Staring, Guessing, and Imagining: Strategies in Visual Working Memory

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Abstract

Although working memory (WM) capacity is often treated as a stable limit, performance in WM tasks is not determined by capacity alone. Emerging evidence suggests that it is also influenced by the strategies individuals adopt to meet task demands – a factor that remains insufficiently explored. This study investigated how strategy use in visual working memory varies depending on the specific requirements of the task, namely the features and combinations of features of visual stimuli to be remembered. Forty-eight students completed a visual WM span task in which they had to remember colors, shapes or both properties of visual stimuli. When both features had to be remembered, colors and shapes were either presented in separate objects (*both separate* condition) or combined within the same objects (*both integrated* condition). Following each task condition, participants reported how often they had used specific strategies by completing a strategy questionnaire. Results showed that visually oriented strategies (e.g., focusing on visual features and imagery) were most common across all conditions. Significant task condition effects emerged for the *staring* and *guessing* strategies, which were reported most often in the *both separate* condition. Furthermore, *active pattern search* was positively correlated with WM span in the *colors* condition, while *passive waiting* was negatively correlated with WM span in the *both separate* condition. These findings highlight that performance in WM tasks reflects not only capacity limits but also the strategies individuals adopt.

Keywords

Visual working memory, working memory strategies, task condition, working memory span

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1 Introduction

The current understanding of working memory (WM) is often based on the multicomponent model of WM proposed by Baddeley and Hitch [1] who conceptualized WM as a system used for the short-term maintenance and manipulation of information [2]. Previous research [3, 4] has highlighted the importance of WM in everyday tasks, including language and reading comprehension, problem solving, and learning.

Given this central role in cognition, researchers have been particularly interested in the capacity limits of WM. Initial efforts to estimate this capacity suggested that it is highly limited. Miller [5] introduced the concept of the magical number 7 ± 2, describing individuals' WM capacity as the ability to retain approximately 7 ± 2 units of information. However, later studies, particularly in the domain of visual WM, have proposed even lower estimates. Cowan [6] estimated the capacity of visual WM to be closer to 3-4 items.

While these estimates help define the capacity limits of WM, task performance is not determined by capacity alone. Individuals often employ strategies that allow them to optimize how information is encoded and maintained. Such strategies do not increase capacity per se but can improve task performance by making more efficient use of available capacity.

Miller [5] described the phenomenon of chunking, a strategy in which individuals combine separate units of information into larger, meaningful ones (e.g., instead of remembering numbers 2 and 3 separately, they are stored together as 23). Subsequent research identified other strategic approaches, as a means to enhance performance [7].

More recent studies have taken a more open-ended approach to investigating WM strategies, allowing participants to report strategies they had spontaneously used, rather than limiting them to narrow predefined categories. For example, Oblak et. al. [8] used qualitative methods to explore individuals' experiences during a WM task, identifying a variety of strategies employed. Building on this work, Slana Ozimič et. al. [9] reported that the strategy use depends on specific task conditions.

However, previous research has either examined strategy use in a very open-ended manner – typically through interviews or freeresponse formats – or has focused on a narrow set of predefined strategies. What has been lacking is a structured yet comprehensive approach to quantitatively assess a broad range of strategies across task conditions. To address this gap – and building on previous literature (e.g., [8–10]) - we developed a structured questionnaire that included a broad set of strategies relevant to visual WM tasks. Using this questionnaire, we examined whether different task conditions encourage the use of different strategies, and whether the spontaneous use of such strategies is related to individuals' WM performance.

2 Methods

2.1 Participants

The study included 48 students (38 female, 8 male, 2 other), aged between 18 and 27 years (M = 19.98 years, SD = 2.23 years). None of the participants reported neurological diseases or conditions and all participants had normal or corrected-to-normal vision.

2.2 Behavioral task and strategy questionnaire

A behavioral task was used to assess visual WM span. The task was presented on a Windows 11 computer using PsychoPy (v2023.1.1), and each participant completed two sessions lasting about 60 minutes. The task included four conditions (two conditions per session), the order of which was pseudo-randomized across participants. In the *colors* condition, participants had to memorize the colors of circles; in the *shapes* condition, they had to memorize the shapes of black outlines. In the *both separate* condition, they were presented with an equal number of colored circles and shape outlines and were asked to remember both features. In the *both integrated* condition, each presented object combined both features—a unique shape filled with a unique color—and participants were instructed to remember both the shape and the color of each object. In each trial, participants were presented with objects defined by color and/or shape for 500 ms. After a 2 s delay interval, they selected from the array of all possible colors and/or shapes those they remembered being shown, by clicking on them (up to the number originally presented). The number of stimuli increased until a stable WM span was obtained in each task condition. Throughout the trial, participants continually repeated the syllables »ta-ma« to suppress verbal rehearsal.

