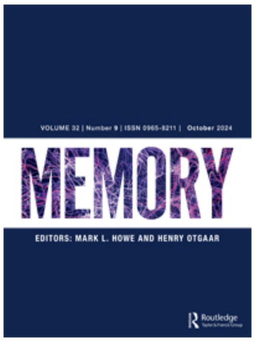

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The role of attention and verbal rehearsal in remembering more valuable item-colour binding

Xiaotong Yin, Jelena Havelka and Richard J. Allen

School of Psychology, University of Leeds, Leeds, UK

ABSTRACT
Selectively remembering more valuable information can improve memory efficiency. Such value effects have been observed on long-term memory for item-colour binding, but the possible contributory factors are unclear. The current study explored contributions from attention (Experiment 1) and verbal rehearsal (Experiment 2). Across two experiments, memory was superior for item-colour bindings that were associated with high (relative to low) point values at encoding, both in an immediate test and a delayed re-test. When availability of attentional resources was reduced during encoding, value only influenced immediate and not delayed memory (Experiment 1). This indicates that a transient value effect can be obtained with little attentional resources, but attentional resources are involved in creating a longer lasting effect. When articulatory suppression was implemented during encoding (Experiment 2), value effects were somewhat reduced in the immediate test and abolished in the delayed re-test, suggesting a role for verbal rehearsal in value effects on item-colour binding memory. These patterns of value effects did not interact with encoding presentation format (i.e., sequential vs. simultaneous presentation of objects). Together, these results suggest that attentional resources and verbal rehearsal both contribute to value effects on item-colour binding memory, with varying impacts on the durability of these effects.

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Memory; attention; value-directed remembering; reward; binding

The visual environment is often very rich, and it is not always possible or optimal to remember all the information we encounter given limitations on our memory and attentional capacity. To improve memory efficiency, one approach is to focus on a subset of stimuli (Atkinson et al., 2018a) and selectively remember information that is more valuable or goal relevant. Directing selective prioritisation based on item value has been shown to benefit retrieval of high value items in working memory and long-term memory tasks. The factors that might contribute to the value effect in long-term memory are however unclear, and have not been explored for item-colour associative memory. Therefore, the current study attempted to address this question, targeting contributions from attention and verbal rehearsal in supporting value-based prioritisation in memory for item-colour bindings when tested immediately and after a delay.

Selectively encoding and remembering more important information has been consistently found in working memory tasks (Allen et al., 2024), with working memory defined as the temporary storage and processing of around 3–4 chunks of information over the time course of a few seconds (e.g., Baddeley et al., 2021). In an example working memory paradigm (e.g., Hu et al., 2014), a small set (e.g., four) of coloured shapes are presented for an immediate memory test. Participants are informed that correctly remembering the item at a particular position (e.g., the first item) could earn more points than the other items. Memory for the items at the high value serial positions or locations has been shown to be better than for lower value items, demonstrating a flexible attentional control ability (see Allen et al., 2024; and Hitch et al., 2020). The effect has also been observed using sequential (e.g., Hu et al., 2023; Hitch et al., 2018) and simultaneous (Allen & Ueno, 2018; Atkinson et al., 2022) encoding contexts, and in children and older adults (Allen et al., 2021; Atkinson et al., 2019).

Value-directed prioritisation also influences performance on long-term memory tasks (Knowlton & Castel, 2022). For present purposes, long-term memory refers to stored knowledge and records of prior events (Cowan, 2008), without the assumed temporal and informational capacity limits of working memory. Thus, a task would require long-term memory when the number of items

CONTACT Richard J. Allen r.allen@leeds.ac.uk School of Psychology, University of Leeds, Leeds, UK

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considerably exceeds working memory capacity, and/or when retention over a filled interval of several minutes is required. As an example, studies using the old/new recognition paradigm have revealed that items allocated with higher reward values typically show enhanced memory (Knowlton & Castel, 2022). This is particularly the case for recollective experience (as indicated by the "Remember" option in the Remember/Know paradigm), with little or no impact on familiarity ("Know" option, Cohen et al., 2017; Elliott et al., 2020a; Elliott & Brewer, 2019; Elliott et al., 2020b; Hennessee et al., 2017; Hennessee et al., 2018). Furthermore, some studies have observed value effects on long-term memory for associative information or contextual detail. These include memory for item-location binding (Elliott et al., 2020b; Siegel & Castel, 2018a, 2018b; Siegel et al., 2021), item-colour binding (Yin et al., 2021), memory for word pairs (Ariel et al., 2015; Griffin et al., 2019) and memory for word plurality status (Cohen et al., 2017). Other studies, in contrast, have only found value effects on long-term memory for item information but not for associative information, such as memory for the colour of visually presented words (Hennessee et al., 2017; Hennessee et al., 2018) or memory for the voice gender in which words were presented (Villaseñor et al., 2021).

The value effect is likely to reflect strategic allocation of attention (Allen et al., 2024; Castel et al., 2002). Participants with attentional impairments such as Alzheimer's disease or ADHD show decreased value effects in long-term memory tasks relative to healthy controls (Castel et al., 2009; Castel et al., 2011). Additionally, increased pupil dilation has been observed when studying high relative to low value words (Miller et al., 2019), and participants spend more time studying and restudying higher valuable words when given free choice (Ariel et al., 2015; Castel et al., 2013; Middlebrooks & Castel, 2018; Robison & Unsworth, 2017). In each case, these behaviours were associated with better memory for more valuable words.

Dual task manipulations have been applied in this long-term memory context to directly examine the contribution from attentional resources. Elliott and Brewer (2019) found that a dual task load during the encoding phase (i.e., random number generation or tone-detection but not articulatory suppression) abolished or reduced the value effect on a subsequent recognition memory task, suggesting an important role of attentional resources. However, other long-term memory studies suggest that attentional resources are not critical for strategic value-directed remembering. For example, Middlebrooks et al. (2017) used three different tone detection tasks to divide attention while participants were remembering words based on point values. Although attention was stressed to different degrees (Middlebrooks et al., 2017), participants' ability to selectively remember more valuable words was not impaired. Using a similar approach, Siegel and Castel (2018b) explored how divided attention during encoding may influence the value effect on long-term memory for item-location binding. While participants in the divided attention conditions recalled fewer item-location associations overall, selectivity for high over low value items remained. Finally, Siegel and colleagues found that value effects in long-term memory were only impaired if the dual task relied on overlapping processing resources with the primary task (Siegel et al., 2021). Relatedly, mixed outcomes have also been observed in the working memory literature, with Hu et al. (2016) finding reduced value effects in visual cued recall following a more demanding concurrent task, while Atkinson et al. (2021) found preserved value effects in auditory verbal serial recall, albeit with low value memory at chance performance. Therefore, given inconsistent findings of the impact of attentional resources on value effects, and an absence of research on item-colour binding in long-term memory, Experiment 1 in the current study examined value and attentional load effects on immediate and delayed item-colour binding memory, with the aim to help clarify whether selectivity is a cost-free ability or requires attentional resources.

Prior studies from the working memory domain showing value effects on item-colour binding memory have typically employed concurrent articulatory suppression tasks to disrupt verbal coding and rehearsal (e.g., Allen et al., 2021; Hitch et al., 2018; Hu et al., 2014, 2016). Additionally, studies which have explicitly manipulated the use of articulatory suppression, either between or within experiments, found no reduction in value effects (Atkinson et al., 2021; Sandry et al., 2014). The reliable observation of value effects under these circumstances would suggest that they are unlikely to critically rely on verbal rehearsal. However, to our knowledge, the role of verbal rehearsal has never been examined in long-term memory for item-colour binding. Verbal coding and rehearsal may play a different role in formation and retention of longer lasting, more durable representations. Therefore, Experiment 2 aimed to explore the role of verbal rehearsal in the long-term memory domain, both in an immediate test and a delayed re-test.

Two experiments are therefore reported examining these research questions. We used an adaptation of the task implemented in previous studies of long-term memory (e.g., Siegel & Castel, 2018b; Siegel et al., 2021). In each experiment, different combinations of object and colour were briefly presented during an encoding phase. Memory for the shape-colour bindings encountered on each trial was assessed in an immediate test, and in a delayed re-test at the end of the encoding phase for each condition. Use of both an immediate test and a delayed re-test for the same material allows us to explore the extent to which any advantage for high value items is relatively transient or more long-lasting in nature. Though we assume that working memory is engaged during encoding and retrieval in this task, we followed prior work (e.g., Siegel & Castel, 2018b; Siegel et al., 2021) by presenting and testing 8-item sets in the immediate phase, with the aim of exceeding working memory capacity and ensuring a role for long-term memory at both test phases.

Experiment 1 examined the impacts of divided attention during encoding, and Experiment 2 applied an articulatory suppression task. In line with prior observations on a shape-colour binding memory task (Yin et al., 2021), we predicted that both immediate and delayed re-test memory would be more accurate for high relative to low value items, when participants are not asked to perform another task during encoding. Any reduction in overall performance and in the value effect that is observed in the dual-task conditions would signal a role for attention and/or verbal processing.

Experiment 1

Experiment 1 aimed to examine whether divided attention during encoding would impact participants' ability to selectively encode more valuable item-colour bindings. Relative to a full attention condition, if divided attention reduced the value effect, that would indicate that attentional resources is essential for strategically prioritising high value item-colour bindings; if divided attention did not influence the value effect, that would suggest that strategically remembering more valuable item-colour bindings is a flexible ability that does not critically dependent on availability of attentional resources. Commonly used dual tasks designed to load on attentional resources include backward/forward counting (e.g., Allen et al., 2006; Allen et al., 2014; Allen et al., 2012), random number generation (e.g., Clark-Foos & Marsh, 2008; Hicks & Marsh, 2000), digit monitoring (e.g., Castel & Craik, 2003; Craik et al., 2010; Kern et al., 2005; Mulligan & Hartman, 1996), and tone detection (e.g., Dell'acqua & Joucoeur, 2000; Iidaka et al., 2000; Naveh-Benjamin et al., 2006; Talmi et al., 2007). Considering that backward/forward counting, random number generation and digit monitoring may interfere with processing of information value (which in the present paradigm is indicated by numbers), we adopted a tone detection task to tax attentional resources (e.g., Middlebrooks et al., 2017; Siegel & Castel, 2018b).

