Prioritization in Visual Working Memory: An Investigation of Distractor Susceptibility and Different Prioritization Modes

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Conflict of interest

The authors have no conflict of interest to declare.

Data availability statement

The data and analysis script are available on the Open Science Framework: https://osf.io/5dcz8/.

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CRediT statement

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Abstract

Previous studies suggest that information in the focus of attention in working memory is better remembered, accessed faster, and better protected from perceptual interference than information outside of the focus of attention. However, this protection has been challenged by studies showing particular vulnerability to perceptual interference within the focus of attention. To advance this debate, the current study investigated whether focusing attention on to-be-prioritized information makes it more or less susceptible to distractors. For this purpose, we made use of two prioritization modes: retro-cueing and rewarding. Throughout ten behavioral experiments in which we used two different paradigms and varied several task parameters, we did not observe any convincing evidence for a detrimental impact of perceptual interference on memory performance, regardless of whether and how the to-be-remembered information had been prioritized. This was unexpected and suggests that visual working memory might be more resilient to perceptual interference than previously assumed. These findings, along with recent studies, indicate that the key question is when information in working memory is vulnerable to interference, rather than how the focus of attention interacts with this vulnerability to protect it. Moreover, cross-experiment analyses revealed that cue-based prioritization is more effective than reward-based prioritization, and that memory gains for the prioritized information is not always as substantial as the memory losses for the unprioritized information.

218 words

Keywords: visual working memory, prioritization, attention, focus of attention, interference

Working memory can be defined as a limited-capacity cognitive system that is in charge of processing and keeping information available for a short period of time (e.g., Baddeley & Hitch, 1974). It is often assumed that disruption by interference is one of the main causes of forgetting in working memory (e.g., Clapp et al., 2010; Logie et al., 1990; Oberauer et al., 2016; Souza & Oberauer, 2015). However, several studies have observed that directing attention towards specific information in working memory, and thereby bringing the information into the focus of attention, can protect this information from interference (e.g., Makovski & Jiang, 2007; Schneider et al., 2017; Souza et al., 2016; van Moorselaar et al., 2015; or see Lorenc et al., 2021 for a review). These studies most often used a *retro-cue* to prioritize information within working memory. A retro-cue typically consists of a spatial signal presented after encoding that indicates the item that is most likely to be tested at the end of the trial and thus, the item that should be prioritized (Griffin & Nobre, 2003; Landman et al., 2003). In studies that investigated the distractor susceptibility of information in the focus of attention, a visual interference display is typically presented during the retention interval that follows the retro-cue. Enhanced memory performance and protection from visual interference were found for the cued item, presumably because cueing an item in working memory brings the item into the focus of attention (e.g., Barth & Schneider, 2018; Makovski & Jiang, 2007; Schneider et al., 2017; Souza et al., 2016; van Moorselaar et al., 2015).

The observation that information in the focus of attention is protected from interference, whereas information outside the focus of attention remains vulnerable, is a benefit that aligns well with other benefits associated with the focus of attention, such as improved memory performance (e.g., Rerko et al., 2014; Souza et al., 2016) and heightened accessibility (e.g., Hautekiet et al., 2023; Vergauwe & Langerock, 2017). Indeed, several theoretical frameworks have proposed that information in the focus of attention resides in a privileged state resulting in improved memory performance, heightened accessibility, and protection from interference (e.g., Cowan, 2011; Cowan et al., 2005; Jonides et al., 2008; Oberauer, 2002, 2009; Oberauer & Lin, 2017; Souza & Oberauer, 2016). Still, the idea that information in the focus of attention is protected from interference is not broadly endorsed. In particular, several studies have observed that information in the focus of attention is particularly vulnerable to interference (e.g., Allen & Ueno, 2018; Hitch et al., 2018; Hu et al., 2014, 2016; Mallett & Lewis-Peacock, 2019). These studies typically made use of a reward pattern to prioritize information within working memory (see Allen et al., 2024, for a recent overview on reward-based prioritization). Specifically, in these studies, participants were presented with a reward pattern before encoding, which maps on to the memory display. This reward pattern consists of different values (e.g., 4-1-1-1) which indicate to the participants which item will result in a high reward (e.g., 4 points) or a low reward (e.g., 1 point) when tested and responded to correctly. Like the cued item, the high reward item is assumed to be prioritized, and thus brought into the focus of attention. Furthermore, in between encoding and test, a *suffix* (i.e., a distractor) could be presented, which has been found to disrupt memory performance (e.g., Ueno, Allen, et al., 2011; Ueno, Mate, et al., 2011). Overall, memory performance was better for the high reward item and while all items were affected by the presence of a suffix, the prioritized, high-reward item turned out to be particularly vulnerable to suffix interference (e.g., Allen & Ueno, 2018; Hitch et al., 2018; Hu et al., 2014, 2016; see also Baddeley et al., 2021 for a recent overview).

Thus, there are currently two contradictory views of what it means for information to reside in the focus of attention. While both sides of the debate agree that information in working memory is vulnerable to interference and that information in the focus of attention is highly available and readily accessible, they have conflicting views on the distractor susceptibility of information in the focus of attention. On the one hand, it has been proposed that information in the focus of attention is protected from interference (e.g., Barth & Schneider, 2018; Makovski & Jiang, 2007; Schneider et al., 2017; Souza et al., 2016; van Moorselaar et al., 2015); on the other hand, it has been proposed that information in the focus of attention is particularly vulnerable to interference (e.g., Allen & Ueno, 2018; Hitch et al., 2018; Hu et al., 2014, 2016; Mallett & Lewis-Peacock, 2019; see also Baddeley et al., 2021). In the current study, we contrasted these competing claims to get a better understanding of the focus of attention in working memory.

Distractor Susceptibility of Information in the Focus of Attention: Protected vs. Particularly Vulnerable

Logically, an item in the focus of attention cannot be at the same time protected from and particularly vulnerable to perceptual interference. Therefore, it seems reasonable to assume that there might be certain task situations or theoretically relevant methodological variables that influence the distractor susceptibility of information in the focus of attention. Indeed, when closely comparing two sets of metholodogically similar studies that found opposing results, one can identify several methodological differences that could potentially explain the difference in results. The most prominent differences are summarized in Table 1.

Table 1

Overview of main differences between studies finding protection (upper part) or a (particular) vulnerability (lower part) to perceptual interference for a representation in the focus of attention in comparison to another representation in working memory.

