Effects of Pre-cueing and Retro-cueing on Visual Working Memory Tasks in Virtual Reality

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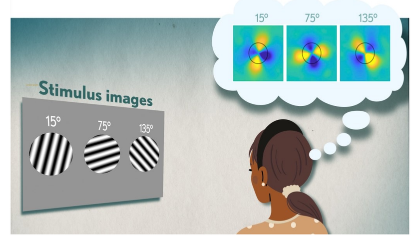


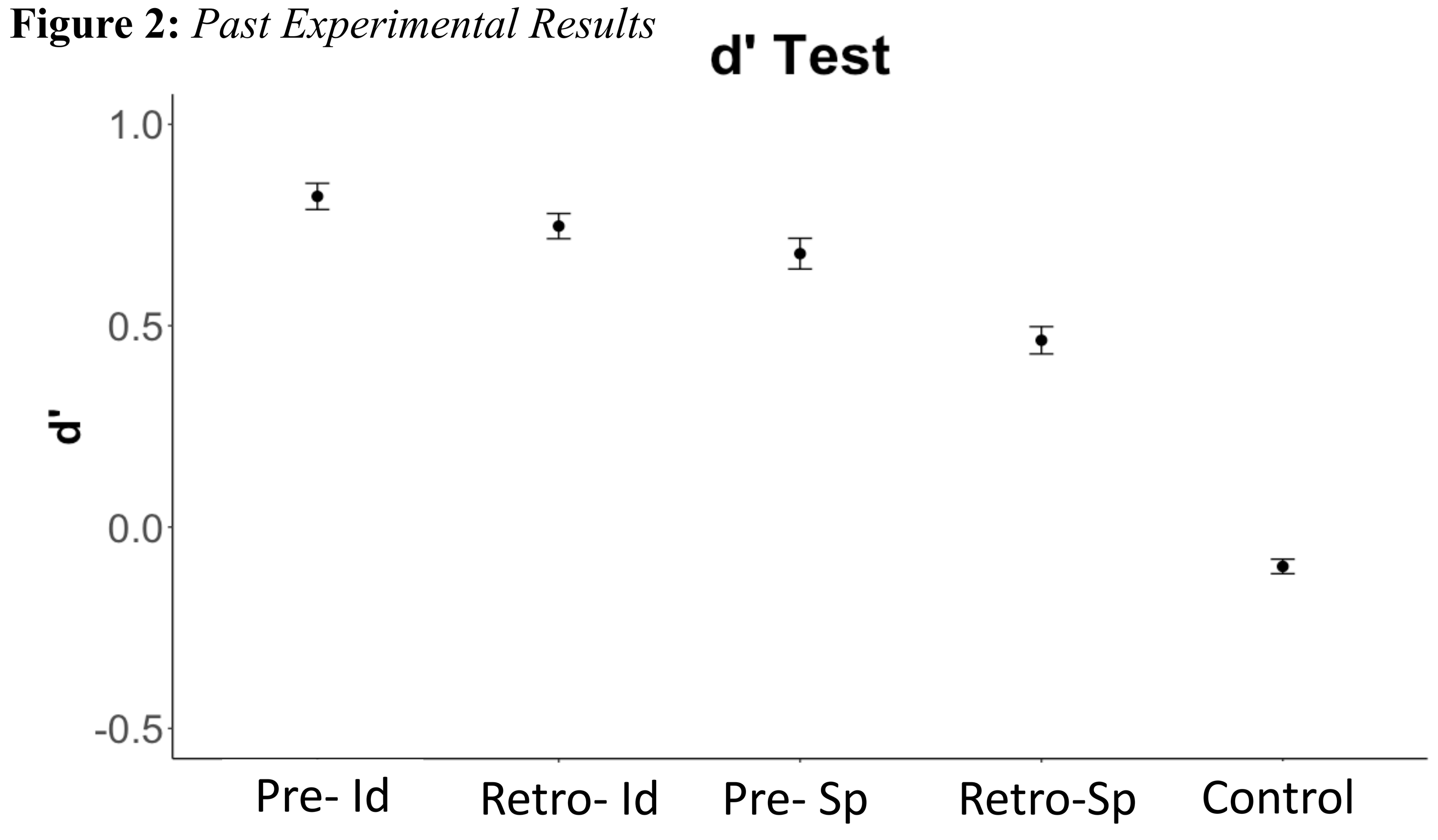
Introduction

- Working memory is responsible for temporarily storing and manipulating stimuli, and it plays a pivotal role in guiding behavior, decision-making, and cognitive processes (Baddeley, 2011).
- Visual working memory (VWM), a subset of this system, deals explicitly with a stimuli's visual and spatial properties. It enables individuals to process and retain an object's visual features, such as shape, color, and spatial location (Luck & Vogel, 2013), facilitating various daily interactions with one's environment.
- Environmental cues particularly influence VWM dynamics and are a key factor in understanding how VWM operates. Color cues emphasize visual details of objects, improving the accuracy of the perception of an object, while location cues aid in processing the spatial properties of objects.
- The timing of cues is crucial as it influences the encoding and retrieval of environmental signals in VWM. Pre-cueing directs attention before presenting the to-be-remembered information (Griffin and Nobre, 2003), and retro-cueing reorganizes and prioritizes signals in VWM for more accurate recall (Brady and Hampton, 2018).
- Most research on cueing effects on VWM has been conducted in traditional 2D settings, which lack the complexity and richness of real-world environments. Virtual Reality (VR) enables the simulation of complex, dynamic scenes, providing a balance between experimental control and ecological validity (Parsons & Rizzo, 2008)
- The proposed research aims to investigate the mechanisms underlying VWM in a VR environment, focusing on the impact of pre and retro-cues on the processing of visual stimuli.
- Hypothesis: VR will improve recall accuracy when compared to traditional 2d environments due to its immersive nature providing an engaging context for attenuating attention towards spatial and identity processing.

