# Assessment and training of visuospatial cognitive functions in virtual reality: proposal and perspective

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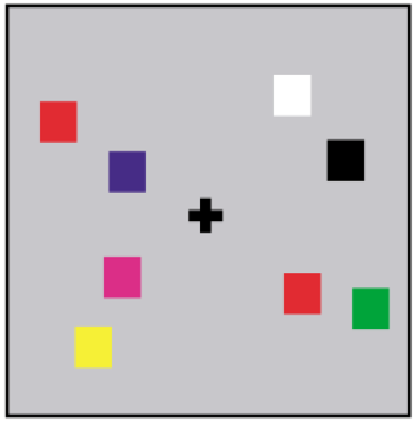
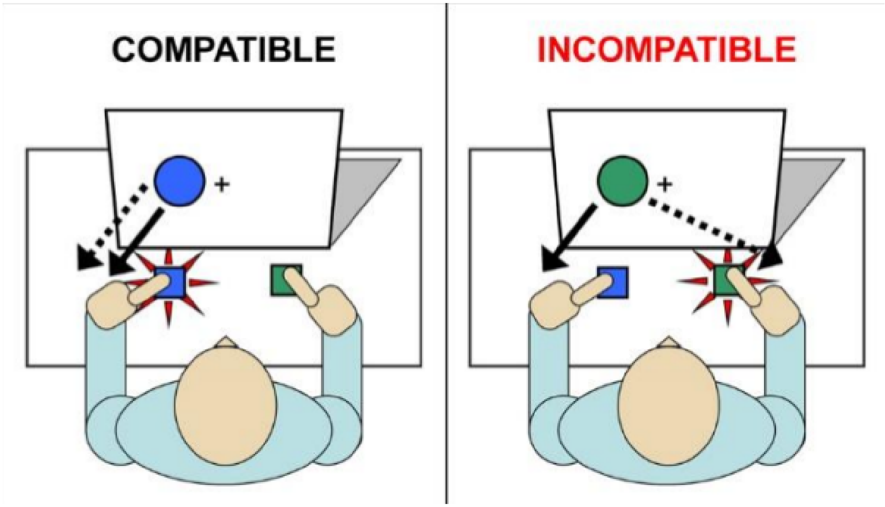
# Visuospatial functions

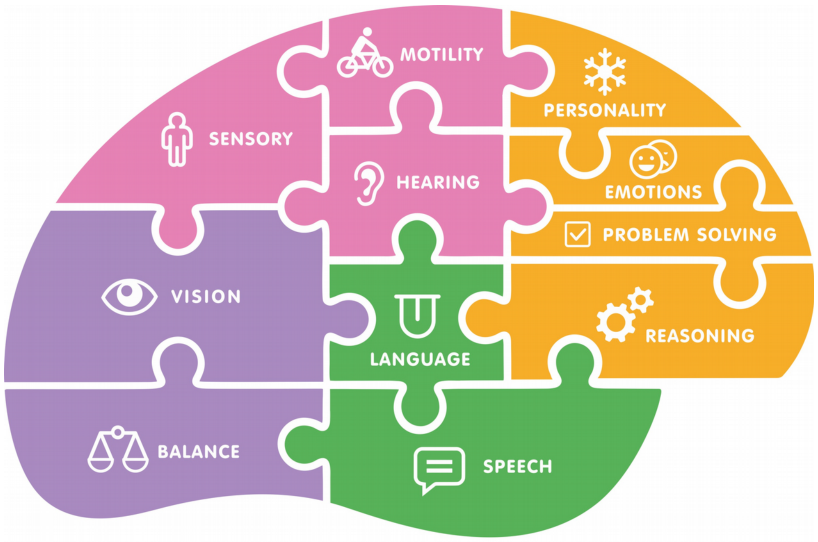
- detection, representation, manipulation, and storage
- allow us to perceive objects, locate their position in space, orient our attention, infer spatial relations, and remember the scene
- enable performing judgments related to direction and distance among external objects and thus allow us to navigate
- focus of psychologists and neuroscientists who have tools how to measure, train and restore them (Baddeley, 2012; Shepard & Metzler, 2011; Polaná et al., 2012; Toril et al., 2016; Barman et al., 2016)