	Memory set		**Prioritization**		**Interference display**			**Articulatory Suppression**	**Result**
	Items	**Presentation**	**Mode**	**Timing**	**Items**	**Similarity**	**Location**		
Makovski & Jiang (2007)	6	Simultaneous	Retro-cue (100%)	After	6	Plausible	Memory set	Yes	Protected
van Moorselaar, et al. (2015)	3	Simultaneous	Retro-cue (100%)	After	3	Implausible	Memory set	No	Protected
Schneider et al. (2017)	2	Simultaneous	Retro-cue (100%)	After	6	Implausible	Memory set	No	Protected
Barth & Schneider (2018)	3	Simultaneous	Retro-cue (100%)	After	3	Implausible	Memory set	No	Protected
Hu et al. (2014) – Exp 2-3	4	Sequential	Reward (1-2-3-4 & 4-3-2-1)	Before (Instructions)	1	(Im)plausible	Central	Yes	Particularly vulnerable
Hu et al. (2014) – Exp 4 (see also Hu et al., 2016; Hitch et al., 2018)	4	Sequential	Reward (4-1-1-1 & 1-1-1-4)	Before (Instructions)	1	(Im)plausible	Central	Yes	Particularly vulnerable
Allen & Ueno (2018) – Exp 1	4	Simultaneous	Reward (1-1-1-4)	Before	1	Plausible	Central	Yes	Equally vulnerable
Allen & Ueno (2018) – Exp 2	4	Simultaneous	Reward (1-1-4-4)	Before	1	Plausible	Central	Yes	Particularly vulnerable
Allen & Ueno (2018) – Exp 3	4	Simultaneous	Reward (1-4-4-4)	Before	1	Plausible	Central	Yes	Particularly vulnerable
Allen & Ueno (2018) – Exp 4	4	Simultaneous	Reward (1-2-3-4)	Before	1	Plausible	Central	Yes	Particularly vulnerable

As can be seen in Table 1, the same conclusion can be drawn from studies using different memory set sizes (e.g., protection was found in studies using 2, 3, or 6 items), different memory presentation styles (e.g., particular vulnerability was observed in studies using both sequential or simultaneous presentation), different types of interference items (e.g., particular vulnerability was observed in studies using both plausible and implausible interference items), and using articulatory suppression or not (e.g., protection was observed in studies with and without articulatory suppression). Therefore, these methodological variations seem unlikely to be the source of the opposing patterns. The remaining differences with potential theoretical relevance are related to how and when information is prioritized in working memory (prioritization mode and timing) and to the type of interference display (number of distracting stimuli, timing, and location).

While the number and location of interference items might contribute to the magnitude of the overall interference effect, these factors seem less likely to explain why the distractor susceptibility of information in the focus of attention might change in function of these interference items. Furthermore, we have recently shown protection for the cued item, regardless of whether the cue is shown before, during, or after encoding, and equal vulnerability for high reward items, regardless of when the reward signal was presented (Vergauwe et al., 2025). This demonstrates that *when* information is prioritized cannot explain why distractor susceptibility is often reduced but sometimes heightened within the focus of attention. A more likely explanation seems to lie in *how* information is prioritized within working memory. In particular, as can be seen in Table 1, the studies finding protection for the item in the focus of attention consistently made use of a 100%-valid retro-cue, whereas the studies observing a (particularly) vulnerable state for the item in the focus of attention all made use of a reward pattern to prioritize information in working memory, indicating that prioritized information is protected from interference when a retro-cue is used (e.g., Barth & Schneider, 2018; Makovski & Jiang, 2007; Schneider et al., 2017; van Moorselaar et al., 2015; Vergauwe et al., 2025), whereas prioritized information is still – and in some cases, particularly - vulnerable to interference when a reward pattern is used (e.g., Allen & Ueno, 2018, Hitch et al., 2018; Hu et al., 2014, 2016, 2023; Vergauwe et al., 2025).

When it comes to understanding how the focus of attention operates, these opposing patterns are problematic. Both prioritization strategies presumably bring information into the focus of attention (e.g., Atkinson et al., 2018, 2022; Souza & Oberauer, 2016), and thus, these opposing patterns imply that information in the focus of attention is not consistently protected from perceptual interference, but that it is sometimes (particularly) vulnerable to perceptual interference. A possible explanation is that, while both prioritization modes rely on the focus of attention, they are not prioritizing information in the same way. Indeed, when comparing the two prioritization modes, there is a critical difference in the relevance of the items throughout the trial. Specifically, when a 100%-valid retro-cue is used, participants know which item will be tested and thus, there is only one relevant item throughout the trial. In this case, the prioritized item will be residing in the focus of attention where it will benefit protection from perceptual interference. In contrast, when a reward pattern is used, participants do not know which item will be tested and thus all items remain relevant throughout the trial. Because of this, participants might attempt to divide their focused attention over several items. Allen and Ueno (2018) speculated that this distributed mode of attention might leave the memory items vulnerable to interference. When there is only one high reward item, participants might attempt to divide their attention over all memory items, resulting in equal vulnerability for the high and low reward items (e.g., Experiment 1, Allen & Ueno, 2018; Vergauwe et al., 2025). In contrast, when there are multiple high reward items, participants divide their focused attention between the high reward items, but not longer include the low reward items. In this case, the impact of the suffix will no longer or barely be traceable for the low reward items whereas it will be for the attended, high reward items. As a result, increased vulnerability is observed for the high reward items compared to the low reward items (Experiments 2-4, Allen & Ueno, 2018; Hu et al., 2014; Hitch et al., 2018). If this is true, it would mean that the common view of information being protected in the focus of attention needs to be modified, because this benefit would only be observed under cue-based prioritization and not under reward-bases prioritization.

However, these two prioritization modes are confounded with the relevance of the prioritized item, which is often 100% (i.e., only relevant item) in cue-based studies, whereas it is much lower (i.e., all items remain relevant) in reward-based studies. Therefore, in the current study, we aim to find out whether the the nature of the prioritization mode is the major determinant of the consequences of focusing attention or whether this is caused by the behavioral relevance of the prioritized item.

The Current Study

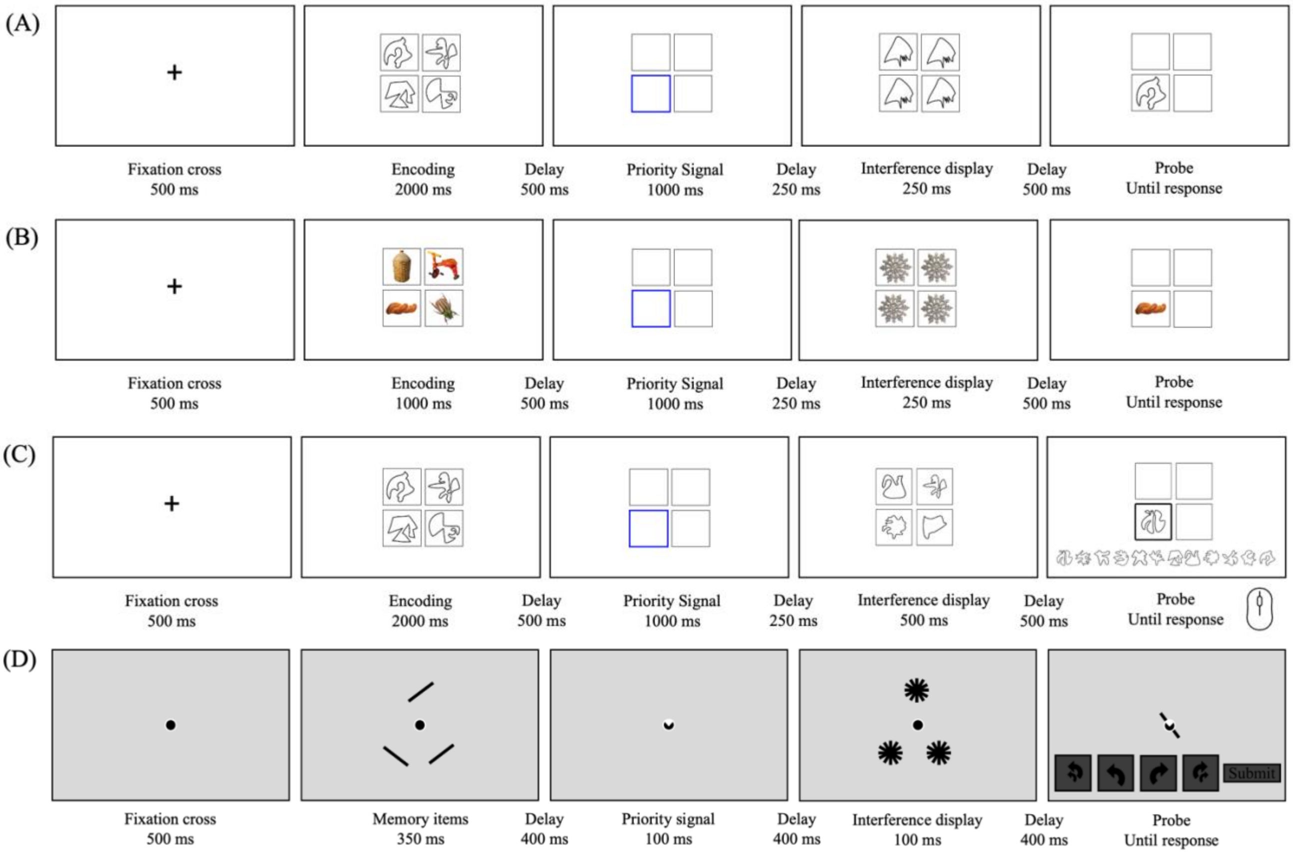
To investigate this, we planned to use cue-based and reward-based prioritization within the same paradigm and manipulate the behavioral relevance of the prioritized items. To decrease the behavioral relevance of cued items, we lowered the validity of the retro-cue, making the relevance of the prioritized item more similar to that of unprioritized items. If the consequences of focusing attention are primarily determined by the behavioral relevance of the prioritized item, rather than how the item is prioritized (cue vs. reward), we expect to observe more evidence for (particular) vulnerability as the behavioral relevance of the cued item decreases. The other way around, we increased the behavioral relevance of the high reward item by increasing the value of the reward associated with the item, making the high-reward item more (subjectively) relevant to the participants, relative to the unprioritized items. If the consequences of focusing attention are primarily determined by the behavioral relevance of the prioritized item, rather than how the item is prioritized (cue vs. reward), we expect to observe more evidence for protection as the behavioral relevance of the high reward item increases. Alternatively, if the consequences of focusing attention are primarily determined by the nature of the prioritization mode (cue vs. reward), we expect to observe evidence for protection for the prioritized item when a cue is used, regardless of the validity of the cue, and (particular) vulnerability for the prioritized item when a reward pattern is used, regardless of the value of the high reward item.