Results

Based on our findings from previous data collected in the TCU Comparative Cognition (Figure 2), we anticipate observing a similar pattern of results with amplified magnitudes. We expect that using VR will lead to better recall than the 2D methods used in past experiments because VR captures attention by immersing participants in a lifelike setting, making it easier for them to concentrate and remember information. It also offers realistic spatial cues that aid in memory formation, as our brains are accustomed to remembering things in three-dimensional space. This realistic approach is likely to make learning and recall more efficient, which is why we believe performance will improve with VR. We predict that pre-cueing will markedly improve recall accuracy, and the use of VR environments will yield novel insights into the processing mechanisms of visual working memory (VWM).

Figure 2: *Past Experimental Results*



Note: This figure illustrates the results of a past experimental study conducted in the Comparative Cognition Lab. Identity and Spatial properties are denoted as Id and Sp, respectively. Pre-Id and Pre-Sp conditions are associated with higher d' scores, reflecting better performance.

Method

Participants: Young adults aged 18-35, primarily TCU students, with normal or corrected-to-normal vision and hearing.

Apparatus: MetaQuest Pro VR headsets with integrated speakers will be employed. Interactions within the VR space will be made via VR controllers or a keyboard. The VR content will be powered by a Dell OptiPlex Tower Plus 7010 computer with an Intel vPro i7-13700 processor and orchestrated using WorldWiz Vizard software, allowing for tailored visual stimuli and cue management. Visual stimuli will consist of 3D isometric shapes, such as spheres, cubes, and pyramids, capable of manipulation along two axes to probe attention and memory influences. Variations in color and spatial positioning will be introduced to assist with identity and spatial memory tasks within the VR setting (Figure 1).

Figure 1: *Task Design*

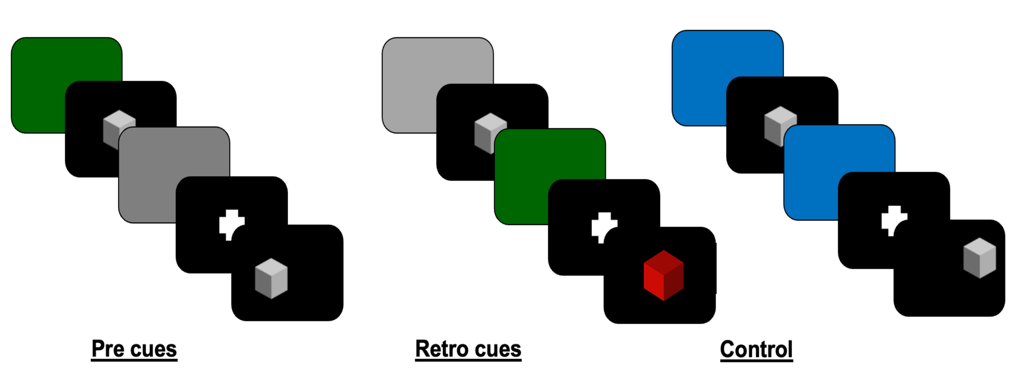


Table 1: *Experimental Design*

Property	Cueing	Training	Test
Identity	Pre	8	16
	Retro	8	16
	No-Cueing	8	16
Spatiality	Pre	8	16
	Retro	8	16
	No-Cueing	8	16

Procedure: Participants will be outfitted with MetaQuest Pro VR headsets and will interact with a virtual environment for one hour. Using the WorldWiz Vizard platform, they will perform tasks involving neutral identity and spatial challenges, interspersed with retro and pre-cues. The task sequence begins with a neutral setting for 1000ms, cueing for 200ms, a stimulus presentation for 2000ms, and concludes with a response to a probe stimulus after subsequent delays. Trials will vary by the presence and type of cues (color-based, location-based) and timing (pre-cueing, retro-cueing, no-cueing), using a within-subjects design (Table 1) to examine the effects on working memory. Participants will be debriefed post-session.

Discussion

This research project has provided our lab with a unique opportunity to explore the interplay of cueing, visual working memory (VWM), and virtual reality (VR), thereby advancing the field of cognitive science. The integration of VR into our study has not only enhanced the ecological validity of our experiments but also allowed us to investigate VWM in a more realistic and immersive context.

- Steep Learning Curve in Coding and System Integration: Many of us did not have a background in computer programming or VR technology. Learning to code and integrate various software and hardware components was a daunting task, but it was essential for the success of our project.
- Importance of Learning to Program for Non-Computer Science Students:
- Versatility in Research: Learning to program as a non-computer science student has allowed us to customize our experiments and analyze data more efficiently, making us more versatile researchers.
- Problem-Solving Skills: Reassessing drawbacks has honed our problem-solving skills, which are valuable in any field of study.
- Innovative Approach to Studying VWM: By using VR, we've been able to simulate complex, real-world environments, providing insights into VWM that would be difficult to achieve with traditional 2D methods.
- Preparation for Future Research: Familiarity with VR technology and its application in research prepares us for future studies that increasingly incorporate advanced technologies.
- Competitive Edge: The skills we've developed in programming and working with VR technology will give us a competitive edge in professional school applications and future research opportunities.

As we approach the conclusion of this study, we are excited about the potential implications of our findings for enhancing educational methods, developing treatments for mental health conditions, and improving tools for industries that rely on spatial awareness and decision-making. The knowledge and skills we have gained from this project will undoubtedly serve us well in our future academic and professional endeavors.

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