# Linking behavior to brain

- cognitive neuroscience approach



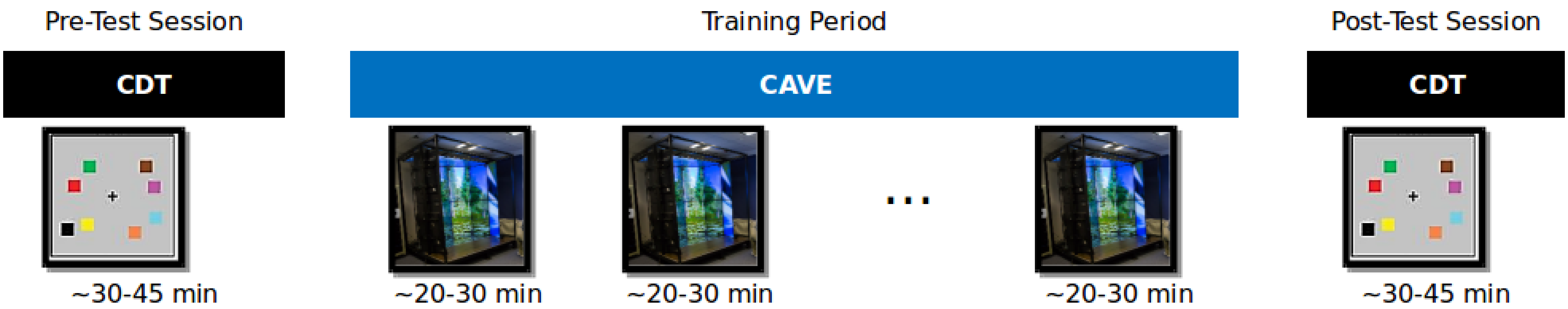
# Testing visuospatial functions

- focus on either simple (automatic) processes or complex ones (deliberative), involving visuospatial short-term or working memory, mental rotations, and executive visual attention (Dijkstra, et al, 2017; Shipstead, 2012)
- Trainings and restoration programs employ brain plasticity (Paulus, 2011)
- Typical training/testing in 2D (reduction of real-life complexity)
- Concerns can be raised w.r.t. (Neubauer et al., 2010)
  - ecological validity
  - generalization of the findings
  - optimization of the training and restoration programs

# Using virtual reality games

- (3D) virtual environments may modulate neuropsychological measures (Schultheis et al, 2002; Matheis et al, 2007; Parsons et al, 2017)
- Research question: Which elements of VR games can lead to improvements of selected cognitive functions?
- Design criteria:
  - natural inclusion of physical space (of the CAVE) to game design
  - adherence to the cognitive goals
  - appropriate difficulty
  - relatively fast and effective implementation