After each task condition, participants completed strategy questionnaire, consisting of 37 items, each formulated as a statement describing a possible strategy (e.g., *"While viewing the stimuli, I actively searched for a pattern in the presented items"*). The items were grouped into three phases of working memory (encoding, maintenance, and recall) and included visual, spatial, verbal, motor, auditory, long-term memory, and transmodal strategies. Participants reported, for each statement, the estimated frequency of its use during the preceding condition, expressed as a percentage.

2.3 Data analysis„

Data were analyzed using R [11]. To assess the effect of task condition on the frequency of strategy use, one-way ANOVAs were conducted separately for each strategy, with task condition (*color, shape, both integrated, both separate*) as the independent variable, and the frequency of strategy use as the dependent variable. In addition, Pearson's correlation analyses were performed to examine relationships between strategy use and WM span within each task condition. All statistical tests were performed separately for each strategy, while FDR corrections were applied within task phases – encoding, maintenance and recall – to reflect the grouping of strategies by phase.

3 Results

First we examined the internal consistency of the questionnaire, which was excellent (Cronbach's $\alpha = .88$), with an average inter-item correlation of .16, indicating that items were related but not redundant. We then examined the mean self-reported frequency of strategy use across all task conditions. The three most frequently reported strategies during encoding were *identifying distinctive features*, *inspecting visual features*, and *representing*. During the maintenance phase, participants predominantly relied on *afterimage*, *rehearsing a visual image*, and *impression*, whereas in the recall phase, the most frequently endorsed strategies were *comparing with a visual image*, *hunch*, and *applying verbal descriptions*. Strategies that were, on average, used in less than 20% of trials were excluded from further analyses, as their low overall frequency suggested limited relevance for interpreting task performance (Figure 1).

On the remaining strategies, we conducted one-way ANOVAs to test for differences in strategy frequency across task conditions. After applying FDR correction, two strategies (*staring* and *guessing*) showed significant task condition effects. For *staring*, a significant effect of task condition was found, $F(3, 183) = 5.99$, $p = .018$, $\eta^2 = .09$, indicating small-to-medium effect size. *Staring* was reported most frequently in the *both separate* condition, followed by the *shapes* and *both integrated* conditions, and least frequently in the *colors* condition. Post hoc comparisons using Tukey's tests revealed that the significant effect of condition was primarily driven by higher reported use of the *staring* strategy in *both separate* condition compared to the *colors* condition (mean diff. = 22.82 %, SE = 7.14 %, $p < .001$).

For *guessing*, there was also a significant effect of task condition, $F(3, 183) = 5.28$, $p = .022$, $\eta^2 = .08$, indicating small-to-medium effect size. Tukey's post hoc comparisons indicated that *guessing* was reported significantly more often in *both separate* condition compared to the *colors* condition (mean diff. = 19.29 %, SE = 6.71 %, $p = .001$), and s*hape* condition (mean diff. = –14.51 %, SE = 6.71 %, $p = .024$).

Lastly, correlation analyses were conducted to examine relationship between the self-reported frequency of each strategy use and WM span within each task condition. After FDR correction only two correlations remained statistically significant. Use of *establishing a pattern* strategy positively correlated with WM span in the *colors* condition ($r = .45$, $p = .045$), while use of *waiting* strategy negatively correlated with WM span in the *both separate* condition ($r = -.44$, $p = .016$).

