Pomona College

2017-18 Sontag Fellowship Application Cover Sheet
Please submit application by May 15, 2017

Name: Richard Lewis Submission Date: May 15, 2018

Department: Psychology and Neuroscience

Title of Project: Immersing the brain in virtual reality: Investigating the role of the frontal pole in cognitive, social, and cultural contexts.

One Sentence Summary of Proposed Project:

We propose to develop a virtual reality – functional near infrared system for measuring frontal cortex activity in response to virtual reality cognitive, social and cultural situations.

Proposed Project Abstract (250 word statement or less):

The anterior pole of the prefrontal cortex (Brodmann Area 10) is probably the least well understood area of the human brain. We are seeking Sontag funds to develop a virtual reality system that will be coupled with our functional near infrared spectroscopy system for measuring human brain activity in order to investigate the role of Area 10 in goal directed intentions. The proposed experiment will replicate a virtual reality shopping game that has been shown to activate Area 10. In addition, we will extend this design to include conditions that will allow us to test the gateway hypothesis of Area 10, which hypothesizes relatively greater lateral activation of Area 10 for monitoring of internally generated intentions and relatively greater medial activation of Area 10 for monitoring external stimulus cues associated with intended actions. Future research will adapt this paradigm to sociocultural virtual environments in order to investigate Area 10's involvement in navigating multiple cultural frameworks in biculturals.

TOTAL REQUESTED: $ 10,000

Project Description

Specific Aims

The proposed research is aimed at achieving the following three goals:
1) To develop a virtual reality paradigm for the study of human brain activity;
2) To test the gateway hypothesis of the anterior frontal pole (Area 10) in an immersion virtual reality prospective memory experiment; and
3) To position our lab to investigate the neural basis of frameswitching in biculturals.

Background

The anterior pole of the frontal cortex, or Brodmann Area 10, may be one of the least understood areas of the human brain (see figure 1). Activation of Area 10 was a ubiquitous finding across disparate cognitive neuroscience studies, making theory development challenging. However, in recent years there has been increasing attention to elucidating its function. Burgess, Dumontheil & Gilbert (2007) have proposed the gateway hypothesis of Area 10. The gateway hypothesis postulates that area 10 is involved in goal-directed coordination of stimulus-oriented and stimulus-independent cognition, with medial Area 10 being involved in stimulus-oriented attention and lateral area 10 being involved in stimulus-independent attention. This model has been proposed to account for a recent flurry of studies investigating area 10's role in *prospective* memory. Prospective memory, or remembering to carry out intended actions has been proposed to be a function of the prefrontal cortex which is involved in goal orientated cognition and behavior (see Dominick & Lewis, 1996; Jurica & Lewis, 1989; Lewis, 1991; Lewis & Dominick, 1996). A recent meta-analysis of neuroimaging studies of prospective memory largely supported the gateway hypothesis with greater involvement of lateral areas for monitoring internal intentions and relatively greater involvement of medial areas for monitoring external prospective memory cues (Cona et al., 2015).

Area 10, is also one of the most unique areas of the human brain. It is disproportionately larger in humans than any other great apes, and has been proposed to be responsible for initiative and planning of future actions (Semendeferi et al. 2001). Area 10's development occurs relatively late, with gray matter densities, dendritic arborization, and myelination maturation continuing through late adolescent and early adulthood (see Burgess & Wu, 2013 for a review). Area 10 also contains von Economo or spindle neurons, which are found only in great apes and are thought to be involved in rapid communication within large brains (Allman et al., 2010). These neurons are altered in frontotemporal dementia and autism, and their dysfunction may underlie problems with self-control associated with these disorders (Cauda et al., 2012). In addition, Area 10 is part of the default mode network, and displays high activity during "resting baseline" states and is related to self-referential thought (Gusnard & Raichle, 2001). The unique qualities of Area 10 have been proposed to be related to the relatively highly developed abilities of goal directed cognition evidenced in humans.

Virtual reality is capturing the imagination of neuroscientists who are attracted to studying brain activity under realistic circumstances in conjunction with laboratory control. Recently, Dong, Wong & Luo (2018) developed an immersion virtual reality game for investigating Area 10 activity during a realistic prospective memory task. Participants were given a shopping list (e.g. buy lettuce) and an action list (e.g. placing a bottle in recycling bin) and instructed to walk along a virtual street while accomplishing the tasks (see Figure 2 for frame examples from the VR task). Area 10 activity was measured using functional near infrared spectroscopy (fNIRS). fNIRS, which measures the reflectance of different wavelengths of light that are associated with sensitivity to deoxyhemoglobin and oxyhemoglobin. Because of the coupling of neural activity with increased oxygenated hemoglobin, the calculation of the relative concentrations of oxy/deoxyhemoglobin is used to infer localized changes in neural activity of the cerebral cortex. fNIRS is the ideal brain measurement technique for virtual reality paradigms relative to the more frequently used EEG and functional magnetic resonance imaging techniques, because it is less susceptible to movement artifacts and less interference with the electrical and magnetic limitations of the latter techniques. Dong et al. measured fNIRS activity when participants read the list of shop items and compared brain activity when an item was on a list and when it wasn't. Dong et al. found that Area 10 showed greater activity when remembering the items on the shopping list, establishing the utility of using fNIRS and VR for investigating human brain activity under realistic situations in the lab.

