Working Memory Recall and Recognition in mTBI

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Abstract: Undergraduates with a history of mild traumatic brain injury (hmTBI) exhibit visual working memory (VWM) deficits. Most VWM tests rely on *recognition*, which engages posterior parietal structures. *Recall* tests are more demanding, and depend on frontal networks. We propose to test participants with or without hmTBI in a VWM task tested by recognition or recall. We predict replicating our finding of worse VWM in the hmTBI group. We also predict there will be greater deficits in VWM tested by recall than recognition.

Introduction: Mild traumatic brain injury (mTBI), or concussion, is an increasing public health concern with an estimated two million seeking treatment per year in the U.S.[1] Many who sustain an mTBI do not seek treatment,[2] so its prevalence is likely underestimated. It is expected that symptoms of mTBI (e.g., issues with attention, processing speed, and memory) fully resolve within three months of injury.[3] However, a subset of individuals continue to report symptoms after this period,[4] which suggests mTBI may have persistent cognitive consequences.

The remote effects of mTBI on cognitive function remain unclear. Working memory (WM) is the ability to hold onto and manipulate information over brief durations. In a decade of past research, we found that undergraduates with a history of mTBI (hmTBI) >4 years post-injury exhibited worse visual WM (VWM) than those without hmTBI when probed by old/new recognition.[5] We note that we did not observe worse VWM in 2022-2023 participants. In addition, previous research suggests impulsivity is linked to differences in executive function. Impulsive individuals are more likely to sustain head injuries.[6,7] Therefore, in this project, we are interested in whether impulsivity is higher in the hmTBI group.

Here, we propose investigating mTBI's effect on VWM in finer detail by assessing recall. Unlike with recognition, probing WM with recall requires individuals to reproduce remembered stimuli. This provides insight into the precision of retained representations, which is not possible with old/new recognition paradigms. WM *recognition* requires parietal structures,[8,9] whereas WM *recall* requires frontal networks.[9] Because of the heterogeneity of mTBI injuries, it is important to clarify who is likely to have lasting cognitive changes, and why. By examining the relationship between potentially different areas of damage and cognitive outcomes the current experiment will allow us to try to predict what kind of mTBI impact causes VWM deficits.

The Memory and Brain Lab studies WM. As a research assistant, I have learned to properly consent and test human research participants and to use computer programs to create behavioral tasks. I propose to examine the relationship between hmTBI status, VWM recall, and VWM recognition. We would record accuracies in a recognition task and degrees of error in a recall task. We would also record participants' levels of impulsiveness to see whether it is higher in the hmTBI group than in controls and is associated with hmTBI deficits. This research would add to our understanding of the fine-grain impacts of mTBI.

We predict that hmTBI students will have lower performance and lower precision than students without hmTBI. Moreover, we predict that hmTBI will perform worse on recall than recognition in blocked trials. If there are VWM deficits in hmTBI, we also predict greater impulsivity would relate to worse performance.

Objectives:

- Gain additional experience in independent coding of behavioral experiments in MATLAB
- Learn how mTBI affects frontal vs. parietal structures
- Expand the mTBI literature to understand fine-detailed differences in WM

Plans for Research: We plan to recruit undergraduates with and without hmTBI from SONA (Psych Pool) and outside SONA using gift cards as compensation ($10/hr). Our previous study on mTBI and WM included 18-25 participants per group and reported a large effect size of group (Cohen's d = .92).[10] Therefore, we plan to collect at least 25 per group (hmTBI/control) to ensure adequate power and similar effect sizes. We will screen participants with a color vision assessment. Each participant will complete two computer-based VWM tasks, an mTBI symptom inventory, and the BIS-Brief. During the VWM recall task, we will record the degree of error in each trial to calculate precision. During the VWM recognition task, we will record accuracy data. We will look at the effect of blocking vs. intermixing trials from both tasks to tease apart frontal or parietal damage. We will also look at impulsivity as a covariate to see if it influences the effect of group. We will analyze data with a three-way ANCOVA, as we have one between-subjects variable (group), two within-subjects variables (task and trial type), and a covariate (impulsivity).

Color Vision Assessment: The tests require color vision. To ensure participants can see the colors we use, we will screen them with the simplified 6-plate version of the Ishihara's test for color blindness.[11]

MTBI Symptom Inventory: To define hmTBI status, we will ask participants to complete 10 questions of demographic information and whether they have had a mTBI. If an individual reports hmTBI, we will ask 10 follow-up questions regarding details of their injury (e.g., time of injury, loss of consciousness, location of impact, etc.). Additionally, we will ask individuals with hmTBI to rate the severity of 28 potential symptoms at the time of injury and currently.

Impulsiveness Questionnaire: We will use the Barratt Impulsiveness Scale-Brief (BIS-Brief) to obtain a unidimensional measure of impulse control.[12] It uses a four-point Likert scale and comprises eight of the 30 items from the BIS-11.[13,14] Response options range from 1 = "Never/Rarely" to 4 = "Almost Always/Always." The BIS-Brief provides a score ranging from 8-32, with a greater score indicating higher impulsivity.