Experiment 1 also examined the impact of presentation format on value effects and how it might interact with attention. Prior research suggests that relative to simultaneous presentation, a sequential format is more demanding (Allen et al., 2006; Blalock & Clegg, 2010; Gorgoraptis et al., 2011; Lecerf & De Ribaupierre, 2005; Siegel & Castel, 2018a, 2018b) and is relatively less advantageous for selective encoding (Ariel et al., 2009; Middlebrooks & Castel, 2018; Siegel & Castel, 2018a, 2018b). Therefore, it is possible that divided attention would tax attentional resources the most in the sequential presentation format relative to other conditions and lead to a greater reduction in the value effect.

Method

Participants

Power analysis was conducted using G*Power (Faul et al., 2007) to determine the appropriate sample size. Our primary factor of interest in these experiments was that of item value. Targeting a medium effect size (Cohen's *d* = 0.5) for the effect of value, with an alpha level of 0.05 and 95% power using frequentist analysis, the analysis estimated that 45 participants would be required. As presentation format was manipulated between subjects, 90 complete participants were required to be recruited for reliable detection of the value effect (i.e., 45 in each presentation format condition). To allow for exclusions due to non-performance of the concurrent task (n = 15 in Experiment 1), 109 participants were ultimately recruited from University of Leeds and The Chinese University of Hong Kong (84 females; mean age = 19.2; range = 18–28 years; $N_{sequential} = 56$, $N_{simultaneous} = 53$). All participants reported having correct or corrected-to-normal vision and were without colour-vision deficits. None reported a history of neurological disorders. Informed consent was acquired in accordance with the guidelines set by the Research Ethics Committee from the University of Leeds (Ethics reference number: PSYC-14) and The Chinese University of Hong Kong (Ethics reference number: 22232022).

Design

The current experiment adopted a 2 (value: high, low) × 2 (attention: FA, divided attention) × 2 (presentation format: sequential, simultaneous) mixed-factor design, with value and attention as within factors and presentation format as a between-subject factor. The full attention and divided attention conditions were conducted in two separate blocks. Each block included five study-immediate test trials and each trial included four high and four low value items. The binding between items and point-values, the items used in each attention condition, and the order of the two attention conditions were counterbalanced across participants. Dependent variables were immediate item-colour memory and delayed item-colour memory.

Materials

Eighty neutral line drawings of daily objects were selected from Snodgrass and Vanderwart (1980) and Cycowicz et al. (1997). The items were presented in eight different colours (red, yellow, blue, green, orange, purple, brown and pink). Half of the items were paired with 1 point, and the other half were paired with 10 points (Figure 1). Colour-image bindings were always the same, but the associations between point values and colour-image bindings were counterbalanced across participants.

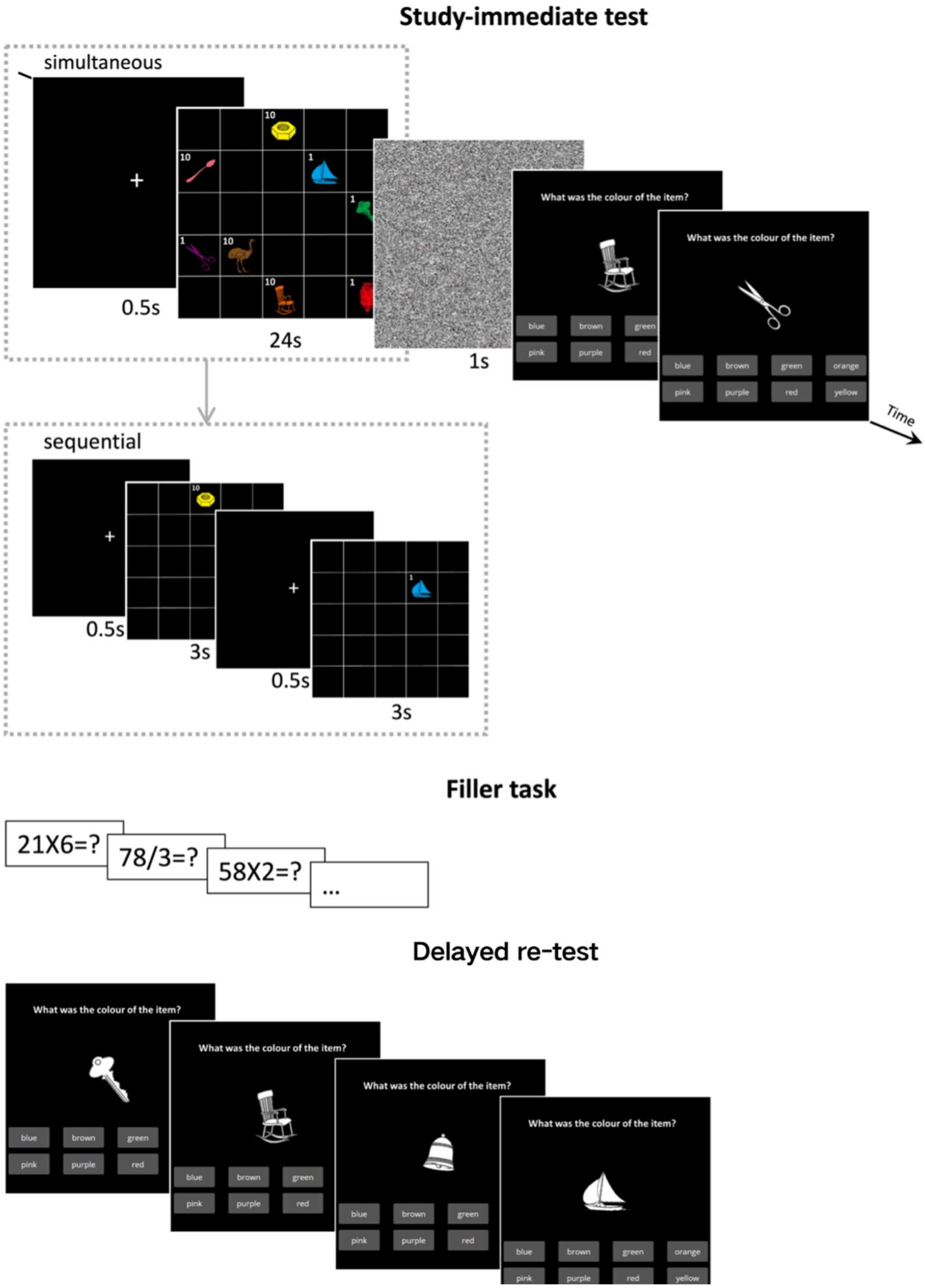

Figure 1. Schematic illustration of the experimental paradigm.

Procedure

The experiment was conducted online using the Gorilla Experiment Builder (Anwyl-Irvine et al., 2020). It consisted of a study-immediate test phase, a filler task phase and a delayed re-test phase (see Figure 1). During the study-immediate test phase, participants were instructed that they would be presented with a series of images in different colours, each paired with a point-value they would earn if they could correctly remember the colour of the images in a later test. The goal was to maximise their point-score. In the sequential presentation condition, eight items (four high value items, four low value items) were presented sequentially within 5×5 grids (see Siegel & Castel, 2018a, 2018b), in the different locations. Each of them was presented for 3 s with a 0.5 s fixation cross interval. In the simultaneous presentation condition, the eight items were presented simultaneously within a 5×5 grid. Participants were given 24 s to study the items (Note: in the sequential format, each of the 8 item-colour bindings was presented for 3.5 s, totalling 28 s; in the simultaneous format, the 8 item-colour bindings were presented for 24.5 s in total). The test phase followed a 1s mask, with the eight items being presented one by one as non-coloured outlines. Participants were asked to choose the colour for each item by clicking one from eight colour buttons (see Figure 1 for an example). They were then informed of how many points they scored in the current study-test trial, and then the next trial began.

There were two attention conditions (full attention vs. divided attention), each including 5 study-test trials. In the full attention condition, the memory task was the only task; under divided attention, participants were asked to do the memory task while performing a tone detection task. Participants were not explicitly instructed as to which task was the primary focus. They were asked to try to maximise their overall score. A series of low-pitched (440 Hz) and high-pitched (1000 Hz) tones were played in the background and participants were asked to press the left key for the low-pitched tone and the right key for the high-pitched tone. The order of tones was randomised for each participant with the constraint that no pitch was played more than three times consecutively. In the simultaneous presentation format, a tone was presented at intervals of 3 s. Each encoding phase contained 8 tones. In the sequential format, to simulate the continuous interruption that occurs during the simultaneous encoding of items, 2 tones were presented for each item. As a result, 2 tones were presented every 3 s. Each encoding phase in the sequential format contained 16 tones. Next, participants completed a filler task (6 multiplication or division questions, e.g., 21×6, $78 \div 3$, lasting around 90 s) to reduce mental rehearsal. Then, they completed an unexpected, delayed colour memory test, in which ten items (half high, half low) from each attention condition were selected and tested again.