# Experiment design

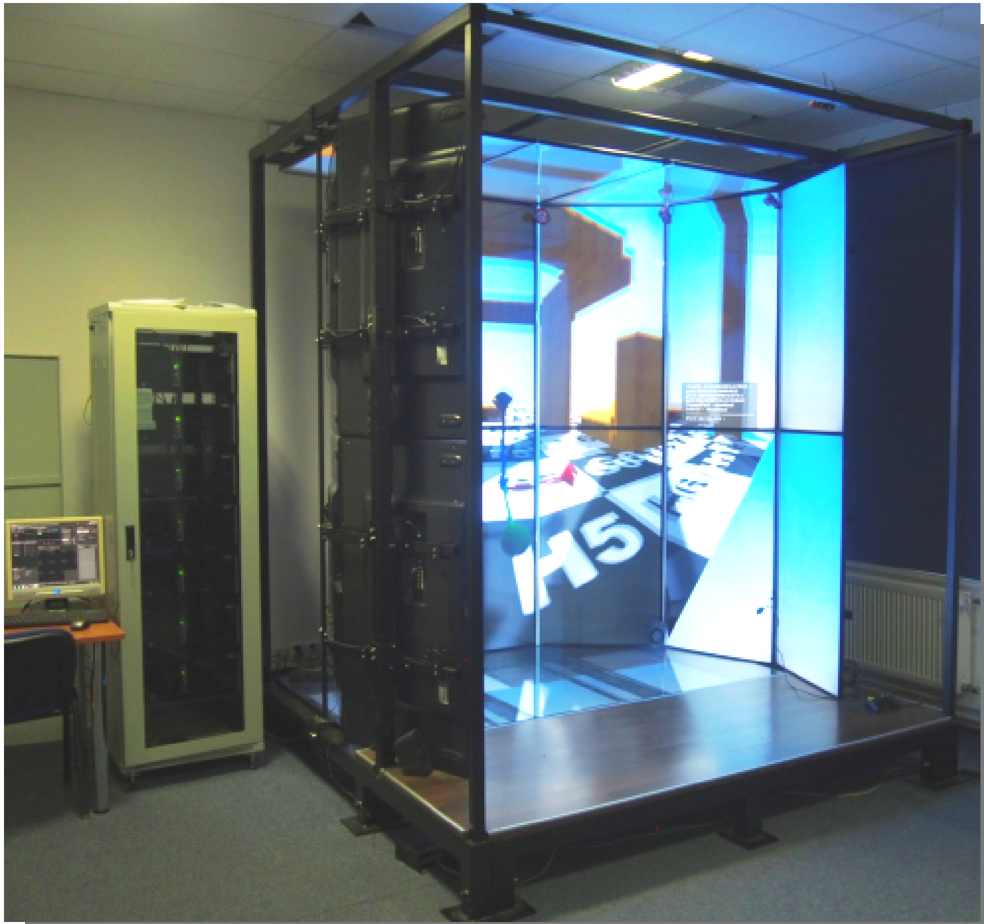



- Experimental group (n=15+): 2-3x CDT to control learning effect, 2-3 EEG measurements (16 channels in posterior cortex), 10 trainings within 2-3 weeks
- Control group (n=15+): no treatment (training)
- User questionnaire to fill-in (current emotions, immersion...)
- Preselection of participants, match-pairs,...