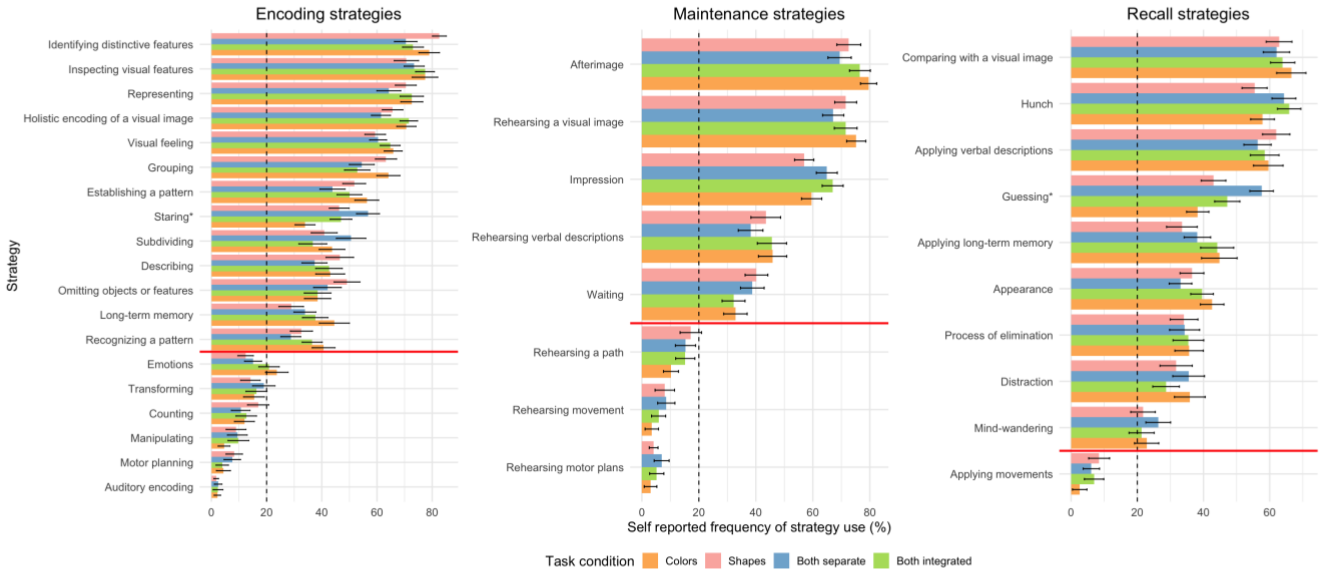

Figure 1: Average self-reported frequency (%) of strategy use across four task conditions

Note. Error bars represent ±1 *SE*. Black vertical dotted lines represent 20% cut-off. Strategies below red horizontal lines were excluded from further analyses; * Strategies with statistically significant one-way ANOVAs after FDR correction.

4 Discussion

The aim of this study was to examine strategies individuals use under different visual WM task conditions, and whether the use of these strategies is related to WM performance. Using a newly developed, literature-based strategy questionnaire, the findings show that the use of strategies during WM tasks differs across task conditions, consistent with previous findings [9].

The most commonly reported strategies across all task conditions were visually based, such as focusing on the visual features of the stimuli (*identifying distinctive features*), relying on afterimage, or mentally comparing the current image with the one stored in WM (*comparing with a visual image*). The predominance of visual strategies is consistent with the nature of the task, which required remembering visual properties – colors and shapes – and thus naturally engages visual encoding and maintenance mechanisms [12]. In contrast participants rarely used motor strategies (e.g., *motor planning*, *rehearsing motor plans*), likely because such strategies are more effective in tasks involving spatial or movement-related information [13].

Significant differences between task conditions emerged for the *staring* strategy, which reflects a passive approach where participants simply looked at the screen with the hope of remembering the stimuli, and the *guessing* strategy, characterized by providing a response without confidence or clear memory of the stimuli. Both strategies showed a similar pattern of use across task conditions: they were reported most frequently in the *both separate* condition, followed by the *shapes* and *both integrated* conditions, and least frequently in the *colors* condition. Post hoc analyses indicated that the difference in *staring* was driven by higher reported use in the *both separate* compared to the *colors* condition, while for *guessing*, significant differences were found between the *both separate* condition and the *shapes* condition and the *colors* conditions. This pattern suggests that participants were more likely to rely on passive or less effortful strategies when task demands increased – particularly when multiple visual features had to be encoded simultaneously in separate objects. Similar findings have been reported in research showing that individuals tend to adopt less demanding strategies as task complexity and cognitive load increases [14].

Finally, our analysis showed that the use of two specific strategies was significantly related to WM span. In the *colors* condition, participants who more frequently *established a pattern*, showed larger WM span, suggesting that combining colors into meaningful patterns supported memory performance. In contrast, in the *both separate* condition, greater reliance on *waiting* – waiting for the prompt to provide the answer – was associated with lower WM span. This indicates that disengaging from active retrieval processes hindered performance in more complex tasks.

The present findings demonstrate that using a structured questionnaire allowed us to identify specific links between WM strategy use and performance - something that was not captured in our previous study [9], which relied on an open-ended interview approach.

5 Conclusion

Taken together these findings suggest that WM strategies play an important role in the dynamic processes underlying WM. The complexity of these processes cannot be captured by WM span alone. While WM span provides useful estimate of capacity, it does not account for the individual differences in strategy use that may influence task performance. Beyond the laboratory, such strategies are likely engaged in everyday contexts, for example, when navigating environments, remembering instructions, or interpreting visual information in educational or occupational settings. Future research in this field should further examine variability in the deployment of strategies, including how such strategies manifest on a neural level.

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