Results

Both frequentist and Bayesian analysis were conducted on the data. Bayesian analysis allows one to consider the likelihood of the data under both the null and alternative hypotheses, and these probabilities are compared via the Bayes Factor (*BF*). BF_{10} describes how many times more likely the alternative hypothesis is than the null hypothesis, while BF_{01} describes how many times more likely the null hypothesis is than the alternative hypothesis. A *BF* between 1 and 3 is considered anecdotal evidence, a *BF* between 3 and 10 is considered moderate evidence, a *BF* between 10 and 30 is considered strong evidence, a *BF* between 30 and 100 is considered very strong evidence, and a *BF* between greater than 100 is considered extremely strong evidence (Jarosz & Wiley, 2014; Schönbrodt & Wagenmakers, 2018).

Tone detection performance

To verify that participants were properly engaged with the tone detection task, we examined their response rate on this task. The response rate was calculated as the number of key presses made by the participant divided by the total number of key presses they should have made, regardless of the accuracy of their responses. We did not use detection accuracy (the number of tones correctly detected out of the total number of tones) as the metric for task engagement, because by reviewing the data, we found that some participants often consistently confused the key assignments, pressing the right key (when they should have pressed left) for low-pitched tones, and the left key (when they should have pressed right) for high-pitched tones. Therefore, detection accuracy would not accurately reflect participants' true engagement with the tone detection task. Response rate was adopted to assess participants' engagement with the task.

Fifteen participants did not provide any responses on the tone detection task. Their data were excluded from the analysis. Therefore, the final analysis included 94 participants. Participants' average response rate on the tone detection task was 0.80 ($SE = 0.04$, range = .025–1).

Immediate test

Immediate and delayed item-colour binding memory as a function of value and attention are displayed in Figure 2, and broken down by presentation format in Table 1. The chance level for the memory test is 0.125. A 2 (value: high, low) × 2 (attention: full attention, divided attention) × 2 (presentation format: sequential, simultaneous) repeated measures ANOVA was conducted. This revealed a main effect of value [$F(1, 92) = 17.51$, $p < .001$, $\eta_p^2 = 0.16$, $BF_{10} = 358.74$], where memory for high value item-colour bindings [marginal means (MMs) = 0.71; standard error (SE) = 0.02] was better than memory for low value bindings ($MMs = 0.63$; $SE = 0.02$). There was also a main effect of attention [$F(1, 92) = 81.99$, $p < .001$, $\eta_p^2 = 0.47$, $BF_{10} >$ 1000], such that divided attention reduced overall memory performance level ($MMs = 0.59$; $SE = 0.02$) relative to that with full attention ($MMs = 0.74$; $SE = 0.02$). The interaction between value and attention was not significant [$F(1, 92) = 1.12$, $p = .29$, $\eta_p^2 = 0.012$, $BF_{01} = 3.65$], suggesting reduced attentional resources do not impact participants' ability to selectively encode and briefly remember more valuable item-colour bindings. The effect of presentation format was not significant, $F(1, 92) = 1.90$, $p = .17$, $\eta_p^2 =$ 0.02, $BF_{01} = 1.37$ (simultaneous presentation format: *MMs*

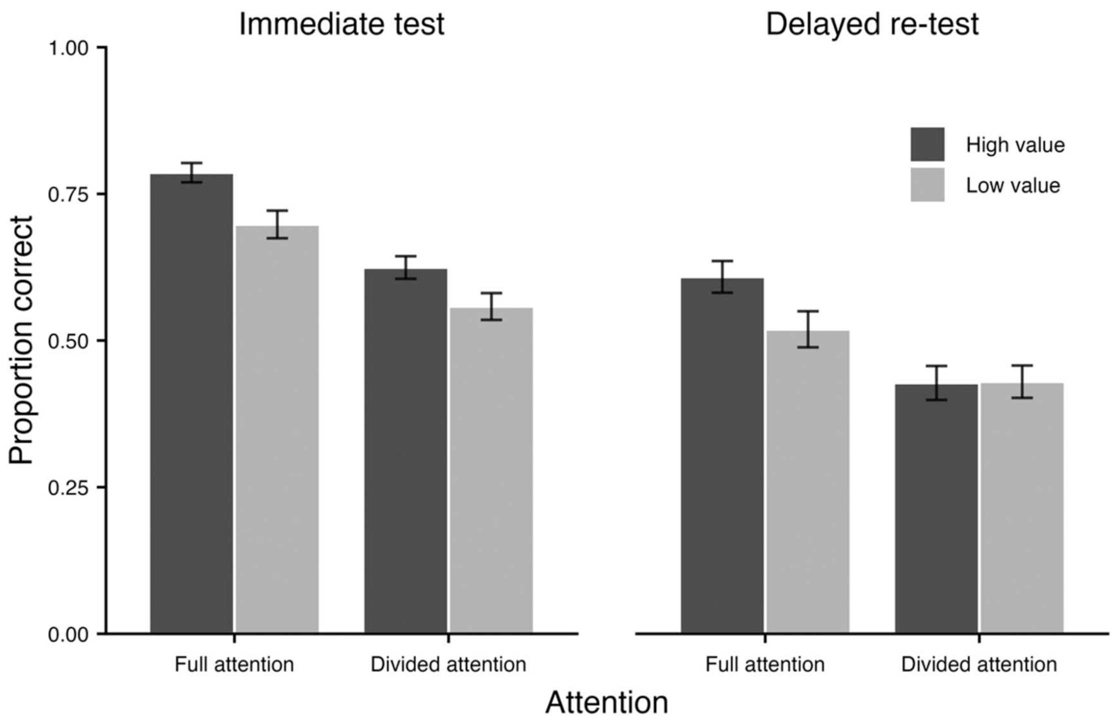

Figure 2. Mean accuracy in immediate test and delayed re-test as a function of value and attention. Chance level: 0.125. Error bars show standard error.

= 0.69, *SE* = 0.02; sequential presentation format: *MMs* = 0.65; *SE* = 0.02). No interaction was observed between presentation format and the other factors (*P*s ≥ 0.12, $BF_{01} \geq 1.34$).

Delayed re-test

A 2 (value: high, low) × 2 (attention: full attention, divided attention) × 2 (presentation format: sequential, simultaneous) repeated measures ANOVA revealed a main effect of attention [$F(1, 92) = 24.49$, $p < .001$, $\eta_p^2 = 0.21$, $BF_{10} > 1000$], such that memory was better with full attention (*MMs* = 0.56; *SE* = 0.02) than with divided attention (*MMs* = 0.43; *SE* = 0.02). The main effect of value was not significant [$F(1, 92) = 3.37$, $p = .07$, $\eta_p^2 = 0.04$, $BF_{01} = 1.52$], but there was an interaction between value and attention [$F(1, 92) = 5.54$, $p = .02$, $\eta_p^2 = 0.06$, $BF_{10} = 2.16$], albeit with only weak BF support. Paired samples t-tests indicated that memory for high value item-colour bindings was better than memory for low value item-colour bindings with full attention [$t(93) = 2.98$, $p = .004$, Cohen's $d = 0.31$, $BF_{10} = 6.96$], but not with divided attention [$t(93) = -0.07$, $p = .95$, $d = -0.007$, $BF_{01} = 8.77$], suggesting attentional resources during encoding are important for long-term maintenance of the value effect. The effect of presentation format was significant [$F(1, 92) = 4.87$, $p = .03$, $\eta_p^2 = 0.05$, $BF_{10} = 1.90$], with better memory under simultaneous presentation format (*MMs* = 0.54, *SE* = 0.03) than memory under sequential presentation format (*MMs* = 0.45, *SE* = 0.03), although the Bayesian analysis suggests little evidence to support the effect. No interaction was observed between presentation format and value or attention (*P*s ≥ 0.36, $BF_{01} \geq 3.33$).

Table 1. Proportion correct on the immediate test and delayed re-test as a function of presentation format, concurrent task, and value.

	Sequential		Simultaneous	
	Immediate	Delayed	Immediate	Delayed
Full attention				
High	.76 (.03)	.57 (.04)	.82 (.02)	.64 (.04)
Low	.71 (.03)	.49 (.04)	.69 (.04)	.55 (.05)
Divided attention				
High	.58 (.03)	.37 (.04)	.67 (.03)	.49 (.04)
Low	.53 (.03)	.38 (.04)	.58 (.03)	.48 (.04)

Discussion

Experiment 1 investigated whether divided attention during encoding affects the ability to selectively encode more valuable item-colour bindings when tested immediately and after a delay. In the immediate test, divided attention decreased overall memory performance level, but it did not impact participants' ability to preferentially encode and briefly maintain high value bindings. In the delayed re-test, the value effect was maintained when full attention was provided, but no value effect was observed when attention was divided. In short, divided attention doesn't change the immediate value effect but it seems to reduce the effect after a delay. These impacts were consistent across simultaneous and sequential presentation formats.

Thus, in line with a large body of research, attentional resources clearly play a role in initial memory encoding

(Craik et al., 1996). The prioritisation of higher value items for immediate memory does not appear to particularly load on attention. This fits with prior work on episodic memory (Middlebrooks et al., 2017; Siegel & Castel, 2018b). However, under divided attention these effects were short-lived and did not survive to the delayed retest. Thus, results from the current experiment indicate that the value effect on item-colour binding memory can be derived during encoding even under divided attention, but this is only relatively transient; attention during encoding may be required to generate a longer-lasting value effect.