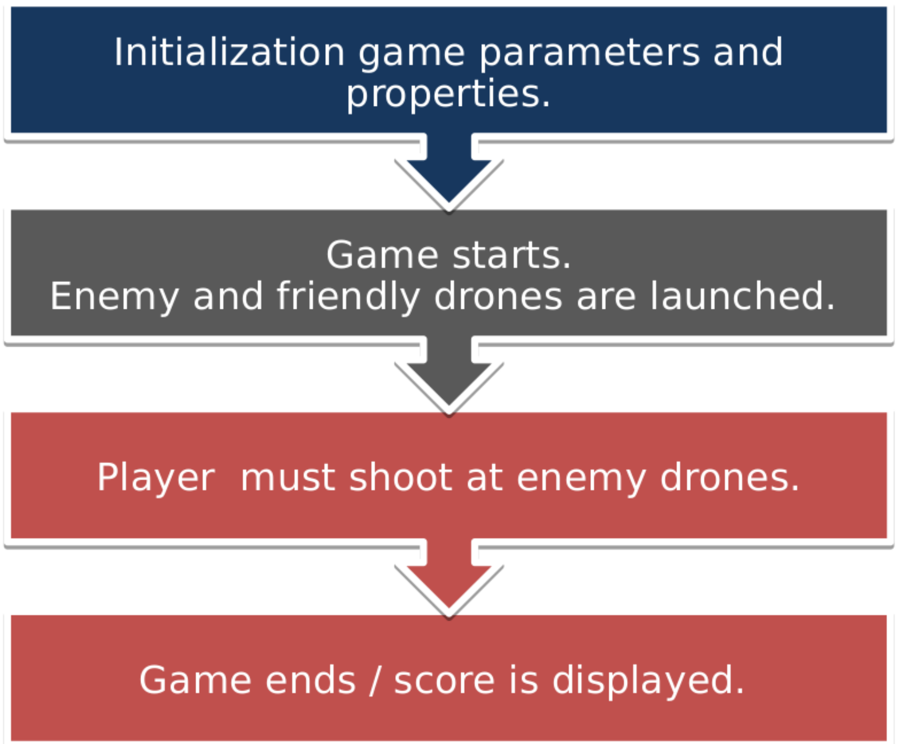
# CAVE system

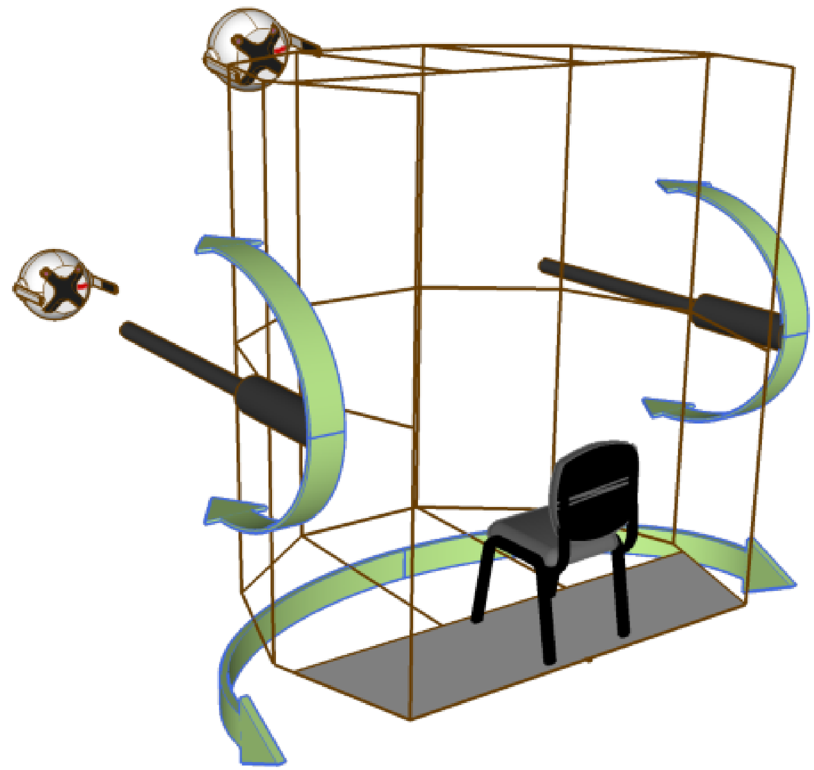
- Compact fully immersive VR environment - 2.5 x 2.5 x 3 m display area
- 250 degree panoramic view
  - provided by 20 LCD screens
- 7 sided hexagon shape
- Computing cluster sctructure
- Head Tracking (OptiTrack)
- OpenSG visualisation core

