Visual Contour Integration in mild Traumatic Brain Injury reveals increased internal noise

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Introduction

Visual complaints are common among mTBI patients (GCS 13-15). Diffuse axonal injury as well as other transmitter disruptions linked to mTBI could potentially increase cortical processing noise across various systems. The integration of simple elements into complex contours engages both low-level and mid-level areas of the visual cortex. Measuring perceptual performance as a function of added external noise allows us to make inferences regarding underlying circuits. Using the Linear Amplifier Model (LAM), we estimated internal noise and efficiency of the visual system for continuity discrimination. In four quadrants, we probed internal noise (computation of the brain) as well as efficiency (how well your brain makes use of information).

Good Continuity task

Fig. 1: The lesser the amplitude modulation, the harder it is to discriminate between good and bad contours, even more so when external noise is added to all elements.

Methods and Materials

2 Groups 4 Quadrants 3 Noise levels
Participants: 38 mTBIs (27F, 11M), 21 controls (11F 10M)
Experimental set-up: 4AFC, 40 trials, 12 reversals
Stimuli: four contours (1 quadrant), one good continuity contour
Performance dependent staircase: modulation of curvature depending on performance at precedent trials (2Down 1Up)
Orientation Noise: Level 1 SD=0°, Level 2 SD=8°, Level 3 SD=16°

Analysis

Psychometric functions show that thresholds differ between groups.

Linear Amplifier Model

Fig. 3: Quadrant specific psychometric functions, Control Subj. 2
Fig. 4: Thresholds plotted as a function of external noise, Control Subj. 2

Results

Fig. 7: Increase in internal noise across quadrants in the mTBI group

Internal noise:

TBI patients exhibited significantly higher internal noise than control subjects (p = 0.034).

Efficiency:

Both groups were more efficient in the lower visual field (p = 0.0005).

When we ordered quadrants, we found a simple effect in the TBI group only where the "noisiest" quadrant tended to be in the upper visual field (p = 0.012).

Conclusion

TBI patients have higher internal noise across all quadrants compared to controls. The hemi-field biases observed for the internal noise and the efficiency in the TBI group are absent in the control group, suggesting a further imbalance incurred after TBI.

The difference in internal noise suggests that TBI could disrupt signals anywhere along the early visual areas, impairing integration by injecting noise in the representation of individual elements, or in the pooling processes that construct higher-order representations.

This novel integration task is a powerful probe for cortical noise and efficiency, promising for other types of injuries or diseases (i.e. strokes, autism, schizophrenia etc.).

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References