However, before varying the behavioral relevance of the prioritized item, we first created a paradigm in which both cue-based and reward-based prioritization could be applied, and tested if we could replicate both sides of the debate within the same paradigm: protection for the prioritized item when a 100% retro-cue is used and (particular) vulnerability for the prioritized item when a reward pattern is used (unpredictive of which item will be tested). Our task is shown in Figure 1 and is based on relevant studies in the literature (see Table 1).

In our first experiment, we presented participants with four shapes in four locations on screen (see Fig. 1, Panel A). At the end of the trial, a probe was presented in one of these locations and participants had to judge whether the probe matched the memorized item for that location or not. In between, a priority signal could be presented. The significance of this signal varied between subjects and could either correspond to a 100%-valid retro-cue (Experiment 1a) or a reward pattern (Experiment 1b). Between the priority signal and the memory test, an interference item could be presented in each memory location. Based on the literature, we expected to observe (1) a boost in memory performance for the cued item (vs. uncued items) and for the high-reward item (vs. low-reward items), (2) an overall detrimental impact of interference on memory performance and (3) an interaction between interference and prioritization mode, such that the cued item is protected from interference whereas the high reward item is (particularly) vulnerable to interference.

Figure 1

Trial example of the task used in Experiment 1a & 1b (Panel A), Experiment 2, condition with familiar images (Panel B), Experiment 3 (Panel C), and Experiment 4a-4f (Panel D). The priority signal corresponded to a retro-cue in Experiments 1a, 2, 3, 4a, 4c, and 4e and to a reward pattern in Experiment 1b, 4b, 4d, and 4f.



To anticipate the results of our first experiment, we observed a benefit for the cued item, but not for the high reward item. Additionally, and more critically, we did not observe protection for the cued item nor (particular) vulnerability for the high reward item. Even more so, memory performance was not affected by the presence of the interference items. These results were unexpected given the substantive amount of studies that have observed interference effects in working memory using similar paradigms (e.g., Allen & Ueno, 2018; Barth & Schneider, 2018; Hautekiet et al., 2025; Hitch et al., 2018; Hu et al., 2014, 2016; Makovski & Jiang, 2007; Schneider et al., 2017; Ueno, Allen, et al., 2011; Ueno, Mate, et al., 2011; van Moorselaar et al., 2015; Vergauwe et al., 2025).

Upon this observation, we varied various task parameters (such as encoding time, type of materials, and type of memory task) in the subsequent experiments using shapes and common objects (Experiments 2 and 3) to optimize our paradigm to observe a detrimental impact of perceptual interference (see Fig. 1, Panel B and C). In these experiments, again, we did not observe any convincing evidence for a disruptive effect of perceptual interference on memory performance. Together, this first set of experiments indicated that, contrary to what is typically assumed and often observed in the literature, working memory representations are not *that* vulnerable, regardless of their priority status.

While this is an important conclusion, we still wanted to investigate our original research question concerning the distractor susceptibility of information in the focus of attention, when interference *does* affect memory. Therefore, in a final set of experiments, rather than using the paradigm we had designed for Experiments 1-3, we used an existing paradigm in which an interference effect had previously been found (van Moorselaar et al., 2015) and replicated by other researchers (e.g., Barth & Schneider, 2018; Schneider et al., 2017). In this task, participants were shown three line orientations (see Fig. 1, Panel D) and were tasked with reproducing one of these at the end of the trial. In between, a priority signal could appear, sometimes followed by an interference display. As before, the priority signal could correspond to either a retro-cue or a reward pattern. Critically, to test whether distractor susceptibility in the focus of attention depends on the prioritization mode or the relevance of the prioritized item, we also manipulated the behavioral relevance of the prioritized item. For cue-based prioritization, we decreased behavioral relevance by decreasing cue validity (100%, 66%, or 33%); for reward-based prioritization, we increased behavioral relevance by increasing the amount of points associated with the high reward item (3 points, 100 points, or 1000 points). As such, across a series of six experiments, the priority signal could correspond to (1) a 100%-valid retro-cue (Experiment 4a), (2) a 3-point high reward (Experiment 4b), (3) a 33%-valid retro-cue (Experiment 4c), (4) a 100-point high reward (Experiment 4d), (5) a 66%-valid retro-cue (Experiment 4e), or (6) a 1000-point high reward (Experiment 4f).

Based on the literature, we expected the prioritized item to be protected from perceptual interference in Experiment 4a (100%-valid retro-cue) but to be (particularly) vulnerable in Experiment 4b (3-point high reward). The next four experiments (4c-4f) allowed us to test whether the behavioral relevance of the prioritized item, rather than the prioritization mode, affects its distractor susceptibility. If so, we expected the prioritized item to be protected from perceptual interference when it was the only (subjectively) relevant item (Experiments 4d and 4f, reward-based prioritization with higher rewards) but to be (particularly) vulnerable when all items remained relevant (Experiments 4c and 4e, cue-based prioritization with lower cue validities).