(Built at LIRKIS lab, TU Košice



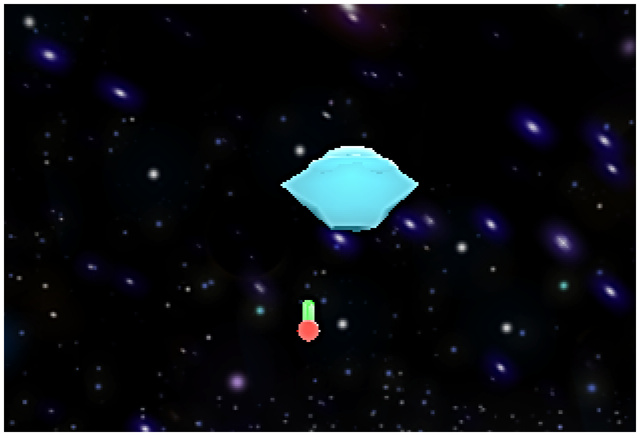
# Tower defense game

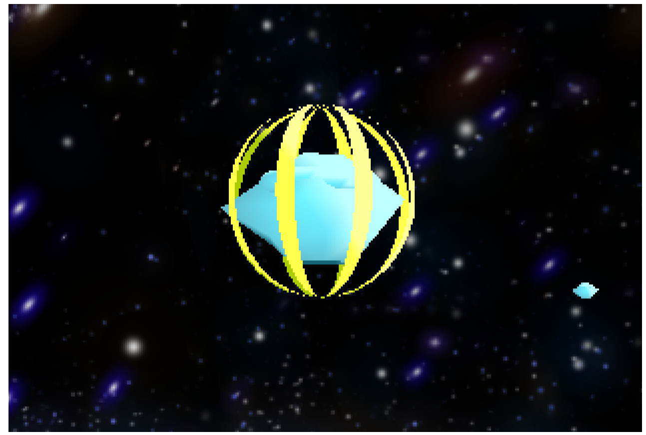


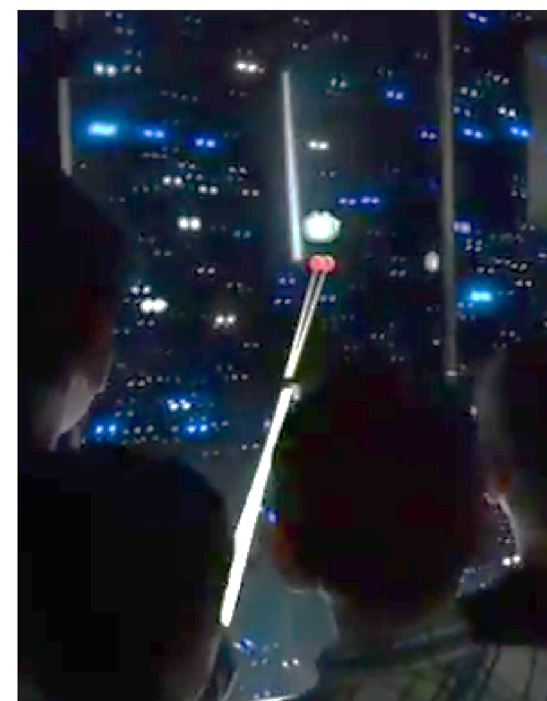
- Several levels of difficulty (increasing $\rightarrow$ CogInfoCom)
  - to preserve “flow” (Csíkszentmihályi, 1975)
- Friendly objects can change after some time, partial visibility possible

