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EXPLORING INDIVIDUAL DIFFERENCES IN VISUAL WORKING MEMORY: SHARED COGNITIVE MECHANISMS ACROSS CHANGE DETECTION AND DELAYED ESTIMATION TASKS

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Abstract

Understanding individual differences in visual working memory performance is critical for uncovering the cognitive mechanisms underlying memory formation and retrieval. In this study, we investigated how performance varies across two widely used tasks: the delayed estimation (DE) task and the change detection (CD) task. Across three experiments, we interspersed DE and CD trials with identical displays while manipulating task expectations to explore their influence on memory encoding and performance. Individual differences analysis revealed strong correlations in performance across tasks and expectations, indicating that both tasks rely on a shared underlying factor that varies between individuals. Additionally, participants who performed better in memory tasks also reported higher confidence, with significant correlations observed across all experimental conditions. These findings demonstrate that despite task-specific encoding differences, DE and CD tasks are underpinned by common cognitive mechanisms that drive individual differences in performance. This work highlights the importance of considering individual variability in visual working memory research and the influence of task type on memory strategies.

Keywords: *Working memory, individual differences, encoding, strategies.*

1. Introduction

Visual Working Memory (VWM) refers to the temporary retention and manipulation of visual information no longer present in the environment (Baddeley & Hitch, 1974). This ability underpins many everyday tasks and has been linked to educational achievement, fluid intelligence, and general intelligence (Engle et al., 1999; Fukuda et al., 2010; Johnson et al., 2013). Among the most widely studied paradigms to measure VWM are the delayed estimation (DE) task and the change detection (CD) task. Recent findings suggest that these two tasks influence how memories are formed and the precision with which information is encoded into VWM in different ways (Cohen-Dallal & Pertzov, 2023).

Although each task may involve distinct memory-encoding processes, it remains unclear whether there is an overarching mechanism that supports performance across both. VWM performance can be affected by a range of cognitive factors, including storage capacity, attentional control, and strategic approaches (Schor et al., 2020; Unsworth et al., 2021; Lin & Leber, 2024). It is therefore plausible that the DE and CD tasks rely more on separate processes than on common ones. To explore this possibility, we designed an experiment in which we manipulated not only which task participants would perform (DE vs. CD) but also their expectations about which task would follow. By doing so, we could directly compare estimation precision under conditions where participants encoded the memory array in anticipation of either a DE or a CD task.

2. Methods & results

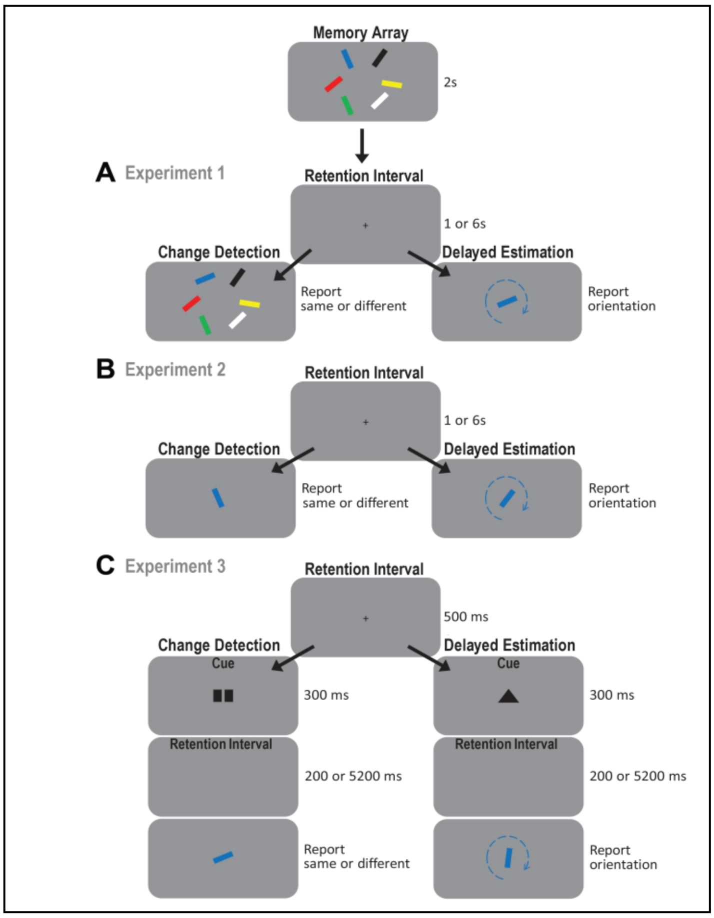
2.1. Participants

Forty-eight neurologically normal participants participated in these study (age range 19-31 years, mean 23.29 ± 2.56, 34 females). This experiment consisted of three experiments; 16 participants participated in each experiment. This study is part of a larger research project that aimed to understand the adaptiveness of visual working memory. This study was approved by the ethics committee of the Social Sciences Faculty at the Hebrew University of Jerusalem, Israel. All participants reported normal or corrected-to-normal visual acuity and had normal color vision.