The protocol for all experiments (including sample size justification, hypotheses, analyses and data exclusions) was preregistered: https://osf.io/8uvnb (Experiment 1a), https://osf.io/af8mj (Experiment 1b), https://osf.io/b35ca (Experiment 2), https://osf.io/amsj6 (Experiment 3), https://osf.io/3vder (Experiment 4a), https://osf.io/2wgty (Experiment 4b), https://osf.io/3hfds (Experiment 4c), https://osf.io/kgqz3 (Experiment 4d), https://osf.io/gy35t (Experiment 4e), and https://osf.io/4wc73 (Experiment 4f). Some deviations from these preregistrations were necessary; these are reported in the supplementary materials (see Table S1, https://osf.io/5dcz8/). The data, analysis scripts, and experimental files are publicly available on the Open Science Framework (OSF), see https://osf.io/5dcz8/.

Experiment 1 (1a & 1b)

In these experiments, we investigated whether a prioritized item, assumed to be in the focus of attention, is protected from or (particularly) vulnerable to perceptual interference compared to other items in working memory, using either a 100%-valid retro-cue (Experiment 1a) or a '4-1-1-1' reward pattern (Experiment 1b). The aim was to replicate the pattern that emerges from the literature regarding the impact of cue-based vs. reward-based prioritization on distractor susceptibility.

Method

Participants & Design

For all included experiments, participants were undergraduate students from the University of Geneva, participating for partial course credit. All participants signed an informed consent form before participating, and approval was obtained from the ethical commission at the University of Geneva. The number of participants was always determined using Bayesian sequential hypothesis testing. Specifically, we preregistered to start with 30 participants and to continue to increase by ten participants[1] (with a maximum of 60 participants) until we obtained a Bayes Factor (BF) of 10 for or against the interaction of interest (between Priority Status and Interference).

In total, 31 participants[2] (25 women, 6 men, mean age = 22.02 years) and 30 participants (23 women, 7 men, mean age = 21.38 years) took part in Experiments 1a and 1b, respectively. As preregistered, participants with less than 55% valid experimental trials (i.e., a correct response to the probe and RT > 150 ms) were excluded. Additionally, the incomplete dataset (< 75% of the data) of one participant from Experiment 1a was excluded.[2] This resulted in a final sample of 29 and 27 participants in Experiments 1a and 1b, respectively.

The design of Experiment 1a was a 2 x 2 factorial design with Priority Status (high vs. equal) and Interference (present vs. absent) as within-subjects variables. The design of Experiment 1b was a 3 x 2 factorial design with Priority Status (high vs. low vs. equal) and Interference (present vs. absent) as within-subjects variables.

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[1] For time efficiency reasons, we preregistered to test a full second batch of 30 participants in Experiment 4e and 4f if the critical BF would be lower than 10 after the first batch, as opposed to increasing per 10.
[2] See Table S1 in the Supplementary Materials for preregistration deviation.

Procedure & Materials

All included experiments were executed on a computer using Psychopy (v2021.2.3). Participants were tested in small groups and sat at a comfortable distance from the screen (approximately 60 cm).

Participants performed the following task (see Fig. 1, Panel A). First, a fixation cross was shown for 500 ms. Next, participants were presented successively with (1) a screen with four squares for 2000 ms filled with a memory item in each of them, (2) a delay showing the four empty squares for 500 ms, and (3) a screen in which one of the squares was highlighted (i.e., thick blue border) for 1000 ms while the others remained as before (i.e., thin black border). During the delays, the four empty squares remained on screen. Furthermore, in the trials without a prioritization signal, the screen following the memory items consisted of the same four empty squares for 1000 ms. Depending on the experiment, the priority signal (i.e., the highlighted square) could mean one of two things. In Experiment 1a, the priority signal indicated to the participant that the item previously presented in that location would be tested at the end of the trial (i.e., 100%-valid retro-cue; see Supplementary Materials for exact instructions). In Experiment 1b, the priority signal indicated to the participant that the item previously presented in that location would result in a high reward (i.e., 4 points) when tested and responded to correctly. In case of the latter, the other items would result in a low reward (i.e., 1 point) when tested and responded to correctly. Thus, in both cases, the priority signal was presented after encoding and using a highlighted box (see Jeanneret, Vergauwe, et al., 2024 and Vergauwe et al., 2025 for a similar task procedure). In trials without interference, the prioritization display was followed by a delay of 1000 ms showing the four empty squares. In interference trials, the prioritization display was followed by a delay of 250 ms showing the four empty squares, the interference display for 250 ms, and another delay of 500 ms showing the empty squares. Importantly, the interference item was never part of the memory set.

The test display consisted of a single probe presented in one of the four locations. In Experiment 1a, when a priority signal had been presented, the probe always had to be compared to the prioritized item. In Experiment 1b, when a priority signal had been presented, all items could still be tested, regardless of the assigned reward value. Participants were instructed to respond whether the presented probe was the same item that had been presented in that location before or not (‘k’-key or ‘d’-key of the keyboard, respectively). The probe stayed on screen until a response was provided or until 4000 ms had elapsed. Regardless of the prioritization mode, the probe could correspond to the previously presented memory item in that location (i.e., match; 50% of the trials) or another item that was not part of the memory set in that trial (i.e., non-match; 50% of the trials). At the beginning of each trial, the figures were randomly selected from a pool of 24 non-verbalizable figures (Endo et al., 2003).

Each experiment included 320 experimental trials. To have an equal number of trials with and without a priority signal, with and without an interference display, and with match and non-match probes, we predefined five trial lists including an equal number of the different trial types but each with a randomized trial order (see Supplementary Materials for more details on randomization). The practice phase remained the same for all participants and consisted of 3 parts: (1) 4 practice trials only including memory items and test, (2) 4 practice trials with or without priority signal, and (3) 16 practice trials of the experimental trials (i.e., with or without priority signal and with or without interference display).

Analysis

For all included experiments: (1) practice trials were eliminated from the data, (2) the preregistered analyses were done on the aggregated data (per participant, per condition), and (3) data preprocessing, analyses, and visualization used the tidyverse package (Wickham et al., 2019) and BayesFactor package (Morey & Rouder, 2018) libraries in R studio with default settings (R core team, 2018; version 2022.07.1). For each experiment, our main analysis was a

Bayesian ANOVA on accuracy data (Experiments 1-3) or response error (Experiment 4). Additionally, we executed two Bayesian paired samples t-tests to investigate whether response error was lower for trials without interference compared to trials with interference, assessing vulnerability for each priority status.

In all analyses, high-priority items come from trials in which a priority signal (i.e., retro-cue or reward pattern) was presented and the indicated item was tested, and low-priority items come from trials in which a priority signal was presented but one of the not-indicated items was tested. Equal-priority items always come from trials in which no priority signal was presented. For the retro-cue experiments, we followed the conventional comparison (high vs. equal priority) for our main analysis, based on what is typically done in the relevant studies in the literature (e.g., Makovski & Jiang, 2007; Schneider et al., 2017; van Moorselaar et al., 2015). Additionally, when the retro-cue validity was less than 100%, we analyzed the data following the alternative, reward-like comparison (i.e., high vs. low priority) as part of the exploratory analysis. In the same way, for the reward experiments, we followed the conventional comparison (high vs. low priority) for our main analysis, based on what is typically done in the early relevant studies in the literature (e.g., Allen & Ueno, 2018; Hu et al., 2014, 2016). Additionally, we analyzed the data following an alternative, cue-like comparison (i.e., high vs. equal priority) as part of the exploratory analysis. Furthermore, in the experiments including three levels of Priority Status (i.e., Experiments 1b, 4b-4f), we also executed exploratory analyses including all three levels (see Supplementary Materials for the results).

