Using Memory Tasks and the Frontal Eye Field to characterize short-term memory

Katie Showers[1]; Lawrence Snyder, MD, PhD[2]; Charles Holmes[2]
[1]University of Missouri- St. Louis
[2]Washington University in St. Louis, Department of Neuroscience

Introduction

- The frontal lobe is one of the most complex areas of the brain and is most commonly known to regulate impulsivity and decision making. This area is implicated in problem solving, language, social behavior, motor functioning, and memory.
  - Many functions of the frontal lobe are classified as higher order thinking, which is highly correlated with intelligence.
- While cognition is fundamentally important, it lacks a great deal in capacity. Much like the correlation between higher order thinking and intelligence, cognition is also highly correlated with working memory. Working memory, the ability for information to be stored long enough to be used, greatly impacts one's capacity to concentrate, follow directions, and plan for higher-order thinking. The average human can only preserve up to four items at a single given time (Buschman et al.).
  - While capacity's limitations are long studied, the mechanisms underlying short term working memory are not widely understood.
- The vastness and overlap of brain function has prompted scientist to map and label the brain beyond the scope of lobes, but as precise as small areas that are implicated in sense expression and basic body functions.
- The Frontal eye field, stretching across the primary motor cortex and primary sensory cortex, is implicated in controlling visual attention and eye movement. This area is frequently identified via electrical stimulation at a low current, which evokes saccadic eye movement.

