interfere with the ability to view pictures, comprehend the use of tools, physical pathology which may result in altered cortical representation of tools or their associated objects, or presence of systemic disease that alters ability of subjects to participate in activities of their choice. Specific exclusion criteria included a history of stroke or neurodegenerative disease, upper extremity neuromuscular pathology, upper extremity orthopedic pathology, and ocular or neurological abnormalities that impact visual function.

Task

SuperLab (Cedrus, TX, USA) and Curry 7 (Compumedics Neuroscan, NC, USA) were used to present stimuli and collect data. The stimuli consisted of high resolution black and white images in one of two categories: normal (using a hammer to drive in a nail) or abnormal (using a brick to drive in a nail). Each trial began using a text prompt explaining the intended action-oriented goal (e.g. “drive a nail”). This was followed by a black-and-white circle and then a black fixation-cross, notifying the participant that the trial was about to start. Next, a blank white screen appeared for a pseudorandom amount of time between 1 and 4 seconds before the stimulus picture was shown. This was meant to avoid any kind of expectancy effect from participants.

Participants received instructions to identify the stimulus type of black-and-white images by pressing a corresponding button on the SuperLab response pad before the experiment began. The response pad then sent a matching event marker to Curry 7 which indicated stimulus type and time of onset. A practice round with 2 examples of each stimulus type was completed before the start of the first block of stimuli to familiarize the participants with the response pad and confirm understanding of the stimuli. Participants completed 9-12 blocks of stimuli total. Each block contained 10-15 pictures. In total, there were 100 stimuli presentations. The participants had built in breaks between blocks to rest, but they were allowed to choose to skip if they wished to do so.

Data collection and Analysis

EEG data were collected using a 64-channel sintered NeuroScan electrode cap and SynampsRT amplifier with Curry 7 software interface (NeuroScan, Compumedics, Charlotte, NC). Using the Curry-SuperLab interface, EEG data was marked in Curry for event onset and category as presented. Unprocessed files were imported into MATLAB to be processed and analyzed using a proprietary processing script with EEGLAB (Delorme & Makeig, 2004) within the MATLAB computing environment (Mathworks, Natick, MA). Custom MATLAB scripts were used to remove artifacts and filter data for frequencies of 8-12Hz (for the alpha band frequency). A functional connectivity analysis was also completed using custom scripts in MATLAB to create images plotting connectivity throughout the brain. Graph theory was also implemented to find degree centrality, or the strength of connections in a particular area, and plot the degree of connections throughout the brain. Connectivity analysis plots and degree centrality plots were rendered for the averages of time slots between 50-200ms and 350-550ms for both the young and older groups in the normal and abnormal circumstances. These plots were then analyzed.

Results

We found significant connectivity in the occipital, parietal and temporal lobes of both the young and older individuals.

Figure 1 show the connectivity and degree centrality plots for both the young and older individuals under the normal condition for both the 50-200ms and 350-550ms time point averages. At the first time point (50-200ms), we observed that much of the activity in the younger individuals takes place in the back portion of the brain in the occipital, parietal, and temporal regions of the brain. This is the area where praxis knowledge is primarily located meaning the individuals are likely processing the image of tool usage by simulating the tool usage in their brain. While the older individuals also have activity in these areas, the activity is shifted slightly forward and recruits a larger portion of the brain including the frontal lobe. This suggests that the older individuals may need to recruit more of the brain and different areas than the younger individuals to complete the same task. At the second time point it appears that nearly all of the connectivity is occurring toward the back of the brain primarily in the occipital lobe. This suggests that the individuals may be done processing the stimulus and are now focusing on other visual information around the room unrelated to this study.

Figure 2 shows the connectivity and degree centrality plots for both the young and older individuals under the abnormal condition for both the 50-200ms and 350-550ms time point averages. At time points 50-200ms it was noticed that while both the young and older individuals have a lot of activity occurring at the back of the brain in the occipital, parietal, and temporal junctions, there is a more forward shift of activity in the older brain as compared to the young brain. Again, we see the heavy recruitment of the frontal lobe in the older group which is not observed in the younger individuals. In the second time point of 350-550ms we again see that most of the activity occurs in the occipital lobe suggesting that the processing of the stimulus is likely completed by this point.

Overall, we observed a forward shift in the processing of the visual stimulus of older individuals in both the normal and abnormal conditions of this study. This suggest that there is greater brain recruitment needed in the older brain as compared to the younger brain to process visual stimuli related to cognitive motor control. This helps to show the differences in processing of visual stimuli in the young brain as compared to the older brain.