Results

For Experiment 1a, we executed a BANOVA on the aggregated accuracy data with Priority Status (high vs. equal) and Interference (present vs. absent) as within-subjects variables (see Supplementary Materials for an exploratory analysis using lmBF and an exploratory analysis of the aggregated RTs). For Experiment 1b, we executed a BANOVA on the aggregated accuracy data with Priority Status (high vs. low) and Interference (present vs. absent) as within-subjects variables. The results are presented in Table 2.

Table 2

Results of the BANOVAs on accuracy data from Experiments 1a and 1b.

Experiment	Analysis	Priority Comparison	Priority Status	Interference	Priority Status x Interference
1a 100%-valid cue	**Main**	*High vs. Equal*	5.16×10^5	0.20	0.05
1b	**Main**	*High vs. Low*	1.26	0.20	0.10
4-1-1-1 reward	**Exploratory**	*High vs. Equal*	0.36	0.67	0.06

Note. Bayes factors (BFs) resulting from model comparison between het best model and the model excluding the effect/interaction (if it is included in the best model) or including the effect/interaction (if it is not part of the best model). The Bayes factors reflect evidence in favor of the tested effect (BF_{10}). When the BF presents conclusive evidence in favor of the tested effect ($BF_{10} > 3$), the text is presented in green; when the BF reflects conclusive evidence against the tested effect ($BF_{10} < 0.33$, which corresponds to $BF_{01} > 3$), the text is presented in red; inconclusive results are present in black ($0.33 < BF_{10} < 3$). When all BFs present evidence against the effect, this means that the null model best represented the data. The last column refers to the full model including the interaction between Priority Status and Interference.

In both experiments, the best model included only the main effect of Priority Status, but the evidence for this factor remained inconclusive for Experiment 1b. For both experiments, we observed moderate evidence against including the main effect of Interference in the best model, and strong evidence against the full model, which included the interaction between Priority Status and Interference[3], when comparing it to the best model. Thus, it seems that memory performance was not, or barely, affected by the interference display, regardless of prioritization mode (see Fig. 2). For Experiment 1b, we also analyzed the data following the alternative comparison (i.e., high vs. equal). The results were similar to the conventional comparison (i.e., high vs. low), except that the evidence against the main effect of Interference was now inconclusive (see Table 2). Finally, Bayesian paired one-sided t-tests for each priority state showed no convincing evidence in favor of an interference effect in any of the priority states, regardless of how information was prioritized, see Table 3.

[3] The evidence for or against the interaction between Priority Status and Interference served as our preregistered stopping rule and so, data collection was terminated in both experiments after the first batch of 30 participants.

Figure 2

Mean accuracy for Experiment 1a (left) and Experiment 1b (middle and right) presented with standard error bars and individual scores (grey).

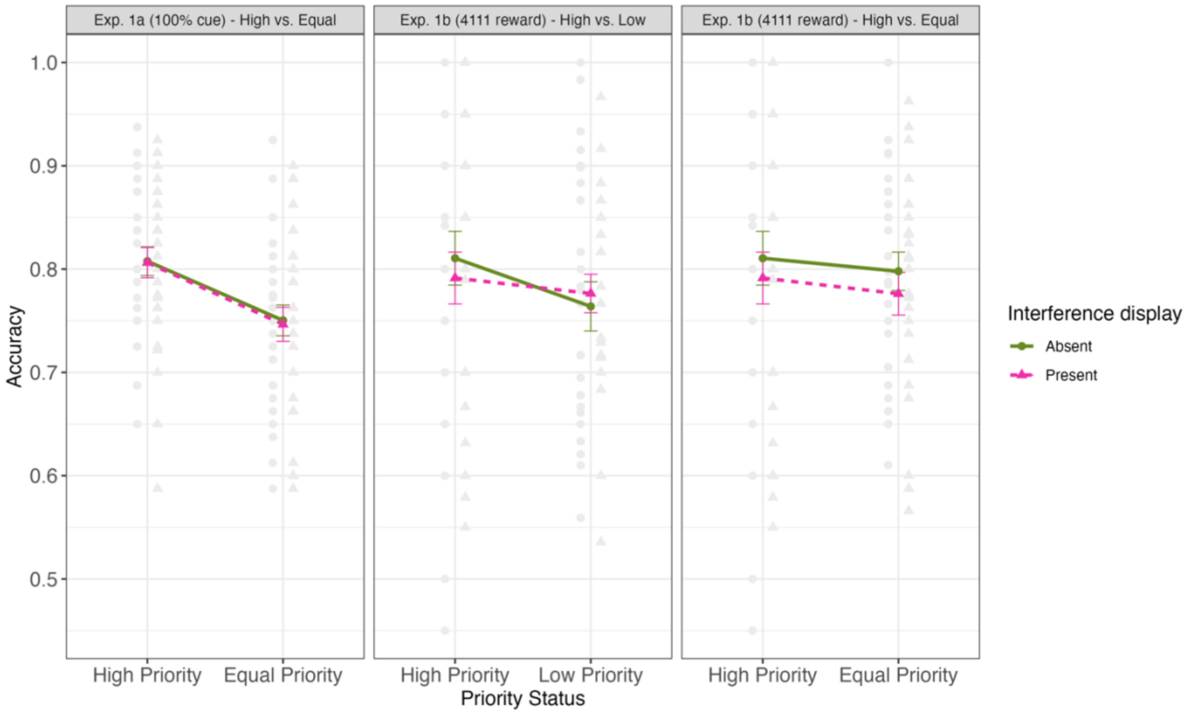


Table 3

Results of Bayesian paired one-sided t-tests (interference absent > present) on accuracy in Experiments 1-3.

Experiment		**1a** **100%-valid retro-cue**	**1b** **4-1-1-1 reward**	**2** **100%-valid retro-cue** **Familiar**	 **Unfamiliar**	**3** **100%-valid retro-cue**
Priority Status	*High*	0.22	0.46	0.58	0.13	1.25
	Equal	0.24	2.31	1.69	0.16	3.13
	Low	/	0.11	/	/	/

Note. The Bayes factors reflect evidence in favor of the tested effect (BF_{10}). When the BF presents conclusive evidence in favor of the tested effect ($BF_{10} > 3$), the text is presented in green; when the BF reflects conclusive evidence against the tested effect ($BF_{10} < 0.33$, which corresponds to $BF_{01} > 3$), the text is presented in red; inconclusive results are present in black ($0.33 < BF_{10} < 3$).

Discussion

The results from Experiments 1a and 1b are threefold. First, we observed a memory performance benefit when a 100%-valid retro-cue is used, which aligns with the retro-cue literature (see Souza & Oberauer, 2016 for a review). Second, we did not observe a memory performance benefit when a '4-1-1-1'-reward pattern is used, which goes against what is typically observed under reward-based prioritization (e.g., Allen & Ueno, 2018; Atkinson et al., 2018; Experiment 2, Jeanneret et al., 2023; Sandry & Ricker, 2020; Vergauwe et al., 2025) but aligns with some other recent studies that did not observe a reward-based benefit in visual working memory (e.g., Experiment 1, Jeanneret et al., 2023; Zhang & Lewis-Peacock, 2022). Third, and most critically, we found no convincing evidence for an interference effect on memory performance. Instead, memory performance appeared unaffected by the interference display, regardless of the priority state of the item or the prioritization mode used. This finding contradicts many previous studies that reported a clear disruptive effect of visual distractors on memory performance. To investigate the lack of an interference effect in Experiments 1a and 1b, we conducted two follow-up experiments.