Experiment 2

The first experiment indicated that the value effect could still be briefly maintained following divided attention at encoding, but that attentional resources during encoding are important for derivation of more durable value effects. What other factors might play a role here and, relatedly, how might we account for the observation of a value effect under divided attention in the immediate test in Experiment 1? Classic work in the long-term memory domain have distinguished maintenance rehearsal and elaborative rehearsal (e.g., Craik & Lockhart, 1972; Craik & Watkins, 1973; Roenker, 1974; Rundus, 1977). Maintenance rehearsal is generally assumed to be a cost-free process. It requires little, if any cognitive resources (Baddeley, 1986; Cowan, 2001). Elaborative rehearsal, however, is a more complex and demanding process (Schneider & Sodian, 1997). Experiment 1 found that value effect could still be observed with reduced attentional resources. It is possible that more valuable associative information may in part be prioritised through maintenance rehearsal. For item-colour binding memory, this could be verbal/subvocal rehearsal, especially when items and colours are both nameable.

To examine the role of verbal rehearsal in value effect on memory for item-colour binding, in Experiment 2, an articulatory suppression task was adopted during encoding (e.g., Atkinson et al., 2018b; Hitch et al., 2018; Hu et al., 2014, 2016; Sandry et al., 2014). If articulatory suppression abolished the value effect, this would suggest that verbal rehearsal is employed to prioritise high value item-colour bindings. As in Experiment 1, Experiment 2 also examined the impact from presentation format and how it might interact with the other factors under investigation.

Method

Design

Experiment 2 adopted a 2 (value: high, low) × 2 (verbal task: no – articulatory suppression, articulatory suppression) × 2 (presentation format: sequential, simultaneous) mixed-factor design, with value and verbal task as within factors and presentation format as a between-subject factor. Counterbalancing and order of conditions was implemented as in Experiment 1. Dependent variables were immediate item-colour memory and delayed item-colour memory.

Participants

One hundred and four participants were recruited from University of Leeds and The Chinese University of Hong Kong (79 females; mean age = 20.3; range = 18-29 years; $N_{sequential} = 53$, $N_{simultaneous} = 51$). None of them have participated in Experiment 1. All participants reported having correct or corrected-to-normal vision and were without colour-vision deficits. None reported a history of neurological disorders. Informed consent was acquired in accordance with the guidelines set by the Ethics Committee from the University of Leeds (Ethics reference number: PSYC-14) and from The Chinese University of Hong Kong (Ethics reference number: 22232022).

Materials and procedure

The material and procedure were the same as Experiment 1 with the following exceptions. Instead of the two attention conditions in Experiment 1, there were two verbal task conditions (no-articulatory suppression vs. articulatory suppression) in Experiment 2. In the no – articulatory suppression condition, the memory task was the only task; in the articulatory suppression condition, three letters were shown before the presentation of items. Participants were asked to repeat the letters out loud during the encoding phase. Before the immediate item-colour memory test, they were asked to type the letters they were asked to repeat. This was implemented to encourage participants to perform the articulatory suppression task in the online environment.

Results

Verbal task performance

Verbal task recordings were checked to ensure that participants were actively engaged in articulatory suppression. Thirteen participants did not perform the verbal task, so their data were excluded from analysis. The final analysis included 91 participants. The response rate in the verbal task was calculated as the number of trials participants performed the verbal task divided by the total number of encoding trials. Participants' average response rate on the verbal task was 0.96 ($SE = 0.01$, range = 0.2–1).

Immediate test

Immediate and delayed item-colour binding memory as a function of value and verbal task are displayed in Figure 3, and broken down by presentation format in Table 2. The chance level for the memory test is 0.125. A 2 (value:

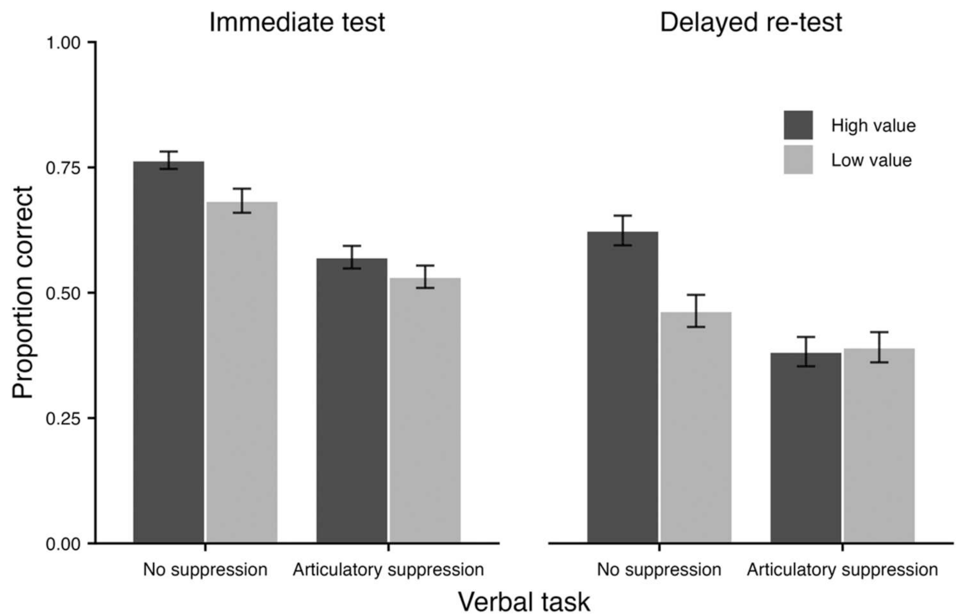

Figure 3. Mean accuracy in immediate test and delayed re-test as a function of value and verbal task. Chance level: 0.125. Error bars show standard error.

high, low) × 2 (verbal task: no-articulatory suppression, articulatory suppression) × 2 (presentation format: sequential, simultaneous) repeated measures ANOVA was conducted. This revealed a main effect of value [$F(1, 89) = 13.73$, $p < .001$, $\eta_p^2 = 0.13$, $BF_{10} = 69.94$], with better memory for high value item-colour bindings ($MMs = 0.67$; $SE = 0.02$) than low value bindings ($MMs = 0.61$; $SE = 0.02$). There was also a main effect of verbal task [$F(1, 89) = 90.36$, $p < .001$, $\eta_p^2 = 0.50$, $BF_{10} > 1000$], such that articulatory suppression reduced overall memory performance level ($MMs = 0.55$; $SE = 0.02$) relative to that with no-articulatory suppression ($MMs = 0.73$; $SE = 0.02$). The interaction between value and verbal task was marginally non-significant and not well supported by Bayesian analysis [$F(1, 89) = 3.77$, $p = .055$, $\eta_p^2 = 0.04$, $BF_{01} = 1.18$]. To further examine any potential differences in value effect, paired samples t-tests were conducted. It was found that memory for high value item-colour bindings was better than memory for low value item-colour bindings without articulatory suppression [$t(90) = 4.03$, $p < .001$, Cohen's $d = 0.42$, $BF_{10} = 165.53$], but this effect was relatively smaller (and not supported by Bayesian analysis) with articulatory suppression [$t(90) = 2.09$, $p = .039$, $d = 0.22$, $BF_{01} = 1.08$]. The effect of presentation format was not significant, $F(1, 89) = 2.61$, $p = .11$, $\eta_p^2 = 0.03$, $BF_{01} = 1.17$ (simultaneous presentation format: $MMs = 0.67$, $SE = 0.02$; sequential presentation format: $MMs = 0.61$; $SE = 0.02$). No interaction was observed between presentation format and other factors ($Ps \geq 0.18$, $BF_{01} \geq 1.76$).

Table 2. Proportion correct on the immediate test and the delayed re-test as a function of presentation format, concurrent task, and value.

	Sequential		Simultaneous	
	Immediate	Delayed	Immediate	Delayed
No articulatory suppression				
High	.74 (.03)	.55 (.05)	.78 (.02)	.69 (.04)
Low	.67 (.04)	.44 (.04)	.69 (.03)	.49 (.05)
Articulatory suppression				
High	.51 (.03)	.34 (.04)	.62 (.04)	.43 (.04)
Low	.51 (.03)	.37 (.04)	.55 (.03)	.41 (.05)

Delayed re-test

A 2 (value: high, low) × 2 (verbal task: no − articulatory suppression, articulatory suppression) × 2 (presentation format: sequential, simultaneous) repeated measures ANOVA revealed a main effect of value [$F(1, 89) = 9.32$, $p = .003$, $\eta_p^2 = 0.10$, $BF_{10} = 7.12$], where memory performance was greater for high value bindings ($MMs = 0.50$; $SE = 0.02$) than that for low value bindings ($MMs = 0.43$; $SE = 0.02$). The effect of verbal task was significant [$F(1, 89) = 27.65$, $p < .001$, $\eta_p^2 = 0.24$, $BF_{10} > 1000$], such that memory was superior with no-articulatory suppression ($MMs = 0.54$; $SE = 0.03$) than with articulatory suppression ($MMs = 0.39$; $SE = 0.03$). Value also interacted with verbal task [$F(1, 89) = 14.75$, $p < .001$, $\eta_p^2 = 0.14$, $BF_{10} = 281.18$]. Paired samples t-tests indicated that memory for high value item-colour bindings was better than memory for low value item-colour bindings without articulatory suppression [$t(90) = 4.66$, $p < .001$, Cohen's $d = 0.49$, $BF_{10} > 1000$], and that articulatory suppression abolished this value effect [$t(90) = -0.29$, $p = .78$, $d = -0.03$, $BF_{01} = 8.26$]. The effect of presentation format was not significant, $F(1, 89) = 3.80$, $p = .054$, $\eta_p^2 = 0.04$, $BF_{10} = 1.20$ (simultaneous format: $MMs = 0.51$; $SE = 0.03$; sequential format: $MMs = 0.43$, $SE = 0.03$). No interaction was observed between presentation format and other factors ($Ps \geq 0.19$, $BF_{01} \geq 2.54$).