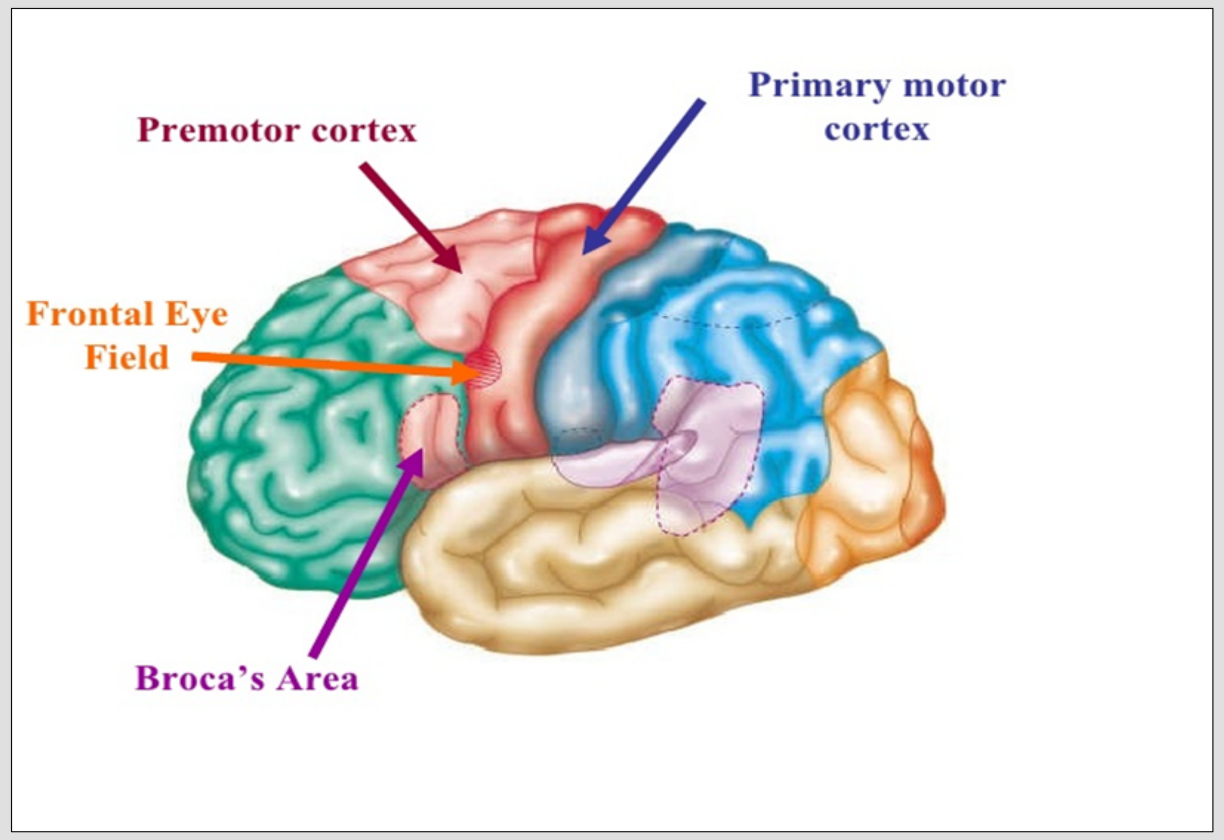

Figure 1. Brain diagram of Rheus Macaque, or Macaca Mulatta. Monkey brains differ from human brains in size and organization.

Materials and Methodology

- **Electrophysiology**
  - Cellular activity within the brain was observed via an implanted recording chamber that housed 32 microelectrodes.
  - Electrodes were advanced within the brain up to three times a week. An electrode impedance checker was used to measure the resistance present within each electrode.
  - Cellular activity was regularly monitored and auditory feedback provided data. A 32 channel box served as auditory access to each channel. One by one, each channel was individually monitored and a decision was made regarding its spatial proximity to a cell. If the audio indicated a cell was close, the microelectrode would not be advanced further into the brain. If there was no auditory indication of cellular presence nearby, electrodes would continue deeper into the brain.
- **Eye Movement & Visually Guided Tasks**
  - Computer processing software measured and calibrated eye position.
  - Three different types of visually guided memory tasks ran in random order. These tasks produced data on correct and incorrect trials, referred to as hits and misses.