A first possibility we considered is the encoding time used in Experiments 1a and 1b, which corresponded to the time used by Allen and Ueno (2018; i.e., 2000 ms), but the latter presented participants with a recall task whereas we used a simple two-alternative forced choice task to test memory. It is possible that an encoding time of 2000 ms results in overly robust representations that might be somewhat affected by the presence of the interference display but that remain strong enough to correctly recognize the item at the end of the trial in our experiment. To address this possibility, we lowered the encoding time from 2000 ms to 1000 ms in Experiment 2 while keeping the two-alternative forced choice recognition task.

A second possibility we considered is the materials used in Experiments 1a and 1b. While we presented participants with non-verbalizable abstract shapes which were unfamiliar to the participants, past studies that observed an interference effect often used more familiar materials such as colored shapes (e.g., Allen & Ueno, 2018; Hitch et al., 2018; Hu et al., 2014, 2016; Makovski & Jiang, 2007). The familiarity of the materials might be a critical factor, as previous studies observed no or reduced evidence for certain attention-related effects in working memory when using unfamiliar materials (e.g., Ricker & Cowan, 2010; Ricker & Vergauwe, 2020; Shimi & Scerif, 2015). For example, Shimi and Scerif (2015) used the same unfamiliar, abstract shapes as in the current Experiments 1a and 1b (originally from Endo et al., 2003), and observed a reduced retro-cue benefit compared to familiar drawings. As unfamiliar materials might already have a higher degree of inter-item interference, presenting an additional item during the retention interval might not produce an interference effect. To test this in Experiment 2, one group of participants was shown the unfamiliar, abstract shapes from Experiments 1a and 1b, while and another group was shown familiar images.

Experiment 2

In this experiment, we investigated whether the lack of an interference effect in Experiments 1a-1b was due to specific task parameters used in that experiment, such as the long encoding time or the use of unfamiliar shapes. If the lack of an interference effect was due to the long encoding time, we expected to observe the effect in both familiarity conditions of Experiment 2, which uses a shorter encoding time. Conversely, if it was due to the use of unfamiliar memory materials, we expected the effect to be present in the familiar condition of Experiment 2 but not in its unfamiliar condition. Because the evidence for a prioritization effect was more convincing for cue-based than for reward-based prioritization in the first experiment, we planned to first test our task-specific hypotheses using a retro-cue, before proceeding with a reward pattern, to maximize resource efficiency.

Methods

Participants & Design

In total, 120 participants (98 women, 21 men, 1 undefined, mean age = 22.4 years) took part. After applying our preregistered exclusion criteria, we obtained a final sample of 116 participants (60 in ‘familiar’ and 56 in ‘unfamiliar’ condition). The design of the experiment was a 2 x 2 x 2 factorial design with Priority Status (high vs. equal) and Interference (present vs. absent) as within-subjects variables and Familiarity Materials (familiar vs. unfamiliar) as a between-subjects variable.

Materials & Procedure

The task procedure remained the same as in Experiment 1a except for two changes: the encoding time and the memory materials. The encoding time was reduced to 1000 ms, and Experiment 2 included two types of figures: familiar figures and unfamiliar images. The familiar images were 24 images randomly selected from a database provided by Brady et al. (2008; see Fig. 1B). The unfamiliar figures remained the same as in Experiments 1a and 1b. The between-subjects variable Familiarity Materials was switched every session, such that every small group of participants tested in the same room received the same material condition. The proportion of trials per condition remained the same as in Experiment 1a (see Supplementary Materials for more information).

Results

Familiarity Materials

We executed a Bayesian repeated-measures ANOVA on the aggregated accuracy data, with Priority Status (high vs. equal) and Interference (present vs. absent) as within-subjects variables, and Familiarity Materials (familiar vs. unfamiliar) as a between-subjects variable (see Supplementary Materials for an exploratory analysis using lmBF and an exploratory analysis on aggregated RTs). The results were very similar to our findings in Experiment 1a (see Table 4). Specifically, the best model included the main effect of Priority Status, the main effect of Familiarity Materials, and their interaction. As expected, memory performance was better for the high-priority items compared to the equal-priority items, and memory performance was better for the familiar materials compared to the unfamiliar materials (see Fig. 3). Additionally, in line with Shimi and Sherif (2015), the memory performance boost was larger for the familiar items than for the unfamiliar items (difference of 8 and 5 percentage points, respectively). Furthermore, we observed modest evidence against the main effect of Interference and very strong evidence against the critical interaction between Priority Status and Interference[4]. Finally, Bayesian paired one-sided t-tests showed no convincing evidence in favor of an interference effect in any of the priority states (see Table 3).

Table 4

Results of the BANOVAs on accuracy from Experiment 2.

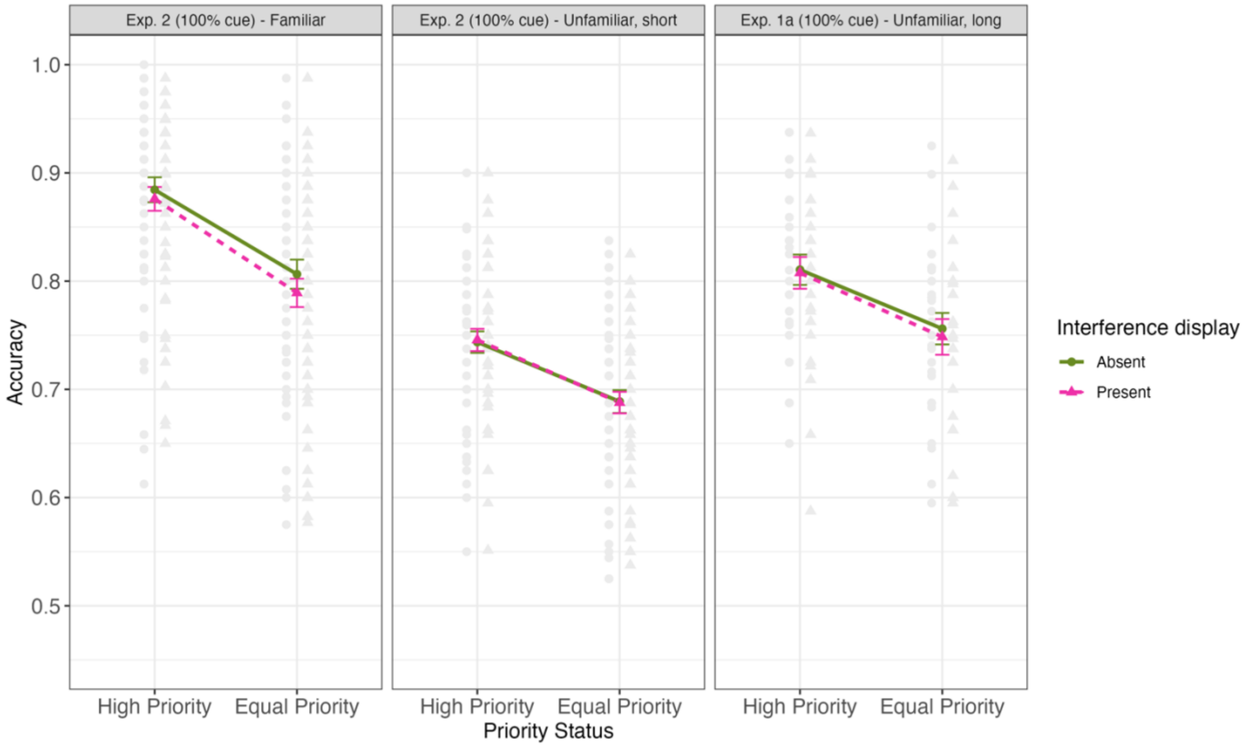
	Effect	**Evidence (BF_{10})**
Familiarity Materials	*Priority Status*	7.19×10^{38}
	Interference	0.26
	Familiarity Materials	9.83×10^{11}
	Priority Status x Interference	0.05
	Priority Status x Familiarity Materials	7.64
	Interference x Familiarity Materials	0.13
	Priority Status x Interference x Familiarity Materials	< 0.01
Encoding Time *(Exp. 2 vs. Exp. 1a)*	*Priority Status*	1.15×10^{19}
	Interference	0.12
	Encoding Time	245.32
	Priority Status x Interference	0.02
	Priority Status x Encoding Time	0.18
	Interference x Encoding Time	0.02
	Priority Status x Interference x Encoding Time	< 0.01