Discussion

Experiment 2 explored the role of verbal coding and rehearsal in the value effect on immediate and delayed item-colour binding memory. Firstly, the value effect observed in Experiment 1 was again replicated at both immediate and delayed test points, confirming that individuals can preferentially encode and retrieve higher value items across different retention durations, and that this can be detected in an online research context. In terms of the impact of articulatory suppression, this reduced overall memory performance immediately and after a delay. In addition, it seems that articulatory suppression somewhat decreased the memory advantage for high value items at the immediate test, and removed the value effect when items were tested again after a delay. These results suggest that verbal rehearsal is involved in selectively remembering more valuable item-colour bindings. These impacts were consistent across simultaneous and sequential presentation formats.

General discussion

The current study explored the value effect on immediate and delayed memory for item-colour bindings, examining the role of attention (Experiment 1) and verbal rehearsal (Experiment 2). An advantage for high over low value items was observed on an immediate test and a delayed re-test in both experiments, replicating and extending previous observations of this phenomenon for shape-colour binding in working memory (Hu et al., 2014) and long-term memory (Yin et al., 2021). The first experiment found that relative to the full attention condition, divided attention at encoding did not impact the value effect in the immediate test, but it seemed to abolish the value effect in the delayed re-test. These results indicate that a transient value effect can emerge even with reduced attentional resources, but sufficient attentional resources are perhaps required to maintain a longer-lasting value effect. The second experiment examined verbal contributions to value-based prioritisation, finding that relative to a no-task condition, articulatory suppression seemed to reduce the value effect in the immediate and clearly abolished the value effect in the delayed re-test, suggesting verbal rehearsal is a critical encoding process involved the value effects. In both experiments, there was little reliable evidence that presentation format and attention/verbal rehearsal during encoding interacted to influence the value effects that were observed.

It is now well established that attentional control resources are important during encoding into memory (e.g., Craik et al., 1996; Hitch et al., 2020). However, previous studies have revealed inconsistent outcomes regarding the role of attention in generating value effects. Some studies found that value effects were maintained under divided attention in various situations, whether the primary task is relatively more attention-demanding (e.g., associative memory, Siegel & Castel, 2018b) or dual tasks stress attention to different degrees (Middlebrooks et al., 2017). Others, in contrast, found that a dual task load during the encoding phase abolished/reduced the value effect (Elliott & Brewer, 2019). Both these outcomes were observed in Experiment 1, such that divided attention did not impact participants' ability to strategically encode and briefly maintain more valuable item-colour bindings in the immediate test, but it did abolish the value effect in a delayed re-test. The results from Experiment 1 may provide a possible explanation for the inconsistent findings from previous studies; while the studies mentioned above all adopted an immediate test paradigm, they differ in the number of study items and thus retention time before the test. In the studies finding value effects under divided attention (Middlebrooks et al., 2017; Siegel & Castel, 2018b), short study lists (between 10–20 stimuli in in each list) were used, resulting in relatively brief retention times before the test. Therefore, value effects were observed under divided attention that might be relatively transient in nature. In the study demonstrating that divided attention during encoding reduced value effects (Elliott & Brewer, 2019), there were 40 study stimuli in each list. This resulted in a longer retention time before the test, during which time a possibly transient value effect may have gradually dissipated. However, we acknowledge the speculative nature of this interpretation. It would be useful for futures studies to further explore how value might interact with attention across different retention intervals, testing points, and without successive testing.

Experiment 1 shows that a value effect could be observed even when under a general attentional load, but this did not survive to the delayed re-test. How might participants use available attentional resources to prioritise more valuable bindings? One possible mechanism is the application of elaborative encoding for higher value information (Ariel et al., 2015; Bui et al., 2013; Cohen et al., 2014, 2016; Hennessee et al., 2019). This is supported by experimental studies (Bui et al., 2013; Hennessee et al., 2019) and by participants' self-report (Ariel et al., 2015) that they use more effective strategies (i.e., imagery mediators, keyword mediators, sentence generation, or relational processing) when learning high value words or word pairs. Evidence has also been found from studies using fMRI; memory selectivity is associated with greater differences between high and low value words during presentation in the activation of semantic processing brain regions (e.g., left inferior frontal gyrus and left posterior lateral temporal cortex), suggesting elaborative semantic processing may be an important mechanism for encoding valuable items (Cohen et al., 2014, p. 2016).

However, the studies mentioned above investigated the value effect on item memory (mostly using words). It is relatively easy to encode words elaboratively in various ways, such as constructing a mental image of the word (e.g., Lutz & Lutz, 1978; MacInnis & Price, 1987), relating it with self (e.g., Klein & Kihlstrom, 1986; Symons & Johnson, 1997) or organising related words together (e.g., Lange et al., 2011; Melkman et al., 1981; Tulving, 1962). In contrast, it might be difficult to spontaneously apply these strategies to associative memory. For instance, Siegel and Castel (2018a) found value effects on memory for item-location bindings but argued that elaborative encoding for such information may be difficult or even impossible. Similarly, a value effect has also been observed on memory for face-name bindings (Festini et al., 2013; Hargis & Castel, 2017). Considering names are usually meaningless and lack semantic associations (e.g., Cohen, 1990; McCluney & Krauter, 1997; Terry, 1994), this value effect might be less likely driven by elaborative encoding for more valuable bindings.

Turning to the present task context, it is possible that the encoding of more valuable item-colour bindings is achieved in part via elaborative rehearsal. For example, participants may choose to remember the associative pairing of *red* and *iron*, by considering that the iron is red because it is hot. This strategic approach may be of variable difficulty depending on the feature pairings but in each case, we would assume that general attentional resources are required. It is also possible that the encoding of more valuable item-colour bindings is achieved via more superficial and resource-light encoding approaches, such as maintenance rehearsal (e.g., vocally/subvocally repeating "red iron"). Our interpretation of the current findings is that the value effect can be derived using different strategic approaches, with the durability of the effect reflective of the strategies that are employed. When individuals can fully focus on the task with no other concurrent activity required, they may choose to implement one or a combination of these approaches. Strategies such as elaborative encoding are more attention-demanding but result in longer-lasting effects that survive to the delayed test. When individuals are unable to fully focus on the task due to concurrent activity, they may flexibly adjust their strategies depending on the nature of the secondary task.

To be more specific, in Experiment 1, when attention was divided, we assume that it was challenging for participants to utilise resource-demanding strategies like elaborative encoding. Instead, they may have reverted to resource-light encoding approaches, such as verbal rehearsal. This allowed for a transient value effect to emerge, but the effect did not reliably persist to the delayed re-test. In Experiment 2, when rehearsal was disrupted by a concurrent verbal task during encoding, participants may have shifted to non-verbal encoding strategies. These non-verbal strategies could be elaborative encoding, visual encoding or other strategies. However, it may be less likely that the non-verbal strategy was elaborative encoding, as verbal processing may be an important aspect of elaborative thinking and articulatory suppression can disrupt this form of processing (Baddeley & Andrade, 2000). In addition, the observation of a value effect on the immediate test but not the delayed re-test suggests that the non-verbal strategies employed were not long-lasting in their benefits. Given these considerations, it is more plausible that the participants relied on visual encoding or other non-verbal approaches in Experiment 2 when rehearsal was disrupted. Nevertheless, it would be interesting for future studies to directly explore whether articulatory suppression impacts elaborative encoding, perhaps through use of self-report measures. A further interesting possibility is that the dominant or more important representational modality might change between test points, for example with the immediate test drawing relatively more on the visual and the delayed re-test more on verbal representations. This could help explain some aspects of the current findings, but it remains speculative and needs further research enquiry to confirm or refute.

Another possible explanation for the results observed in the current study is that the tone detection task and the verbal task may have disrupted initial stages of consolidation to some degree. Processes of memory consolidation can apply across extended time periods, but in the present context this broadly refers to the post-encoding stabilisation of transient memory traces into more durable representations that are resistant to forgetting (Cotton & Ricker, 2022). Providing more time and central attentional resources for the consolidation process typically leads to improved memory (Cotton & Ricker, 2022). In the current study, when participants were required to perform a concurrent dual-task (tone detection task or verbal task), that may have diverted time and attentional resources away from the memory task, making it difficult for memory traces of more valuable item-colour bindings to be adequately strengthened, at least in the early period of the consolidation process. Therefore, no value effect was observed in delayed re-tests with concurrent dual tasks.

Another possibility to consider is whether the tone detection task was interfering with the ability to verbally rehearse, thus resulting in the diminished value effects found in Experiment 1. The tone detection task may have some impact on the ability to engage in verbal rehearsal, but we believe this effect is likely to be relatively small. The tone detection task requires general attentional resources, so it primarily interferes with tasks that are particularly attentionally demanding. However, maintenance rehearsal is generally assumed to be a relatively cost-free process that requires few cognitive resources (Baddeley, 1986; Cowan, 2001). In Experiment 1, we observed that the value effect on memory for item-colour bindings survived even with the concurrent tone detection task in the immediate test. We speculate that such value effect may be achieved through verbal rehearsal, as verbal rehearsal appears to be less affected by demands on attentional resources.

A subsidiary factor of interest in the present study was whether and how patterns might change with presentation format. In the delayed re-test from Experiment 1, memory accuracy for item-colour bindings was greater in the simultaneous presentation format than sequential presentation format, consistent with previous findings (Allen et al., 2006; Blalock & Clegg, 2010; Gorgoraptis et al., 2011; Lecerf & De Ribaupierre, 2005; Siegel & Castel, 2018a, 2018b), but this was not well supported by Bayesian analysis. There was also no evidence for effects in the immediate test or in Experiment 2, and there was little evidence that presentation format and attention/verbal rehearsal interacted to influence value effects in either experiment. However, we acknowledge that our required sample sizes were estimated based on item value as the primary factor of interest, and this was implemented within-subjects. Presentation format was a between-subjects factor and thus our study may be somewhat underpowered to detect any meaningful effects.

