Vestibular involvement in cognition: Visuospatial ability, attention, executive function, and memory


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Group 7: A Cognitive Training Quiz Application

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Project: A Cognitive Training Quiz Application

• Web application for visuospatial cognitive training and testing
• Based upon an existing pen-and-paper set of exercises and exams.
  • Paper exam designed to be taken with assistance from clinician
• Electronic format allows for accessibility, data collection & interactivity
  • Measure per-question response latency
  • Instant feedback
Paper Selection

“Vestibular involvement in cognition: Visuospatial ability, attention, executive function, and memory”

• Review paper
  • Studies investigating the contribution of the inner ear vestibular system on cognitive function

• Relevance: background & motivation
  • Overview of visuospatial cognitive functions
  • Methods for assessing visuospatial cognitive ability
Background

Visuospatial ability: the ability to comprehend and organize space

• Spatial memory
  • The ability to retain certain types of information about the environment:
    • Geometry
    • Relative positions and distances
    • Size
    • Orientation

• Navigation
  • The ability to move purposefully through the environment

• Mental rotation
  • The ability to determine whether similar objects at different orientations are identical
Assessing Spatial Memory

Morris Water Maze Task
• Primarily for animals (lab rats)
• Participants repeatedly dropped into pool
• Navigate to invisible platform
• External visual cues for reference
Assessing Spatial Memory (cont’d)

Virtual Morris Water Maze Task
• Electronic analog for humans
• Patients with bilateral vestibular dysfunction perform worse
  • Longer path length
  • Less time spent in correct quadrant
Assessing Spatial Memory (cont’d)

Corsi block test
• Participants are shown sequence tapped on blocks
• Must repeat sequences
  • Sequences grow progressively longer
• Vestibular deficit leads to poorer performance
Assessing Navigational Ability

- Movement along memorized paths or towards memorized targets
- Patients with vestibular function have impaired navigational ability
  - Particularly when blindfolded
- Compensation occurs after loss of vestibular input
  - Visual and somatosensory cues allow for maintained balance
  - Cognitive visuospatial deficit persists
Assessing Mental Rotation Ability

• Two similar objects in different orientations:
  • Identical or not?

• Patients with vestibular deficits perform worse
Summary of Results

• Patients with vestibular deficit do worse on cognitive tasks that don’t require vestibular input
  • Tests taken seated, stationary
  • Findings suggest vestibular input important in forming a mental representation of 3-dimensional space

• Explanation?
  • Kahneman’s Capacity Model of Attention
    • Limited pool of attention and cognitive resources
    • Brain allocates to mental tasks
    • Balancing is harder for individuals with vestibular deficit, requires more cognitive resources
Interesting Digressions/Additional Review Topics

• Vestibular experiments... in space
  • Reduced visuospatial ability and attention in astronauts

• Vestibular stimulation
  • Attempting visuospatial tasks while being physically rotated
    • Mental rotation is easier in the direction of physical rotation
Significance

• Methodology for assessing cognitive visuospatial ability
  • Analogous assessments: coverage (somewhat inherent by design)
    • Corsi box test for Spatial memory
    • Navigation
    • Rotation of objects
  • Prior attempts at translating these tests into electronic format
    • Validation studies compare effectiveness
Assessment

• Review spans many independent studies; results indicate fairly decisively that a vestibular deficit causes cognitive deficit
• Some studies have small sample sizes - ~10 patients, 10 control
• Does Kahneman’s attention model really explain why this happens?
  • In all likelihood, yes. However:
  • 2002 Yardley et al. dual-task study – statistically significant
    • Hypothesis testing: merely shows a difference in distribution in the populations
  • Patients with vestibular deficit tend to perform worse on cognitive tests of all sorts, even under regular testing conditions
Conclusion/Application

• Assessment is only part of our project; we also attempt to provide cognitive training that can help patients improve their visuospatial abilities.

• We assess the same major components of cognitive visuospatial ability:
  • Spatial memory, navigation, mental rotation
  • Fairly analogous assessments to those in wide usage