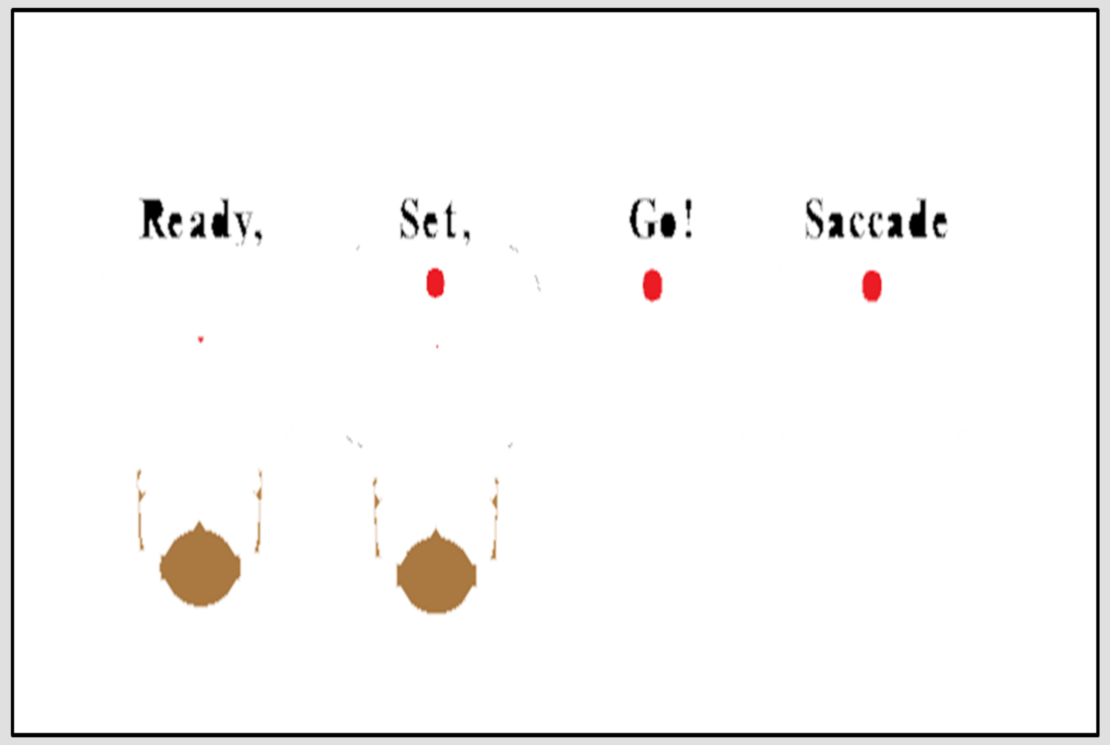

Figure 2. Progression of Visually Guided Memory Task. Time Length and progression of task depends on each Visually Guided Memory Task. **Figure 3.** Progression of the One-Item Memory Task. **Figure 4.** Progression of the Simultaneous Two-Item Memory Task. **Figure 5.** Progression of the Sequential Two-Item Memory Task.

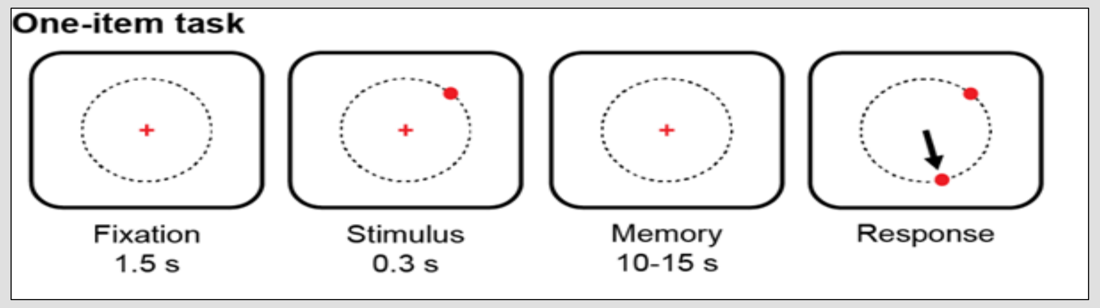

Figure 3.

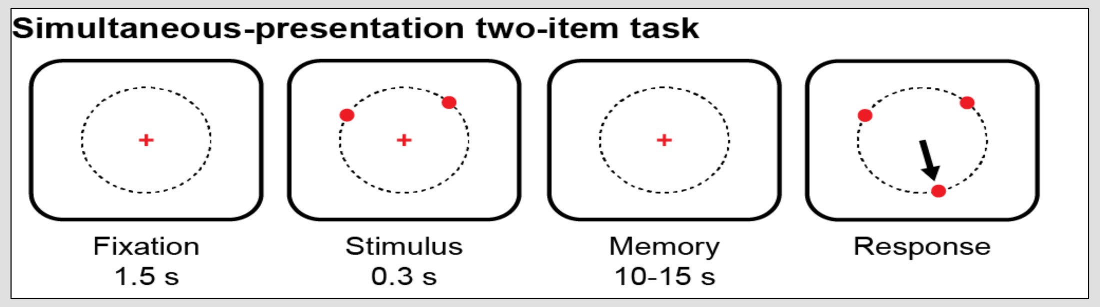

Figure 4.

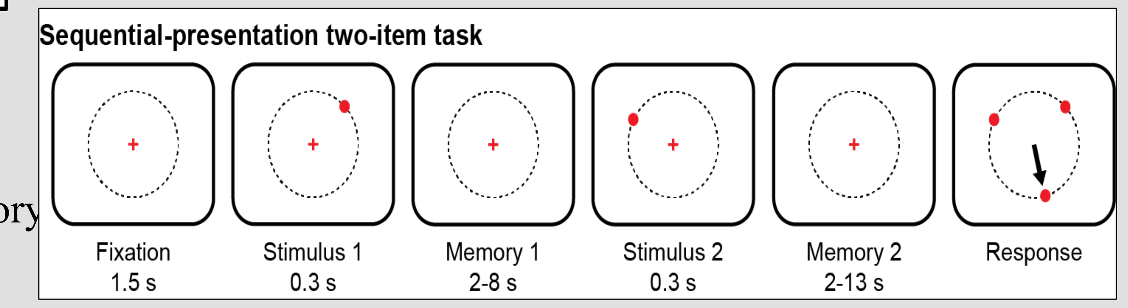

Figure 5.