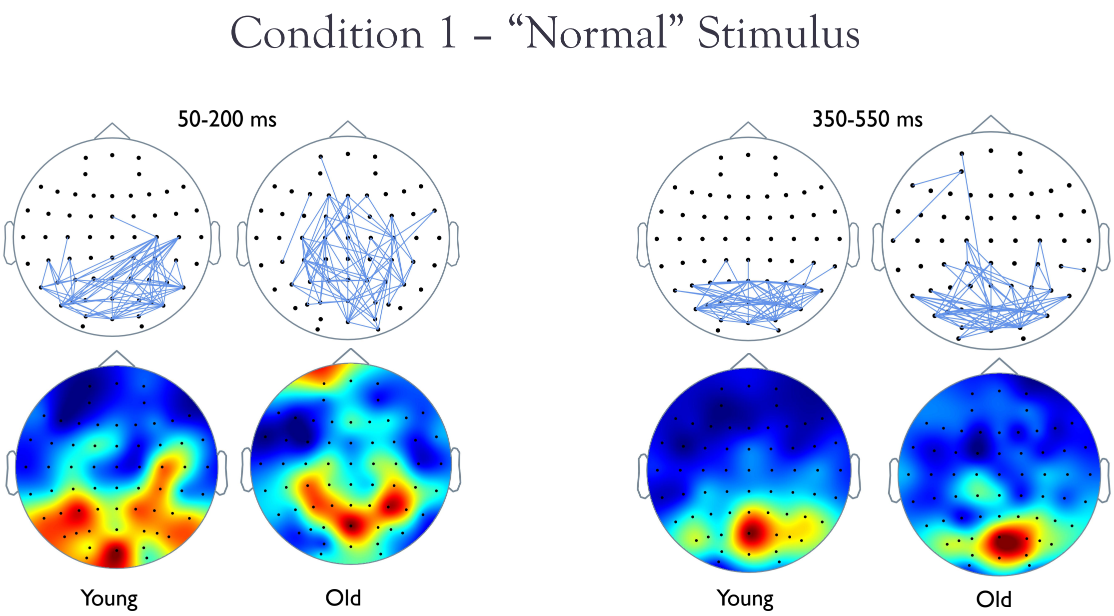

Figure 1: Normal stimulus functional connectivity (top images) and degree centrality (bottom imgages) plots of young and older individuals across multiple time points.

Condition 2 – “Abnormal” Stimulus

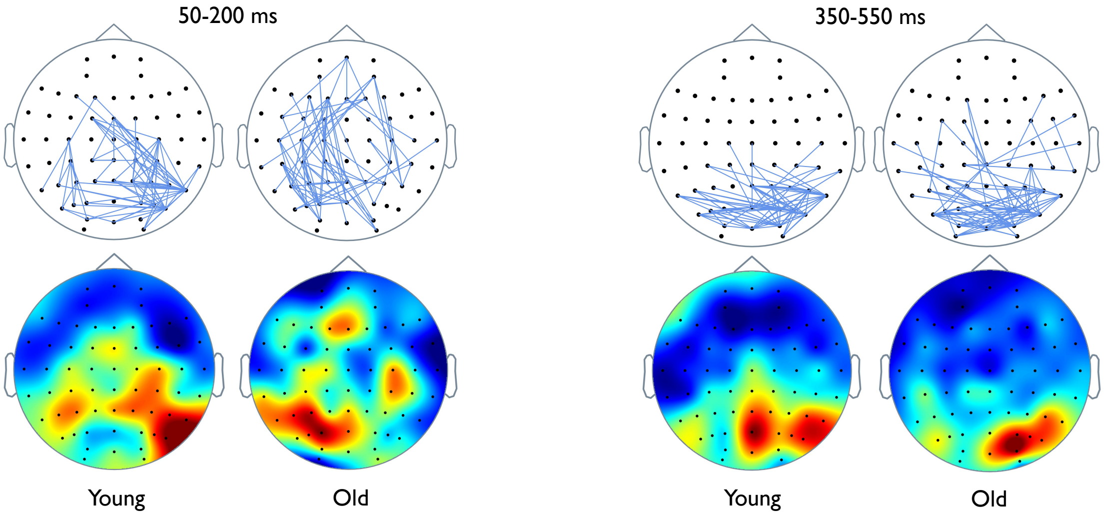

Figure 2: Abnormal stimulus functional connectivity (top images) and degree centrality bottom images) plots of young and older individuals across multiple time points.

Discussion

In this study we observed clear differences in the way that the young and older brain work to process cognitive motor control tasks. Since we now know that the older brain, when healthily aging, acts differently than the young brain, we can use this as a baseline model for healthy aging in relation to cognitive motor control. We observed a more frontal shift of processing of cognitive motor control and a broader recruitment of the brain as compared to younger individuals suggesting that the ways that older individuals process these stimuli are fundamentally different than that of the younger group. Therefore, without an understanding of how healthy aging occurs in the brain we cannot fully understand how to treat the neurological challenges of the older population.

The information found in this study can be used by future studies and practitioners alike to further research in neurological challenges related to cognitive motor control and stroke rehabilitation. By providing a baseline for what healthy aging should look like, better rehabilitation protocols can be created to help neurodivergent older individuals return back to a brain function that is comparable to that of neurotypical older individuals.

This study is one of the first studies to map out the neurological impacts of healthy aging on cognitive motor control, but other studies can be conducted in the future to map out other brain processes that can be affected by neurological challenges that come with healthy aging to create a more comprehensive view of what aging truly does to the brain. We cannot fully understand how to aid older individuals with common neurological challenges such as stroke until we fully understand how the brain is affected by the impacts of healthy aging.

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