Note. Bayes factors (BFs) resulting from model comparison between het best model and the model excluding the effect/interaction (if it is included in the best model) or including the effect/interaction (if it is not part of the best model). The Bayes factors reflect evidence in favor of the tested effect (BF_{10}). When the BF presents conclusive evidence in favor of the tested effect ($BF_{10} > 3$), the text is presented in green; when the BF reflects conclusive evidence against the tested effect ($BF_{10} < 0.33$, which corresponds to $BF_{01} > 3$), the text is presented in red; inconclusive results are present in black ($0.33 < BF_{10} < 3$).

[4] The evidence against this interaction was below 10 (i.e., $BF_{10} = 0.20$) after the first batch of 60 participants, and thus, following our preregistration, data collection continued beyond the first batch.

Figure 3

Mean accuracy results of Experiment 2 for the familiar materials (left) and the unfamiliar materials with short encoding time (middle). For comparison, the results of Experiment 1a including unfamiliar materials and long encoding time (right) are also shown. All graphs are presented with standard error bars and individual scores (grey).



Encoding Time

Next, we executed a Bayesian repeated-measures ANOVA on the aggregated accuracy data, with Priority Status (high vs. equal) and Interference (present vs. absent) as within-subjects variables and Encoding Time (long vs. short) as a between-subjects variable. For this analysis, we selected the data from the unfamiliar condition of the current Experiment 2 and the full dataset of Experiment 1a (using unfamiliar images). The best model included again the main effects of Priority Status and Encoding Time. Furthermore, we observed moderate evidence against Interference, and very strong evidence against the critical interaction between Priority Status and Interference (see Table 4). As can be seen in Figure 3, longer encoding times slightly improved accuracy but interference had barely any impact on accuracy scores for both encoding times.

Discussion

This experiment examined whether the absence of an interference effect in Experiments 1a and 1b was due to the long encoding time or the unfamiliar materials. The findings from Experiment 2 suggest that it was neither. In particular, we once again observed a benefit in memory performance for cued information but no evidence of perceptual interference affecting memory performance. Because a disruptive effect of perceptual interference on memory performance is crucial to be able to test our main research question concerning distractor susceptibility in the focus of attention, and because the lack of such effect goes against several previous studies, we decided to further examine why we did not observe an interference effect in our first two experiments.

A first possibility is that the interference display might not have been disruptive enough and could easily be ignored. In our first two experiments, the memory set consisted of four different, simultaneously presented items, each associated with a location on screen. The interference display, on the other hand, consisted of four times the same item presented in each of the memory locations. This procedure is similar to previous studies in the literature (e.g., Makovski & Jiang, 2007; Schneider et al., 2017; van Moorselaar et al., 2015). Still, it could be that, in our experiments, the interference items are seen as one chunk of four items rather than four individual items (like the memory set). Because of this, participants might be less prone to confuse one of the memory items with the interference chunk. To address this, we presented participants with four different interference items in Experiment 3. In addition, we increased the presentation time of the interference items to 500 ms in Experiment 3 (vs. 250 ms in the previous experiments), to make it harder for participants to ignore the stimuli.

A second possibility is that our memory test was not optimal for measuring the impact of perceptual interference. Specifically, we presented participants with either the correct memory item in the probed location or with another item that had not been part of the trial (i.e., neither another memory item nor the interference item). This memory test may have prevented participants from confusing the interference item with the memory item, as the interference item was never shown at test. A more suitable setup would present participants with different response options including the interference items. For example, in the memory test used by Allen and Ueno (2018), participants were presented with a color or a shape, and participants had to respond with the corresponding other feature. As there were eight colors and eight shapes included in the task, participants always had a choice between these eight colors or shapes (depending on the probed feature). This task setup allowed participants to confuse features of the memory item with features of the other memory items or the interference item. To create a more similar task setup, we changed the memory test in Experiment 3 such that we now asked participants to choose the correct figure from a list of 12 items (including the interference items).

Experiment 3

In Experiment 3, we further refined our paradigm to increase our likelihood of detecting an interference effect. To do so, we (1) presented four different interference items (instead of repeating the same item as in Experiments 1-2), (2) prolonged the interference display duration to 500 ms (instead of 250 ms as used in 1-2), and (3) changed the memory test such that participants now selected their response from a list of 12 items including the interference stimuli.

Methods

Participants & Design

In total, 60 participants (50 women, 10 men, mean age = 22.07 years) took part. The design of the current experiment was a 2 x 2 factorial design with Priority Status (high vs. equal) and Interference (present vs. absent) as within-subjects variables.

Procedure & Materials

The procedure and materials remained the same as used in Experiment 1a except for the following changes (see also Fig. 1, Panel C; see Supplementary Materials for minor change in the instructions regarding the priority signal). First, we presented four different interference items. At the start of the trial, these four interference items as well as the four memory items were randomly drawn from the pool of 24 non-verbalizable figures (as used in Experiment 1a; Endo et al., 2003). Second, we presented the interference display for 500 ms. Because of this, the total time of the retention interval was now 2250 ms (compared to 2000 ms in Experiment 1a). Third, we changed the type of memory test such that participants now had to select the target item from a list of 12 items. The list of response possibilities consisted of the four memory items, the four interference items, and four additional items randomly selected from the same pool of items that were not part of the trial (presented in random order). When no interference display had been presented in the trial, the test display consisted of the four memory items and eight additional items that had not been part of the trial (presented in random order). The proportion of trials per condition remained the same as in Experiment 1a (see Supplementary Materials for more information).

Results and Discussion

We executed a Bayesian repeated-measures ANOVA on the aggregated accuracy data, with Priority Status (high vs. equal) and Interference (present vs. absent) as within-subjects variables (see Supplementary Materials for an exploratory analysis using lmBF and an exploratory analysis on aggregated RTs). The best model included the main effect of Priority Status and Interference. While there was now some evidence for including the main effect of interference, it was not very convincing ($BF_{10} = 3.02$). In contrast, the evidence for including the main effect of Priority Status was very strong ($BF_{10} = 1.74 \times 10^{24}$), and there was modest evidence against the full model including the interaction between Priority Status and Interference (BF_{10} = 0.20).[5]