It is worth noting recent evidence that value-based prioritisation applied during encoding in visual working memory tasks does not always consistently translate into value effects on a later, delayed long-term memory task (Atkinson et al., 2024; Jeanneret et al., 2023) material. This stands in apparent contrast to the positive effects observed on item-colour binding in the present long-term memory study, and those in the broader literature on value-directed remembering in long-term memory (Knowlton & Castel, 2022). The study by Atkinson et al. (2024) used articulatory suppression during encoding, which may have contributed to the absence of effects, given that there is some evidence that working memory value effects can transfer to long-term memory when using verbal stimuli (Labaronne et al., 2023; Sandry et al., 2020). In addition, both Atkinson et al. (2024) and Jeanneret et al. (2023) employed a shorter encoding time (between 250 and 500 ms per item) than the present study (3 s per item) and others on value-directed remembering in long-term memory. More extended encoding times may impact on choice of encoding strategy, which, in turn, can influence the durability of value effects. Overall, durability of value effects is likely to reflect a combination of factors including resource availability, motivation, and encoding strategy, along with the actual memoranda involved.

Our aim in the current study was to examine value effects under different encoding conditions and track how these change for the same items when tested immediately after encoding and then again after a short delay. However, this method of testing the same items at two time points introduces a potential limitation in that a testing effect may be operating, with value effects observed at the delayed test partly reflecting more successful retrieval at the earlier immediate test. While earlier testing is indeed likely to impact on later performance, this does not offer an explanation for the removal of value effects following concurrent activity that was observed at the delayed re-test. Nevertheless, it would be useful to explore how earlier testing and retrieval might interact with value and concurrent load on delayed memory.

It is also useful to reflect on our use of a filler task during the retention interval between the immediate test and the delayed re-test. Items in all concurrent task conditions underwent the same filled retention interval and therefore suffered from forgetting as a result. At the delayed re-test, value effects were apparent in no-task conditions, despite this following the filled delay. However, these value effects at the delayed re-test did not survive when the participant had earlier performed the tone or verbal task during the encoding phase. Thus, the filler task was a constant for each encoding concurrent task condition; the value effect that we saw in the delayed re-test was seemingly dependent on what the participant was doing during encoding, and not during the retention interval between tests. Nevertheless, there is a speculative possibility for how the filler task might be contributing to the set of outcomes on the delayed re-test. Following prior studies (e.g., Atkinson et al., 2024; Baddeley et al., 2019; Jeanneret et al., 2023), it was deliberately implemented to prevent active strategic maintenance over the delay. A value-based representational boost that is weaker due to a concurrent task being performed during encoding might then also be reliant on active maintenance over time, and more vulnerable to a demanding activity performed during retention that prevents this. This is an interesting possibility and would warrant further research exploring what happens to memory representations, including value benefits and costs, over retention intervals of differing durations and cognitive demands.

Conclusions

The current study sought to shed light on the conditions under which value effect can be derived in item-colour binding memory. Memory was superior for item-colour bindings that were associated with high (relative to low) point values at encoding, an effect that emerged on an immediate test and a delayed re-test in both experiments. A transient value effect on item-colour binding memory was obtained when availability of attentional resources was reduced during encoding, with the high-value advantage only emerging on the immediate and not the delayed re-test (Experiment 1). This indicates that attention-demanding strategic encoding approaches (possibly including, but not limited to, elaborative processing) are involved in producing long-lasting value effects. Verbal rehearsal appears to reduce value effect in the immediate test and clearly abolished the effect in the delayed re-test, suggesting verbal rehearsal is another important factor driving the value effects (Experiment 2). These findings indicate that different strategic approaches can be engaged during encoding to prioritise high value items.

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Data availability statement

Data are available on the Open Science Framework at this link: https://osf.io/cv24j.

References

Allen, R. J., Atkinson, A. L., & Hitch, G. J. (2024). Paying attention to what is important in working memory. *Quarterly Journal of Experimental Psychology*, https://doi.org/10.1177/17470218241258102

Allen, R. J., Atkinson, A. L., & Nicholls, L. A. B. (2021). Strategic prioritisation enhances young and older adults' visual feature binding in working memory. *Quarterly Journal of Experimental Psychology*, *74*(2), 363–376. https://doi.org/10.1177/1747021820960712

Allen, R. J., Baddeley, A. D., & Hitch, G. J. (2006). Is the binding of visual features in working memory resource-demanding? *Journal of Experimental Psychology: General*, *135*(2), 298–313. https://doi.org/10.1037/0096-3445.135.2.298

Allen, R. J., Baddeley, A. D., & Hitch, G. J. (2014). Evidence for two attentional components in visual working memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *40*(6), 1499–1509. https://doi.org/10.1037/xlm0000002

Allen, R. J., Hitch, G. J., Mate, J., & Baddeley, A. D. (2012). Feature binding and attention in working memory: A resolution of previous contradictory findings. *Quarterly Journal of Experimental Psychology*, *65*(12), 2369–2383. https://doi.org/10.1080/17470218.2012.687384

Allen, R. J., & Ueno, T. (2018). Multiple high-reward items can be prioritized in working memory but with greater vulnerability to interference. *Attention, Perception, & Psychophysics*, *80*(7), 1731–1743. https://doi.org/10.3758/s13414-018-1543-6

Anwyl-Irvine, A. L., Massonnié, J., Flitton, A., Kirkham, N., & Evershed, J. K. (2020). Gorilla in our midst: An online behavioral experiment builder. *Behavior Research Methods*, *52*(1), 388–407. https://doi.org/10.3758/s13428-019-01237-x

Ariel, R., Dunlosky, J., & Bailey, H. (2009). Agenda-based regulation of study-time allocation: when agendas override item-based monitoring. *Journal of Experimental Psychology: General*, *138*(3), 432. https://doi.org/10.1037/a0015928

Ariel, R., Price, J., & Hertzog, C. (2015). Age-related associative memory deficits in value-based remembering: The contribution of agenda-based regulation and strategy use. *Psychology and Aging*, *30*(4), 795–808. https://doi.org/10.1037/a0039818

Atkinson, A. L., Allen, R. J., Baddeley, A. D., Hitch, G. J., & Waterman, A. H. (2021). Can valuable information be prioritized in verbal working memory? *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *47*(5), 747–764. https://doi.org/10.1037/xlm0000979

Atkinson, A. L., Baddeley, A. D., & Allen, R. J. (2018a). Remember some or remember all? Ageing and strategy effects in visual working memory. *Quarterly Journal of Experimental* Psychology, *71*(7), 1561–1573. https://doi.org/10.1080/17470218.2017.1341537

Atkinson, A. L., Berry, D., Waterman, A. H., Baddeley, A. D., Hitch, G. J., & Allen, R. J. (2018b). Are there multiple ways to direct attention in working memory? *Annals of the New York Academy of Sciences*, *1424*(1), 115–126. https://doi.org/10.1111/nyas.13634

Atkinson, A. L., Oberauer, K., Allen, R. J., & Souza, A. S. (2022). Why does the probe value effect emerge in working memory? Examining the biased attentional refreshing account. *Psychonomic Bulletin & Review*, 1–10.

Atkinson, A. L., Waterman, A. H., & Allen, R. J. (2019). Can children prioritize more valuable information in working memory? An exploration into the effects of motivation and memory load. *Developmental Psychology*, *55*(5), 967–980. https://doi.org/10.1037/dev0000692

Atkinson, A. L., Waterman, A. H., & Allen, R. J. (2024). Does value-based prioritization at working memory enhance long-term memory? *Memory & Cognition*, 1–16.

Baddeley, A. D. (1986). *Working memory*. Oxford University Press.

Baddeley, A. D., & Andrade, J. (2000). Working memory and the vividness of imagery. *Journal of Experimental Psychology: General*, *129*(1), 126–145. https://doi.org/10.1037/0096-3445.129.1.126

Baddeley, A., Atkinson, A., Kemp, S., & Allen, R. (2019). The problem of detecting long-term forgetting: Evidence from the crimes test and the four doors test. *Cortex*, *110*, 69–79. https://doi.org/10.1016/j.cortex.2018.01.017

Baddeley, A. D., & Hitch, G. (1974). Working memory. In *Psychology of learning and motivation* (Vol. 8, pp. 47–89). Elsevier.

Baddeley, A. D., Hitch, G., & Allen, R. (2021). A multicomponent model of working memory. In *Working memory: State of the science* (pp. 10–43).

Baddeley, A. D., Lewis, V., Eldridge, M., & Thomson, N. (1984). Attention and retrieval from long-term memory. *Journal of Experimental Psychology: General*, *113*(4), 518. https://doi.org/10.1037/0096-3445.113.4.518

Baddeley, A. D., & Logie, R. H. (1999). Working memory: The multiple-component model. In A. Miyake, & P. Shah (Eds.), *Models of working memory: Mechanisms of active maintenance and executive control* (pp. 28–61). Cambridge University Press. https://doi.org/10.1017/CBO9781139174909.005

Baddeley, A. D., Thomson, N., & Buchanan, M. (1975). Word length and the structure of short-term memory. *Journal of Verbal Learning and Verbal Behavior*, *14*(6), 575–589. https://doi.org/10.1016/S0022-5371(75)80045-4

Barrouillet, P., Bernardin, S., & Camos, V. (2004). Time constraints and resource sharing in adults' working memory spans. *Journal of Experimental Psychology: General*, *133*(1), 83–100. https://doi.org/10.1037/0096-3445.133.1.83

Barrouillet, P., & Camos, V. (2001). Developmental increase in working memory span: Resource sharing or temporal decay? *Journal of Memory and Language*, *45*(1), 1–20. https://doi.org/10.1006/jmla.2001.2767

Barrouillet, P., & Camos, V. (2007). The time-based resource-sharing model of working memory. In N. Osaka, R. H. Logie, & M. D'Esposito (Eds.), *The cognitive neuroscience of working memory* (pp. 59–80). Oxford University Press.