# TD game parameters and visualization



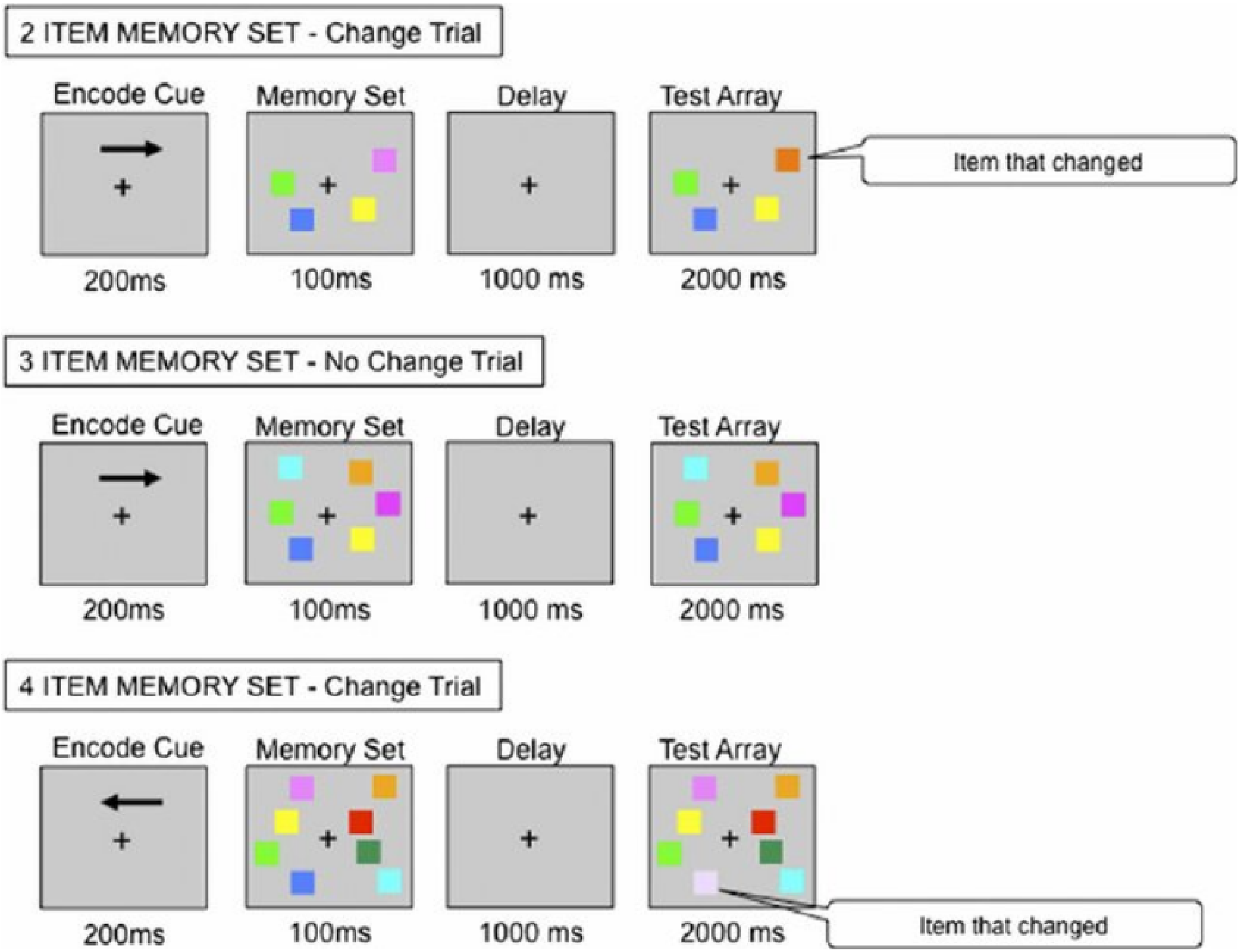



| **Property** | **Meaning** |
|---|---|
| *speed* | speed of the drone. |
| *droneShotPower* | turret damage by one drone shot. |
| *droneShotProb* | probability that the drone hits the turret. |
| *droneShotFreq* | drone fire rate. |
| *dronePassEv2City* | defines how the drone affects the defended location. after passing the turret (positively or negatively). |
| *dronePassEv2Turret* | defines how the drone affects the turret after passing it (positively). |
| *dronePassEvProb* | probability that the previous two effects happen. |