VWM Tasks (Recall, Recognition): We will replicate the VWM tasks from Zhang and Luck.[15] In each trial, participants encode a sample array of three colored squares (100 ms). A WM delay (900 ms) will follow. In recognition trials, participants report whether a single square matched the corresponding sample square (50% same, 50% off by 180 degrees in color space) in color via key press. In recall trials, participants report the color of a square in the original sample (indicated by a thick outline box) by clicking on a color wheel. The wheel will have 180 colors distributed equally across CIE *L*a*b** color space and rotate between trials. We will look at performance in blocking and intermixing trials.

Timeline

1/22 - 2/12	Program and pilot experiment
2/12 - 4/23	Data collection; begin writing paper
4/23 - 5/7	Data analysis; poster development

Dissemination of Results: I will present at the Wolf Pack Discoveries 2024 Spring Symposium and hope to submit for Cognitive Neuroscience Society (December abstract deadline, Spring Conference).

Human Subjects: *IRB approval is in place* regarding this minimal-risk study. Participants will view images on a screen and hit buttons. The inclusion criteria consist of being 14 years or older and having normal or corrected to normal color vision.

References

1. Roy D, Ghosh A, Yan H, et al. Prevalence and Correlates of Depressive Symptoms Within 6 Months After First-Time Mild Traumatic Brain Injury. *J Neuropsychiatry Clin Neurosci*. 2022;34(4):367-377. doi:10.1176/appi.neuropsych.21080207
2. Demakis GJ, Rimland CA. Untreated Mild Traumatic Brain Injury in a Young Adult Population. *Arch Clin Neuropsychol*. 2010;25(3):191-196. doi:10.1093/arclin/acq004
3. McInnes K, Friesen CL, MacKenzie DE, Westwood DA, Boe SG. Mild Traumatic Brain Injury (mTBI) and chronic cognitive impairment: A scoping review. Kobeissy FH, ed. *PLOS ONE*. 2017;12(4):e0174847. doi:10.1371/journal.pone.0174847
4. Prince C, Bruhns M. Evaluation and Treatment of Mild Traumatic Brain Injury: The Role of Neuropsychology. *Brain Sci*. 2017;7(12):105. doi:10.3390/brainsci7080105
5. Arciniega H, Shires J, Furlong S, et al. Impaired visual working memory and reduced connectivity in undergraduates with a history of mild traumatic brain injury. *Sci Rep*. 2021;11(1):2789. doi:10.1038/s41598-021-80995-1
6. Arciniega H, Kilgore-Gomez A. Loss of consciousness, but not etiology, predicts better working memory performance years after concussion. *J Clin Transl Res*. Published online 2020. doi:10.18053/jctres.05.2020S4.003
7. Romer D. Adolescent risk taking, impulsivity, and brain development: Implications for prevention. *Dev Psychobiol*. 2010;52(3):263-276. doi:10.1002/dev.20442
8. Berryhill ME, Wencil EB, Branch Coslett H, Olson IR. A selective working memory impairment after transcranial direct current stimulation to the right parietal lobe. *Neurosci Lett*. 2010;479(3):312-316. doi:10.1016/j.neulet.2010.05.087
9. Berryhill ME, Chein J, Olson IR. At the intersection of attention and memory: The mechanistic role of the posterior parietal lobe in working memory. *Neuropsychologia*. 2011;49(5):1306-1315. doi:10.1016/j.neuropsychologia.2011.02.033
10. Arciniega H, Kilgore-Gomez A, Harris A, et al. Visual working memory deficits in undergraduates with a history of mild traumatic brain injury. *Atten Percept Psychophys*. 2019;81(8):2597-2603. doi:10.3758/s13414-019-01774-9
11. Ishihara S. *Ishihara's Tests for Colour-Blindness 38 Plates Edition*. Kanehara Shuppan Co., Ltd.; 1992.
12. Steinberg L, Sharp C, Stanford MS, Tharp AT. New tricks for an old measure: The development of the Barratt Impulsiveness Scale–Brief (BIS-Brief). *Psychol Assess*. 2013;25(1):216-226. doi:10.1037/a0030550
13. Patton JH, Stanford MS, Barratt ES. Factor structure of the Barratt impulsiveness scale. *J Clin Psychol*. 1995;51(6):768-774. doi:10.1002/1097-4679(199511)51:6<768::aid-jclp2270510607>3.0.co;2-1
14. Stanford MS, Mathias CW, Dougherty DM, Lake SL, Anderson NE, Patton JH. Fifty years of the Barratt Impulsiveness Scale: An update and review. *Personal Individ Differ*. 2009;47(5):385-395. doi:10.1016/j.paid.2009.04.008
15. Zhang W, Luck SJ. Discrete fixed-resolution representations in visual working memory. *Nature*. 2008;453(7192):233-235. doi:10.1038/nature06860