The Impact of Mindfulness Training on Working Memory Performance and White Matter Microstructural Integrity in Major White Matter Tracts Associated With the Hippocampus

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Overview

- We found that mindfulness training (MT) resulted in significant differences in white matter microstructural integrity (WMMI), as quantified by diffusion metrics, within major white matter tracts associated with the hippocampus including the right ventral portion of the cingulum bundle (R CBV), the left dorsal portion of the cingulum bundle (L CBD), and the left uncinate fasciculus (L UF).
- Post-MT, participants showed significantly greater scores on working memory performance (WMP) scores which was associated with increases in L CBD WMMI.

Background

- Alterations in hippocampal structure and function, associated with healthy aging, have been hypothesized to underlie decreases in cognitive performance
- Older adults consistently show declines in performance on tasks that require quick processing and/or transforming of information in order to make a decision. This cognitive domain is known as working memory.
- Several computer-based working memory interventions (WMI) have been designed to preserve WMP in aging adults. Investigations into the efficacy of these interventions have produced mixed results, potentially due to the numerous methodological limitations.
- Growing evidence suggests that mindfulness-based interventions (MBI) may reduce normal age-related cognitive declines and thus, may be an alternative method to promote WMP.

Methods

- 96 participants were recruited for random assignment to either an 8-week MT (n=47) or cognitive fitness training (CFT) (n=49) program.
- The MT program, derived from mindfulness-based stress reduction (MBSR), teaches mindfulness meditation exercises to participants in order to promote attention and memory. Mindfulness instruction varied each week, as follows: Weeks 1 and 2- breath meditation and body scan; Week 3- walking meditation; Week 4- mental noting; Week 5- focus on the five senses and sensations; Week 6- standing meditation; Week 7- mindful eating and the five senses; and Week 8- review all techniques.
- Weekly instruction in the CFT program included: Week 1- word search and crossword puzzles; Week 2 & 3- Sudoku; Week 4- word jumbles; Week 5 & 6- KenKen; and Week 7 & 8- review. Each participant received puzzles at a constant difficulty level, based on their individual puzzle-solving abilities.
- WMP was measured by the mnemonic similarity task (MST) (Figure 1).
- Structural MRI and DTI were collected pre- and post-intervention and subsequently processed using Freesurfer 7.2.0. Ten major WM tracts associated with the hippocampus were reconstructed with Freesurfer's TRACULA (Figure 2).
- All statistical analyses were performed on Rstudio.

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Figure 1: *Mnemonic Similarity Task (MST) Procedure*

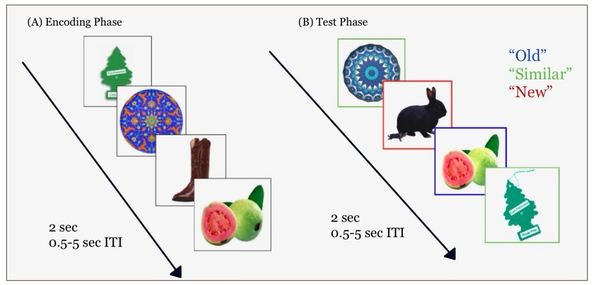

Figure 1: *During the MST (A) encoding phase, participants are presented with images of random everyday objects for 2 seconds, with randomized inter-trial intervals (ITI) between 0.5 and 5 seconds. In the test phase (B), participants must identify images within one of the three trial categories: indistinguishable from the encoding image ("Old"), similar to the encoding image ("Similar"), or not seen before ("New"). Participants indicated their responses by pressing a button with their index, middle, and ring fingers to indicate the three trial categories.*

Figure 2: *Visualized reconstructed WM pathways*

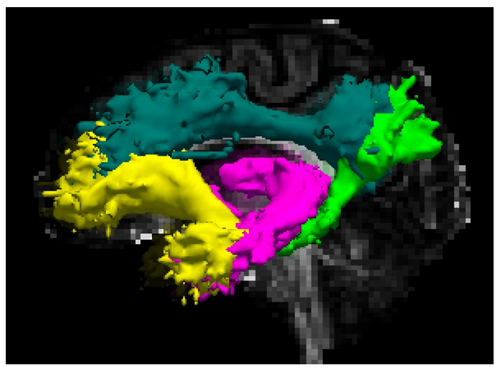

Figure 2: *A left sagittal view of pathways reconstructed automatically with TRACULA: fornix (magenta), uncinate fasciculus (UF) (yellow), dorsal portion of cingulum bundle (CBD) (teal), ventral portion of cingulum bundle (CBV). The distribution of each pathway is displayed as an isosurface over the T1 image of a randomly selected control participant.*