# Change detection task (CDT)

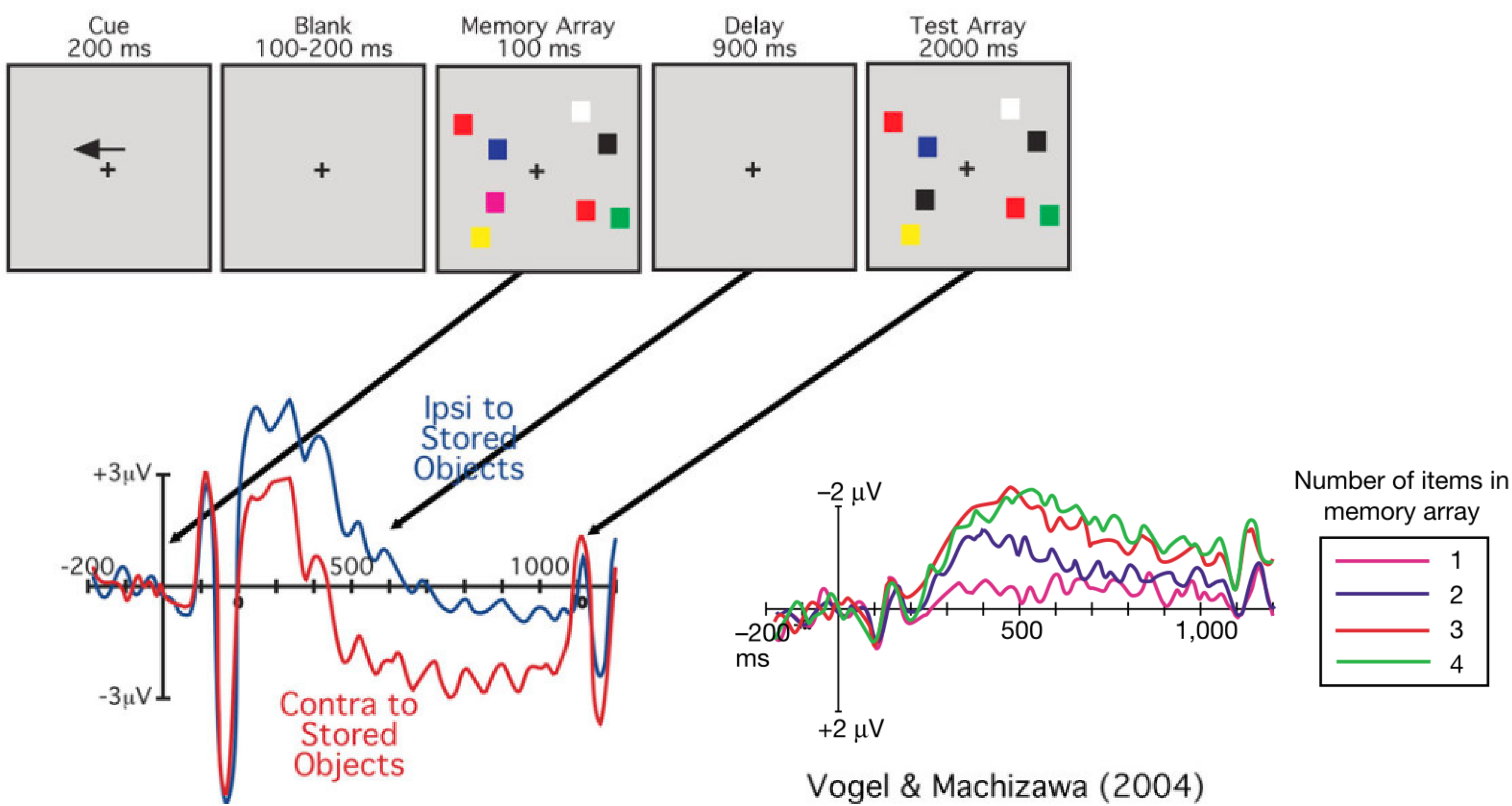
- applied before and after training in VR, responses stored



# Measuring brain signatures

- event-related potentials (ERPs), i.e. time- and phase-locked electrical responses of the brain to a specific event
- due to background EEG ("noise"), averaging over more trials (40+) necessary
- ERP protocols for testing visual working memory and spatial attention were implemented
- experimental design (Vogel & Machizawa, 2004) – elicits contralateral delay activity (CDA) component of ERP
- CDA = well-defined neural correlate of working memory capacity (Luria et al, 2016)
  - (cognitive operations of) maintenance and filtering

# Contralateral delay activity (CDA)



# Summary

- We outlined a more ecologically valid experiment using 3D training (testing in 2D)
- Game design (for CAVE) is being finalised, preliminary testing done
- CDT (for pre/post test) protocol is ready
- Experimental group ready-to-go in October
- Our goal: to find an effect (of VR), both behaviorally and neurally

Thank you for your attention.