Blalock, L. D., & Clegg, B. A. (2010). Encoding and representation of simultaneous and sequential arrays in visuospatial working memory. *Quarterly Journal of Experimental Psychology*, *63*(5), 856–862. https://doi.org/10.1080/17470211003690680

Brown, L. A., & Brockmole, J. R. (2010). The role of attention in binding visual features in working memory: Evidence from cognitive ageing. *Quarterly Journal of Experimental Psychology*, *63*(10), 2067–2079. https://doi.org/10.1080/17470211003721675

Bui, D. C., Friedman, M. C., McDonough, I. M., & Castel, A. D. (2013). False memory and importance: Can we prioritize encoding without consequence? *Memory & Cognition*, *41*(7), 1012–1020. https://doi.org/10.3758/s13421-013-0317-6

Castel, A. D., Balota, D. A., & McCabe, D. P. (2009). Memory efficiency and the strategic control of attention at encoding: Impairments of value-directed remembering in Alzheimer's disease. *Neuropsychology*, *23*(3), 297–306. https://doi.org/10.1037/a0014888

Castel, A. D., Benjamin, A. S., Craik, F. I., & Watkins, M. J. (2002). The effects of aging on selectivity and control in short-term recall. *Memory & Cognition*, *30*(7), 1078–1085. https://doi.org/10.3758/BF03194325

Castel, A. D., & Craik, F. I. (2003). The effects of aging and divided attention on memory for item and associative information.

Psychology and Aging, *18*(4), 873–885. https://doi.org/10.1037/0882-7974.18.4.873

Castel, A. D., Lee, S. S., Humphreys, K. L., & Moore, A. N. (2011). Memory capacity, selective control, and value-directed remembering in children with and without attention-deficit/hyperactivity disorder (ADHD). *Neuropsychology*, *25*(1), 15–24. https://doi.org/10.1037/a0020298

Castel, A. D., Murayama, K., Friedman, M. C., McGillivray, S., & Link, I. (2013). Selecting valuable information to remember: Age-related differences and similarities in self-regulated learning. *Psychology and Aging*, *28*(1), 232–242. https://doi.org/10.1037/a0030678

Clark-Foos, A., & Marsh, R. L. (2008). Recognition memory for valenced and arousing materials under conditions of divided attention. *Memory (Hove, England)*, *16*(5), 530–537. https://doi.org/10.1080/09658210802007493

Cohen, G. (1990). Why is it difficult to put names to faces? *British Journal of Psychology*, *81*(3), 287–297. https://doi.org/10.1111/j.2044-8295.1990.tb02362.x

Cohen, M. S., Rissman, J., Hovhannisyan, M., Castel, A. D., & Knowlton, B. J. (2017). Free recall test experience potentiates strategy-driven effects of value on memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *43*(10), 1581–1601. https://doi.org/10.1037/xlm0000395

Cohen, M. S., Rissman, J., Suthana, N. A., Castel, A. D., & Knowlton, B. J. (2014). Value-based modulation of memory encoding involves strategic engagement of fronto-temporal semantic processing regions. *Cognitive, Affective, & Behavioral Neuroscience*, *14*(2), 578–592. https://doi.org/10.3758/s13415-014-0275-x

Cohen, M. S., Rissman, J., Suthana, N. A., Castel, A. D., & Knowlton, B. J. (2016). Effects of aging on value-directed modulation of semantic network activity during verbal learning. *NeuroImage*, *125*, 1046–1062. https://doi.org/10.1016/j.neuroimage.2015.07.079

Cotton, K., & Ricker, T. J. (2022). Examining the relationship between working memory consolidation and long-term consolidation. *Psychonomic Bulletin & Review*, *29*(5), 1625–1648. https://doi.org/10.3758/s13423-022-02084-2

Cowan, N. (1999). An embedded-processes model of working memory. In A. Miyake, & P. Shah (Eds.), *Models of working memory: Mechanisms of active maintenance and executive control* (pp. 62–101). Cambridge University Press. https://doi.org/10.1017/CBO9781139174909.006

Cowan, N. (2001). The magical number 4 in short-term memory: A reconsideration of mental storage capacity. *Behavioral and Brain Sciences*, *24*(1), 87–114. https://doi.org/10.1017/S0140525X01003922

Cowan, N. (2008). Progress in Brain Research. *Progress in Brain Research*, *169*, 323–338. https://doi.org/10.1016/S0079-6123(07)00020-9

Craik, F. I., Govoni, R., Naveh-Benjamin, M., & Anderson, N. D. (1996). The effects of divided attention on encoding and retrieval processes in human memory. *Journal of Experimental Psychology: General*, *125*(2), 159–180. https://doi.org/10.1037/0096-3445.125.2.159

Craik, F. I., & Lockhart, R. S. (1972). Levels of processing: A framework for memory research. *Journal of Verbal Learning and Verbal Behavior*, *11*(6), 671–684. https://doi.org/10.1016/S0022-5371(72)80001-X

Craik, F. I., Luo, L., & Sakuta, Y. (2010). Effects of aging and divided attention on memory for items and their contexts. *Psychology and Aging*, *25*(4), 968–979. https://doi.org/10.1037/a0020276

Craik, F. I., & Watkins, M. J. (1973). The role of rehearsal in short-term memory. *Journal of Verbal Learning and Verbal Behavior*, *12*(6), 599–607. https://doi.org/10.1016/S0022-5371(73)80039-8

Cycowicz, Y. M., Friedman, D., Rothstein, M., & Snodgrass, J. G. (1997). Picture naming by young children: Norms for name agreement, familiarity, and visual complexity. *Journal of Experimental Child Psychology*, *65*(2), 171–237. https://doi.org/10.1006/jecp.1996.2356

Dell'acqua, R., & Joucoeur, P. (2000). Visual encoding of patterns is subject to dual-task interference. *Memory & Cognition*, *28*(2), 184–191. https://doi.org/10.3758/BF03213798

Elliott, B. L., Blais, C., McClure, S. M., & Brewer, G. A. (2020a). Neural correlates underlying the effect of reward value on recognition memory. *NeuroImage*, *206*, 116296. https://doi.org/10.1016/j.neuroimage.2019.116296

Elliott, B. L., & Brewer, G. A. (2019). Divided attention selectively impairs value-directed encoding. *Collabra: Psychology*, *5*(1), 4. https://doi.org/10.1525/collabra.156

Elliott, B. L., McClure, S. M., & Brewer, G. A. (2020b). Individual differences in value-directed remembering. *Cognition*, *201*, 104275. https://doi.org/10.1016/j.cognition.2020.104275

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*(2), 175–191. https://doi.org/10.3758/BF03193146

Festini, S. B., Hartley, A. A., Tauber, S. K., & Rhodes, M. G. (2013). Assigned value improves memory of proper names. *Memory (Hove, England)*, *21*(6), 657–667. https://doi.org/10.1080/09658211.2012.747613

Gorgoraptis, N., Catalao, R. F., Bays, P. M., & Husain, M. (2011). Dynamic updating of working memory resources for visual objects. *Journal of Neuroscience*, *31*(23), 8502–8511. https://doi.org/10.1523/JNEUROSCI.0208-11.2011

Griffin, M. L., Benjamin, A. S., Sahakyan, L., & Stanley, S. E. (2019). A matter of priorities: High working memory enables (slightly) superior value-directed remembering. *Journal of Memory and Language*, *108*, 104032. https://doi.org/10.1016/j.jml.2019.104032

Hargis, M. B., & Castel, A. D. (2017). Younger and older adults' associative memory for social information: The role of information importance. *Psychology and Aging*, *32*(4), 325–330. https://doi.org/10.1037/pag0000171

Hennessee, J. P., Castel, A. D., & Knowlton, B. J. (2017). Recognizing what matters: Value improves recognition by selectively enhancing recollection. *Journal of Memory and Language*, *94*, 195–205. https://doi.org/10.1016/j.jml.2016.12.004

Hennessee, J. P., Knowlton, B. J., & Castel, A. D. (2018). The effects of value on context-item associative memory in younger and older adults. *Psychology and Aging*, *33*(1), 46–56. https://doi.org/10.1037/pag0000202

Hennessee, J. P., Patterson, T. K., Castel, A. D., & Knowlton, B. J. (2019). Forget me not: Encoding processes in value-directed remembering. *Journal of Memory and Language*, *106*, 29–39. https://doi.org/10.1016/j.jml.2019.02.001

Hicks, J. L., & Marsh, R. L. (2000). Toward specifying the attentional demands of recognition memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *26*(6), 1483–1498. https://doi.org/10.1037/0278-7393.26.6.1483

Hitch, G. J., Allen, R. J., & Baddeley, A. D. (2020). Attention and binding in visual working memory: Two forms of attention and two kinds of buffer storage. *Attention, Perception, & Psychophysics*, *82*(1), 280–293. https://doi.org/10.3758/s13414-019-01837-x

Hitch, G. J., Hu, Y., Allen, R. J., & Baddeley, A. D. (2018). Competition for the focus of attention in visual working memory: perceptual recency versus executive control. *Annals of the New York Academy of Sciences*, *1424*(1), 64–75. https://doi.org/10.1111/nyas.13631