Figure 3: *Violin Plots of Extracted Diffusion Metrics*

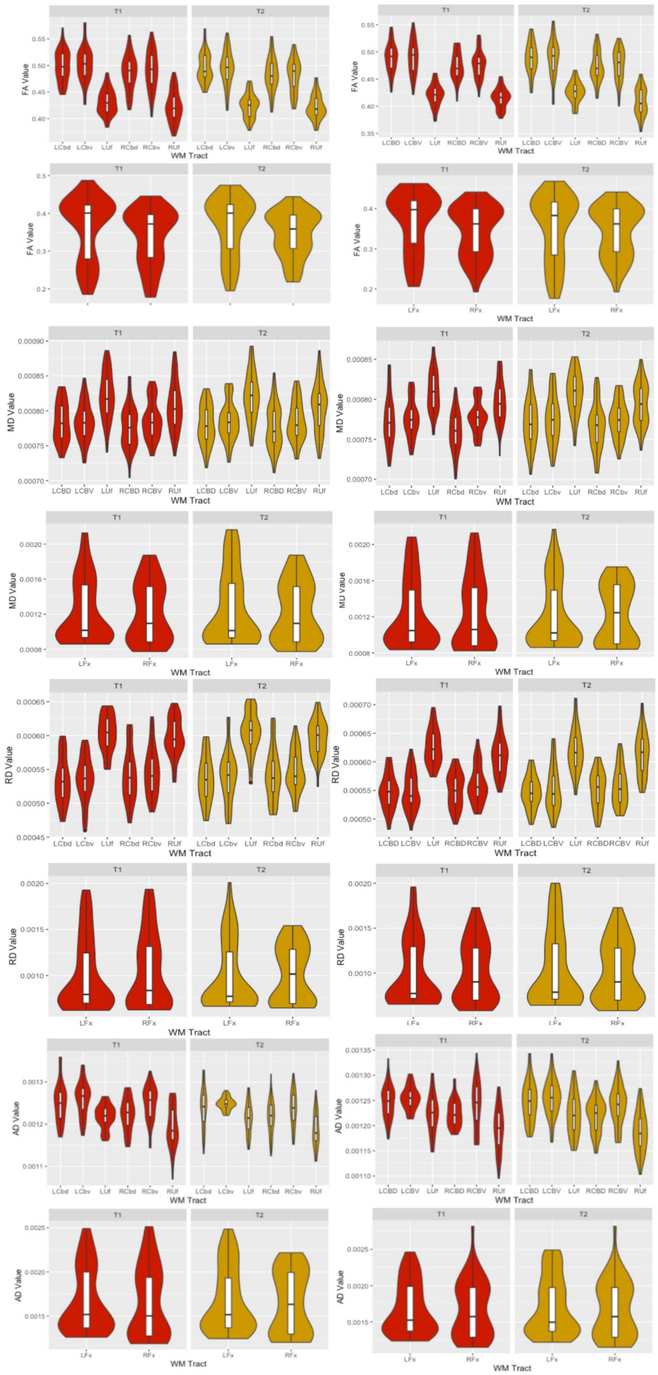

Figure 3 (Right): *Graphs displaying distribution of mean FA (A), MD (B), RD (C), and AD (D) values in participants pre- and post- (T1 and T2, respectively) MT, left, and CFT, right. Diffusion metrics within the fornix typically span a wider range compared to other selected ROI's. As such, value distribution in this region is displayed separately.*

Figure 4: *Change in LDI Scores pre- versus post-intervention*

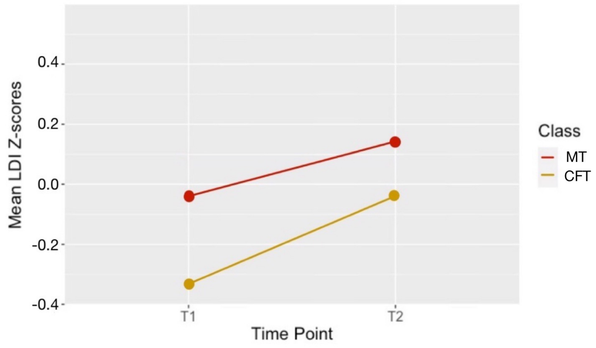

Figure 4: This graph displays the relationship between average L CBD MD values and LDI Z-scores, supporting LMM results. The dark-red regression line, surrounded by a 95% confidence band, is superimposed on the data.

Figure 5: *The relationship between Average L CBD MD values and LDI Z-Scores Post-Intervention*

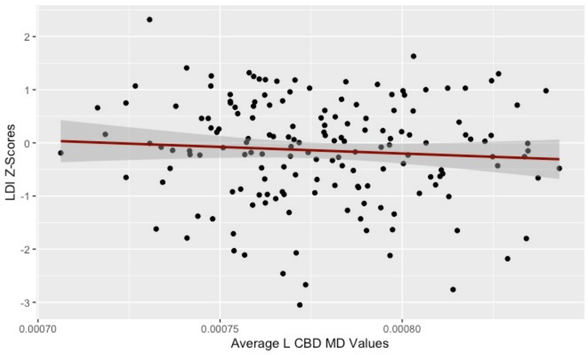

Figure 5: This graph displays the relationship between average L CBD MD values and LDI Z-scores, supporting LMM results. The dark-red regression line, surrounded by a 95% confidence band, is superimposed on the data.

Conclusions

- Compared to CFT, MT may result in distinct WMM alterations within the R CBV and L CBD thereby promoting WMP.
- Significant differences in WMMI within the UF may reflect benefits of socialization
- These results support the implementation of MT, and other similar MBI's, as an alternative approach to improving WMP in older adults.
- Future investigations are necessary to improve current methodological limitations and to elucidate the long-term effects of MBI's on WMP compared to existing interventions.