Proposed Research

The first goal of the proposed research is to replicate the Dong et al.'s (2018) finding and extend it to testing the gateway hypothesis. In addition to the two categories of tasks provided participants: a shopping list (e.g. buy lettuce) and an action list (e.g. placing a bottle in recycling bin), our participants will be provided a third category of task that will place relatively heavier demands on internally generated intentions. We will also have participants buy gifts (e.g. 'buy a birthday gift for your best friend'). The three categories of tasks should place differential demands on lateral and medial portions of Area 10. The shopping list generated by the experimenter will place relatively greater demand on medial Area 10 due to the attention to the list of items listed at each virtual store, whereas the more internally generated gift list should place a greater demand on lateral Area 10 due to monitoring internally generated intentions. The action list (e.g. placing a bottle in recycling bin) should result in activity more equally involving the medial and lateral areas due to the demand on monitoring the intended action in accordance with attending to the appropriate stimulus (e.g. recycling bin) when "walking" along the street.

We will use a 16 channel optode array to measure the hemodynamic response to Area 10 with our TechEn CW6 functional near infrared spectroscopy (fNIRS) system. Thirty undergraduates will participate in the experiment, and the optode array will be placed bilaterally over Area 10 according to the 10-20 electrode placement system utilizing head landmarks. Optode arrangement will be verified using the Polehmus 3-d digitizer system in conjunction with Homer 2 Atlas software. Participants will engage in an immersion virtual reality game involving walking along a street. Three categories of tasks will be assigned to the participants: 1) buy item on a shopping, perform a series of activities, and buy gifts, each with hypothesized differences in relative demands placed on the medial and lateral portions of Area 10.

Future Directions

According to the gateway hypothesis, Area 10 is supramodal. That is, its role is independent of the nature of the external stimuli or internal intention. Therefore, Area 10 should be equally involved in coordinating internal and external attention to goal directed behavior of *social* as well as non-social situations. Following the development of a prospective memory virtual reality paradigm for the investigation of Area 10 neural activity, we will develop virtual reality paradigms for the investigation of Area 10 in sociocultural situations. My lab, in coordination with Sharon Goto's lab, has been investigating sociocultural influences on brain activity (*Fong et al., 2014; Goto et al., 2009; Goto et al., 2013; Lewis, et al., 2008; *Park et al. *in press*). More specifically, we have been trying to understand patterns of neural activity that are associated with cultural orientations of the self in relation to others (see Markus and Kitayama, 1991). European American cultures have been characterized as displaying independent self-construal. That is, they view themselves as being autonomous and separate from others. Individuals with independent self-construal emphasize self-reliance, competition, and uniqueness, and see their behavior as resulting from their own internal thoughts, attitudes, and feelings rather than stemming from relations to others. In contrast, East Asian cultures have been characterized as displaying interdependent self-construal. That is, they view themselves as being connected to each other. Individuals with an interdependent self-construal emphasize sociability and in-group harmony, and see their behavior in relation to others' thoughts, attitudes, feelings, and actions. Differences in self-construal have implications for how we think, feel, and behave (e.g., Triandis & Suh, 2002).

One dimension of our research is focused on how biculturals navigate two cultural frameworks. Individuals in multicultural environments often switch between cultural schemas according to the immediate sociocultural context (Hong et al., 2000). We were able to document the switching of neurophysiological activity associated with changes in cultural context (See *Fong et al., 2014). But, this left open the question of which brain area was responsible for the switching. Area 10, with its proposed role in coordinating internal intentions and external cues is a prime candidate for the switch. When biculturals are faced with an independent social context (characteristic of European American culture), we predict that there will be relatively greater activity of the lateral portion of Area 10 due to a greater attention on promoting goals of the self. In contrast, when biculturals are faced with an interdependent social context (characteristic of East Asian cultures), we predict that there will be relatively greater activity of the medial portion of Area 10 due to greater attention to promoting goals of others.

In conclusion, Sontag funding will enable our lab to develop virtual reality paradigms to be used in conjunction with fNIRS measurement of the frontal pole that will provide our students with a unique opportunity to extend our understanding of how Area 10 is involved in navigating multicultural space.