2.2. Procedure

See Figure 1 for the experimental procedure. All trials started with the presentation of a memory array consisting of 6 oriented bars in random orientations and different colors for 2000 ms. After a blank retention interval with variable durations, a probe appeared. In the DE task the probe consisted of one bar and participants were required to rotate it to match the orientation of the target bar. In the CD task the probe consisted of all the bars in the memory array in Experiment 1, or a single bar in experiments 2 and 3. Experiment 3 included a cue that appeared after the memory array indicating the upcoming task on this trial (CD or DE). Next, a blank retention interval was introduced for 1000 or 6000 ms (the delay length was randomly assigned in each trial). If the trial was a DE trial, at the end of the retention interval a single bar (probe) was presented in the center of the screen in a random orientation and participants were required to adjust its orientation to match the bar with the same color from the memory array. In the CD condition, participants were required to report whether the second memory array was identical to the original memory array or not, by pressing the left or right keys of the mouse. The display appeared until the mouse was pressed. A confidence report appeared at the end of each trial. Participants were required to report their confidence in their response on a scale of one to six. The experiment was divided into two sessions conducted on different days, where one session included 85% CD trials (main trial type) and one session had 85% DE trials. The order of the sessions was counterbalanced across participants. At the beginning of each session the participants were informed which one of the trial types would be more frequent. Each session included four blocks with 52 trials. Of the 52 trials in each block, 44 were from the main trial type. Each block started with eight consecutive trials of the main trial type, to encourage participants to form the appropriate encoding strategy. Two trials of the infrequent trial type did not appear consecutively, apart from cases where they appeared at the end of the block. Each session started with four consecutive practice trials on each trial type separately. Participants were encouraged to do their best; they were informed at the end of each block of their achievement and received bonus payment for good achievements.

Figure 1. Experimental procedure for Experiments 1, 2 and 3.



Memory performance was analyzed separately for the CD and DE trials. The dependent variable in the DE analysis was the angular error between the reported orientation and the correct orientation of the target bar. The dependent variable in the CD trials was the proportion of incorrect responses. We investigated whether individual differences in memory performance would correlate across both tasks and expectations. Therefore, we conducted Pearson correlations on participants' DE and CD task performance within the two main trail type (MTT) conditions. Across the three experiments, we observed some variability in how strongly performance on the two tasks correlated. In Experiment 1**,** the correlations between CD an DE trail types were not significant. In Experiment 2**,** the correlations reached statistical significance, when MTT:CD (r = .71, p < .001), and between MTT:DE-TT:DE and MTT:CD-TT:CD (r = .55, p < .05). Finally, in Experiment 3**,** we observed robust correlations within both MTT conditions (MTT:CD, r = .59, p < .001, MTT:DE, r = .72, p < .001) and also across MTT conditions (MTT:DE-TT:DE and MTT:CD-TT:CD, r = .50, p < .001; MTT:DE-TT:CD and MTT:CD-TT:DE, r = .54, p < .001). To receive a general picture across experiments we conducted a partial correlation analysis in which experiment was added as a covariate. The results show strong correlations in all comparisons. The only insignificant correlation was between DE performance when MTT was CD and CD performance when MTT was DE (see Table 1). We also found significant correlations between performance and confidence in all experimental conditions.

Table 1. Partial correlations between performance across experiments.

	MTT	CD		DE	
MTT	Trial Type	CD	DE	CD	DE
CD	CD	1			
	DE	**.53****	1		
DE	CD	**.25***	.20	1	
	DE	**.47****	**.63****	**.36***	1

* Significant at p < .05, ** Significant at p < .001
MTT- main trail type; DE- Delayed Estimation: CD- Change detection

3. Discussion

These findings demonstrate that despite eliciting task-specific encoding and memory precision differences, a shared cognitive mechanism underlies individual differences in performance in the two tasks. Moreover, the data suggest that when the tasks become more alike, their performance correlations increase. Notably, Experiment 2 showed higher correlations than Experiment 1, while Experiment 3 outperformed Experiment 2. These findings are significant because they offer clearer insight into how the interplay of task demands influences memory performance, emphasizing both the convergent and divergent processes at work. In conclusion, recognizing this combination of task-specific and shared factors is crucial for advancing our understanding of the cognitive processes that underlie visual working memory and for refining future experimental designs to better capture the nuances of memory processes.

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