Results

The results presented are just a portion of this research experiment and the experiment is ongoing.

The One-item Memory Task had a total of 9,365 attempts. Out of these attempts, 7,784 were hits and 1,581 were misses. The percentage of hits in the One-Item Task is 83.12%. The Two-Item Simultaneous Memory Task had a total of 10,346 attempts. Out of these attempts, 7,832 were hits and 2514 were misses. The percentage of hits in the Two-Item Simultaneous Task is 75.7%. Lastly, the Sequential Two-Item Memory Task had a total of 19,762 attempts. Out of these attempts, 15,232 were hits and 4,530 were misses. The percentage of hits in this task is 77.1%.

Attempts to evoke saccades with 60 μA of current were unsuccessful. Low current was increased to 100 μA and saccades were produced. These saccades were not replicable. Current was then increased to 200 μA and saccades were produced and reproduced.

Future Work

Future work in regards to this research includes studying the ways in which the allocation of scarce resources impacts memory capacity and duration, as well as examining the relationship between local field potential rhythms and memory encoding. The overarching goal of this study is to characterize the circuitry of working short term memory. The results produced will challenge current circuitry and input/output mappings.

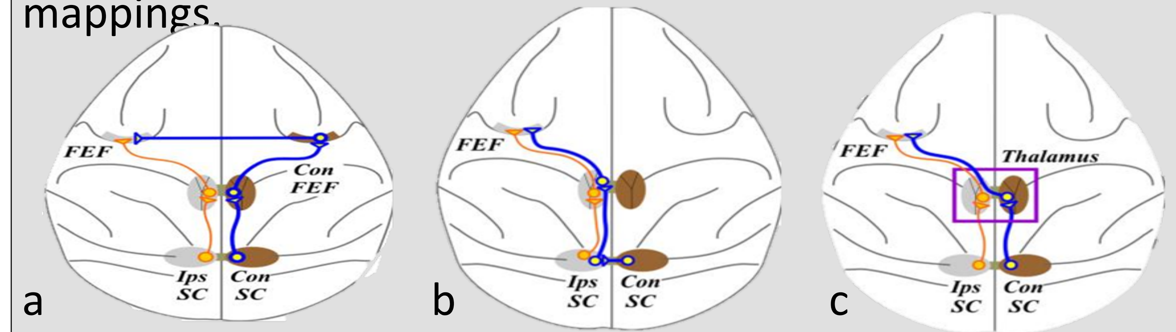

Figure 6. Hypothetical Routes for Crossed Connections proposed in Craspe, T.B. & Sommer, M.A (2009).

References

- Bruce, C. J., & Goldberg, M. E. (1985). Primate Frontal Eye Fields. I. Single Neurons Discharging Before Saccades. *Journal of Neurophysiology, 53*, 603-635.
- Bruce, C. J., Goldberg, M. E., Bushnell, M. C., & Stanton, G. B. (1985). Primate Frontal Eye Fields. II. Physiological and Anatomical Correlates of Electrically Evoked Eye Movements. Journal of Neurophysiology, 54, 714-734.
- Buschman, T. J., Siegel, M., Roy, J. E., & Miller, E. K. (2011). Neural substrates of cognitive capacity limitations. *Preceedings of the National Academy of Sciences of the United States of America, 108, 27,* 11252-11255.
- Craspe, T.B. & Sommer, M.A. (2009). Frontal eye field neuron with spatial representations predicted by their subcortical input. *Journal of Neuroscience, 29, 16*, 5308-5318.

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