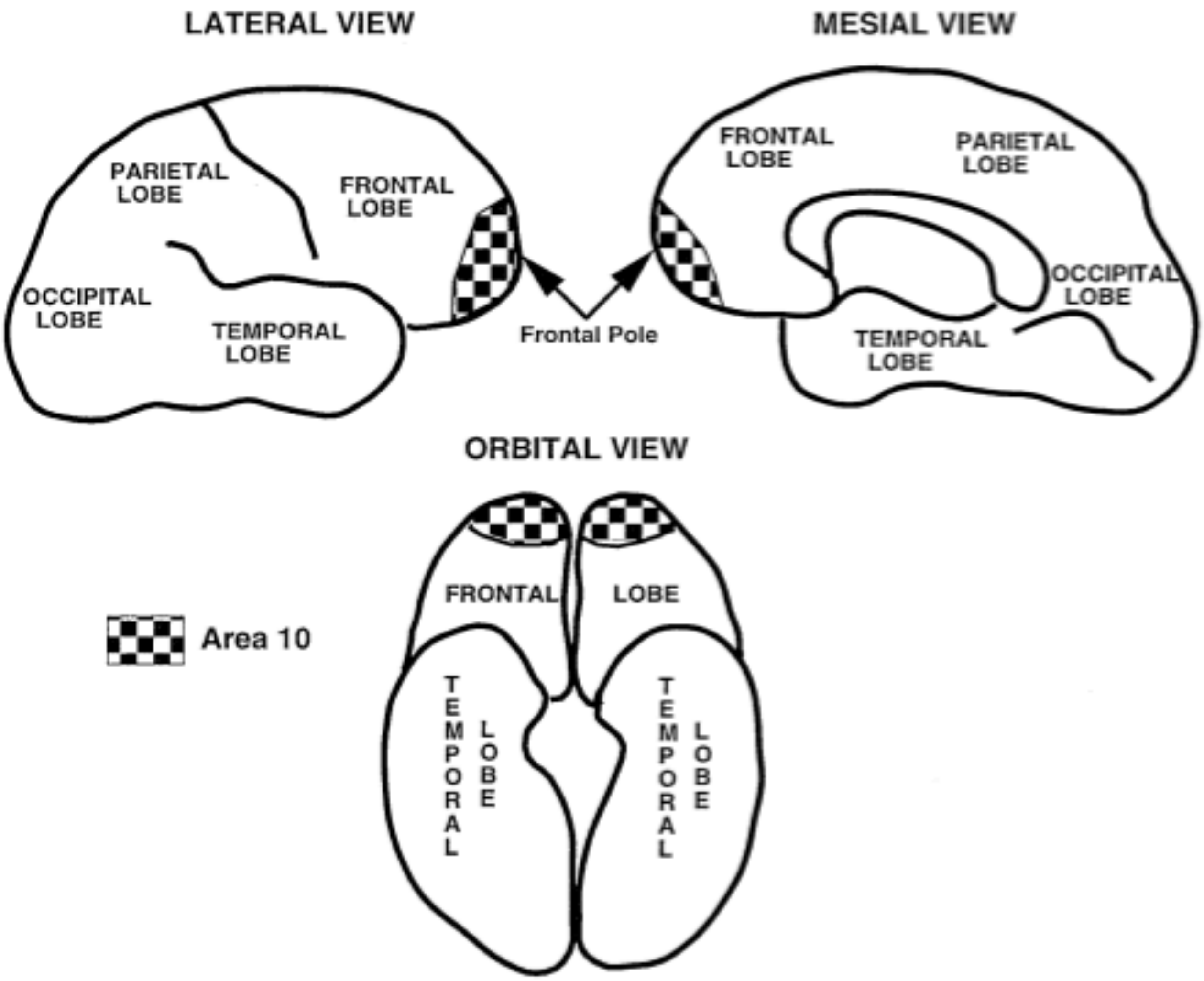

Figure 1: Anterior Frontal Pole (Area 10)

Figure 4. The view of VR shopping street.

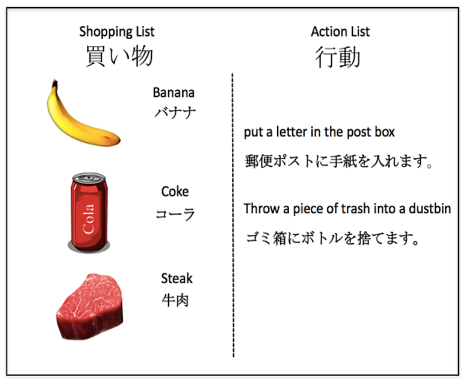

Figure 5. Shopping list and action list.

Figure 6. Example of a shopping menu in a coffee shop.

Figure 2: Prospective Memory Virtual Reality Game (from Dong, Wong & Luo, 2018)

Budget

Subject Payment $750

We will test 30 undergraduates at a rate of $25 per session (1.5 hours)

HTC Vive Pro Virtual Reality Headset with Leap Motion controller $1,200

ITS specialist, Asya Sklyar, recommended this virtual reality configuration for our experiment

1 Dell PC $4,400

ITS specialist, Asya Shklyar, recommended a Dell PC that she recently purchased for CS Department, which includes keyboard, monitor, mouse and 2 CPUs

Programming of VR environment $1,500

The virtual reality environment will need to be programmed. We are estimating 75 hours at $20/hour. We will use free, open source Godot software.

Research Assistant $1,650

Funds for one research assistant working 5 hours per week at $11/hour for 15 weeks in the Fall and 15 weeks in the Spring are being requested.

TechEn manufacture of optode headset $500

We are requesting $500 to cover the design and manufacture of the 16 optode array headset.

Total Requested **$10,000**

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