Hu, Y., Allen, R. J., Baddeley, A. D., & Hitch, G. J. (2016). Executive control of stimulus-driven and goal-directed attention in visual working memory. *Attention, Perception, & Psychophysics*, *78*(7), 2164–2175. https://doi.org/10.3758/s13414-016-1106-7

Hu, Y., Allen, R. J., Baddeley, A. D., & Hitch, G. J. (2023). Visual working memory phenomena based on categorical tasks replicate using a continuous measure: A simple interpretation and some methodological considerations. *Attention, Perception, and Psychophysics*, *85*(5), 1733–1745. https://doi.org/10.3758/s13414-023-02656-x

Hu, Y., Hitch, G. J., Baddeley, A. D., Zhang, M., & Allen, R. J. (2014). Executive and perceptual attention play different roles in visual working memory: Evidence from suffix and strategy effects. *Journal of Experimental Psychology: Human Perception and Performance*, *40*(4), 1665–1678. https://doi.org/10.1037/a0037163

Iidaka, T., Anderson, N. D., Kapur, S., Cabez, R., & Craik, F. I. (2000). The effect of divided attention on encoding and retrieval in episodic memory revealed by positron emission tomography. *Journal of Cognitive Neuroscience*, *12*(2), 267–280. https://doi.org/10.1162/089892900562093

Jarosz, A. F., & Wiley, J. (2014). What are the odds? A practical guide to computing and reporting Bayes factors. *The Journal of Problem Solving*, *7*(1), 2. https://doi.org/10.7771/1932-6246.1167

Jeanneret, S., Bartsch, L. M., & Vergauwe, E. (2023). To be or not to be relevant: Comparing short- and long-term consequences across working memory prioritization procedures. *Attention, Perception, & Psychophysics*, *85*(5), 1486–1498. https://doi.org/10.3758/s13414-023-02706-4

Johnson, M. K. (1992). MEM: Mechanisms of recollection. *Journal of Cognitive Neuroscience*, *4*(3), 268–280. https://doi.org/10.1162/jocn.1992.4.3.268

Kern, R. P., Libkuman, T. M., Otani, H., & Holmes, K. (2005). Emotional stimuli, divided attention, and memory. *Emotion*, *5*(4), 408–417. https://doi.org/10.1037/1528-3542.5.4.408

Klein, S. B., & Kihlstrom, J. F. (1986). Elaboration, organization, and the self-reference effect in memory. *Journal of Experimental Psychology: General*, *115*(1), 26–38. https://doi.org/10.1037/0096-3445.115.1.26

Knowlton, B. J., & Castel, A. D. (2022). Memory and reward-based learning: A value-directed remembering perspective. *Annual Review of Psychology*, *73*(1), 25–52. https://doi.org/10.1146/annurev-psych-032921-050951

Labaronne, M., Ferreri, L., & Plancher, G. (2023). How do intentions modulate the effect of working memory on long-term memory? *Psychonomic Bulletin & Review*, 1–12.

Lange, D., Lee, P. M., & Dai, Y. (2011). Organizational reputation: A review. *Journal of Management*, *37*(1), 153–184. https://doi.org/10.1177/0149206310390963

Lecerf, T., & De Ribaupierre, A. (2005). Recognition in a visuospatial memory task: The effect of presentation. *European Journal of Cognitive Psychology*, *17*(1), 47–75. https://doi.org/10.1080/09541440340000420

Lutz, K. A., & Lutz, R. J. (1978). Imagery-eliciting strategies: Review and implications of research. In K. Hunt, & A. Abor (Eds.), *Advances in consumer research* (Vol. 05, pp. 611–620).

MacInnis, D. J., & Price, L. L. (1987). The role of imagery in information processing: Review and extensions. *Journal of Consumer Research*, *13*(4), 473–491. https://doi.org/10.1086/209082

McCluney, M. M., & Krauter, E. E. (1997). Mr. Barber or a barber: Remembering names and occupations. *Psychological Reports*, *81*(3), 847–863. https://doi.org/10.2466/pr0.1997.81.3.847

Melkman, R., Tversky, B., & Baratz, D. (1981). Developmental trends in the use of perceptual and conceptual attributes in grouping, clustering, and retrieval. *Journal of Experimental Child Psychology*, *31*(3), 470–486. https://doi.org/10.1016/0022-0965(81)90031-X

Middlebrooks, C. D., & Castel, A. D. (2018). Self-regulated learning of important information under sequential and simultaneous encoding conditions. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *44*(5), 779–792. https://doi.org/10.1037/xlm0000480

Middlebrooks, C. D., Kerr, T., & Castel, A. D. (2017). Selectively distracted: Divided attention and memory for important information. *Psychological Science*, *28*(8), 1103–1115. https://doi.org/10.1177/0956797617702502

Miller, A. L., Gross, M. P., & Unsworth, N. (2019). Individual differences in working memory capacity and long-term memory: The influence of intensity of attention to items at encoding as measured by pupil dilation. *Journal of Memory and Language*, *104*, 25–42. https://doi.org/10.1016/j.jml.2018.09.005

Mulligan, N. W., & Hartman, M. (1996). Divided attention and indirect memory tests. *Memory & Cognition*, *24*(4), 453–465. https://doi.org/10.3758/BF03200934

Naveh-Benjamin, M., Kilb, A., & Fisher, T. (2006). Concurrent task effects on memory encoding and retrieval: Further support for an asymmetry. *Memory & Cognition*, *34*(1), 90–101. https://doi.org/10.3758/BF03193389

Robison, M. K., & Unsworth, N. (2017). Working memory capacity, strategic allocation of study time, and value-directed remembering. *Journal of Memory and Language*, *93*, 231–244. https://doi.org/10.1016/j.jml.2016.10.007

Roenker, D. L. (1974). Role of rehearsal in long-term retention. *Journal of Experimental Psychology*, *103*(2), 368–371. https://doi.org/10.1037/h0036843

Rundus, D. (1977). Maintenance rehearsal and single-level processing. *Journal of Verbal Learning and Verbal Behavior*, *16*(6), 665–681. https://doi.org/10.1016/S0022-5371(77)80026-1

Sandry, J., & Ricker, T. J. (2020). Prioritization within visual working memory reflects a flexible focus of attention. *Attention, Perception, & Psychophysics*, *82*(6), 2985–3004. https://doi.org/10.3758/s13414-020-02049-4

Sandry, J., Schwark, J. D., & MacDonald, J. (2014). Flexibility within working memory and the focus of attention for sequential verbal information does not depend on active maintenance. *Memory & Cognition*, *42*(7), 1130–1142. https://doi.org/10.3758/s13421-014-0422-1

Sandry, J., Zuppichini, M. D., & Ricker, T. J. (2020). Attentional flexibility and prioritization improves long-term memory. *Acta Psychologica*, *208*, 103104. https://doi.org/10.1016/j.actpsy.2020.103104

Schneider, W., & Sodian, B. (1997). Memory strategy development: Lessons from longitudinal research. *Developmental Review*, *17*(4), 442–461. https://doi.org/10.1006/drev.1997.0441

Schönbrodt, F. D., & Wagenmakers, E. J. (2018). Bayes factor design analysis: Planning for compelling evidence. *Psychonomic Bulletin & Review*, *25*(1), 128–142. https://doi.org/10.3758/s13423-017-1230-y

Siegel, A. L., & Castel, A. D. (2018). Memory for important item-location associations in younger and older adults. *Psychology and Aging*, *33*(1), 30–45. https://doi.org/10.1037/pag0000209

Siegel, A. L., & Castel, A. D. (2018). The role of attention in remembering important item-location associations. *Memory & Cognition*, *46*(8), 1248–1262. https://doi.org/10.3758/s13421-018-0834-4

Siegel, A. L., Schwartz, S. T., & Castel, A. D. (2021). Selective memory disrupted in intra-modal dual-task encoding conditions. *Memory & Cognition*, *49*(7), 1453–1472. https://doi.org/10.3758/s13421-021-01166-1

Snodgrass, J. G., & Vanderwart, M. (1980). A standardized set of 260 pictures: Norms for name agreement, image agreement, familiarity, and visual complexity. *Journal of Experimental Psychology: Human Learning and Memory*, *6*(2), 174–215. https://doi.org/10.1037/0278-7393.6.2.174

Symons, C. S., & Johnson, B. T. (1997). The self-reference effect in memory: a meta-analysis. *Psychological Bulletin*, *121*(3), 371–394. https://doi.org/10.1037/0033-2909.121.3.371

Talmi, D., Schimmack, U., Paterson, T., & Moscovitch, M. (2007). The role of attention and relatedness in emotionally enhanced memory. *Emotion*, *7*(1), 89–102. https://doi.org/10.1037/1528-3542.7.1.89

Terry, W. S. (1994). On the relative difficulty in recalling names and occupations. *The American Journal of Psychology*, 85–94. https://doi.org/10.2307/1423291

Thalmann, M., Souza, A. S., & Oberauer, K. (2019). Revisiting the attentional demands of rehearsal in working-memory tasks. *Journal of Memory and Language*, *105*, 1–18. https://doi.org/10.1016/j.jml.2018.10.005

Tulving, E. (1962). Subjective organization in free recall of "unrelated" words. *Psychological Review*, *69*(4), 344–354. https://doi.org/10.1037/h0043150

Villaseñor, J. J., Sklenar, A. M., Frankenstein, A. N., Levy, P. U., McCurdy, M. P., & Leshikar, E. D. (2021). Value-directed memory effects on item and context memory. *Memory & Cognition*, *49*(6), 1082–1100. https://doi.org/10.3758/s13421-021-01153-6

Yin, X., Havelka, J., & Allen, R. J. (2021). The effect of value on long-term associative memory. *Quarterly Journal of Experimental Psychology*, https://doi.org/10.1177/17470218211014439