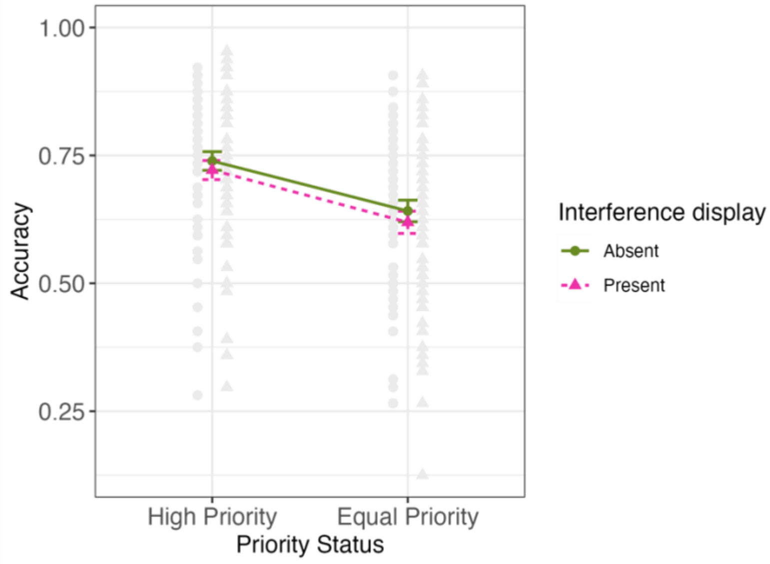
Furthermore, two Bayesian paired one-sided t-tests tested whether accuracy was better when the interference display was absent compared to when it was present. The results for the high-priority items remained inconclusive (BF_{10} = 1.25) while there was some modest evidence in favor of this difference for the equal-priority items (BF_{10} = 3.13). As can be seen in Figure 4, memory performance appeared slightly worse for both types of items when interference was present. However, this difference was not statistically supported for high priority items and only weakly for equal priority items (see Table 3). Additional analyses of the types of errors made are consistent with this observeation and are reported in Supplementary materials.

Altogether, despite our efforts to optimize the paradigm to detect a disruptive effect of perceptual interference on memory performance, we still did not find strong evidence for such an effect. Although there was some indication of a negative impact of interference, the evidence remained very weak. Moreover, there was no evidence in our data that this effect was modulated by the priority status of the information.

[5] The evidence against the critical interaction between Prioritization and Interference was < 10 (BF_{10} = 0.29) after the first batch of 30 participants, and thus data collection continued as preregistered.

Figure 4

Mean accuracy for Experiment 3 presented with standard error bars and individual scores (grey).



Interim Discussion Experiments 1-3

Across multiple experiments with varying task parameters, we did not observe any convincing evidence for a negative impact of perceptual interference on memory performance. Therefore, these experiments did not allow us to address our initial research question, i.e., whether a representation in the focus of attention is protected from or (particularly) vulnerable to perceptual interference in comparison to other items in working memory. Moreover, our findings contradict previous work that did observe an impact of perceptual interference on memory performance using similar types of paradigms (e.g., Allen & Ueno, 2018; Hautekiet et al., 2025; Hu et al., 2014, 2016; Makovski & Jiang, 2007; Ueno, Allen, et al., 2011; Ueno, Mate, et al., 2011; van Moorselaar et al., 2015). One could argue that Experiment 3 provided some evidence for a disruptive effect of interference. While that may be true, we considered this evidence too weak to justify further use of the paradigm to investigate our main research question.

Therefore, to address our initial question, we decided to adopt a different approach. Instead of creating a new paradigm, we used an existing paradigm that has shown an interference effect on memory performance in the past, i.e., the paradigm of van Moorselaar et al. (2015). In this task, participants memorize three line orientations and reproduce one of these orientations at the end of the trial. In between, a 100%-valid retro-cue and an interference display could be presented. Using cue-based prioritization, the results showed that the representation in the focus of attention is protected from perceptual interference, while other items remain vulnerable (see also Barth & Schneider, 2018 and Schneider et al., 2017 for a similar paradigm and results). In Experiment 4a, we ran a close replication of this task (van Moorselaar and colleagues, 2015; Experiment 1). Next, in Experiment 4b, we aimed to replicate the finding that the representation in the focus of attention is (particularly) vulnerable to perceptual interference (Allen & Ueno, 2018; Hitch et al., 2018; Hu et al., 2014, 2016), using reward-based prioritization within the same paradigm.

Furthermore, we aimed to determine whether the distractor susceptibility of the prioritized item is primarily driven by its relevance or by how it was prioritized. To investigate this, we manipulated both prioritization mode and the relevance of the prioritized item in a series of four experiments. In Experiment 4c, we lowered the validity of the retro-cue to 33% such that all items had an equal chance of being tested, but we still asked participants to attend to the cued item even though it does not predict which item will be tested (similar to a refreshing cue; see Camos et al., 2018 for a review). In Experiment 4d, we increased the value of the high-reward item to 100 points (vs. 3 points in Experiment 4b), whereas the other items still were worth 1 point. This was done to make the high-reward item the only (subjectively) relevant item to the participants, similar to what is typically the case in a retro-cue paradigm. For completeness, we conducted two more experiments. In Experiment 4e, a 66%-valid retro-cue was used to make the prioritized item somewhat more relevant while all items could still be tested.[6] Finally, in Experiment 4f, we increased the high reward value to 1000 points to make

[6] This experiment was added when data collection for Experiments 4a-4d was ongoing and thus, before the results were known. The percentage of the validity was chosen because it falls right in between 33% and 100%.

this item the only (subjectively) relevant item throughout the trial as 100 points might not be convincing enough.[7] An overview of Experiments 4a-f is presented in Table 5, together with the expected results under the hypothesis that an item's distractor susceptibility depends on prioritization mode vs. item relevance.

Table 5

Overview of Experiments 4a-4f.

EXP	Prioritization Mode	Item Relevance	Expected result if an item's susceptibility depends on	
			Prioritization Mode	Item Relevance
4a	*100%-valid retro-cue*	Only one relevant item	Protection	Protection
4b	*3-1-1 reward paradigm*	All items remain relevant	Vulnerability	Vulnerability
4c	*33%-valid retro-cue*	All items remain relevant	Protection	Vulnerability
4d	*100-1-1 reward paradigm*	Only one (subjectively) relevant item	Vulnerability	Protection
4e	*66%-valid retro-cue*	All items remain relevant	Protection	Vulnerability
4f	*1000-1-1 reward paradigm*	Only one (subjectively) relevant item	Vulnerability	Protection

Experiment 4 (4a-4f)

Methods

Participants

Experiment 4a included 30 participants (24 women, 6 men; mean age = 21.02 years), Experiment 4b included 41 participants[8] (32 women, 9 men; mean age = 21.20 years), Experiment 4c included 33 participants[8] (29 women, 4 men; mean age = 23.57 years), Experiment 4d included 44 participants[8] (39 women, 5 men; mean age = 22.51 years), Experiment 4e included 33 participants[8] (24 women, 9 men; mean age = 21.75 years), and

[7] This experiment was added after the results of Experiment 4a-4e were known. We added this experiment with the aim to demonstrate that even with an extremely high high-reward value, the results do not change.
[8] See Table S1 in the Supplementary Materials for preregistration deviation.

finally, Experiment 4f included 29 participants[9] (22 women, 7 men; mean age = 23.84 years). Some participants did not complete the experiment within the provided time. As a not-preregistered rule of thumb, we excluded participants when less than 75% of the data was collected[8]. This resulted in the exclusion of one participant in Experiment 4c and thus, Experiment 4c had a final sample size of 32 participants. In all other experiments, the final sample corresponds to the collected sample.

Materials

The stimuli were based on the paradigm of van Moorselaar et al. (2015).[10] A small black circle with a white border was used for fixation (see Fig. 1, Panel D). Three black line orientations were used as memory items, presented on the corners of one of two invisible triangles, one smaller and one larger (alternated trial by trial to reduce afterimage effects). The memory orientations were randomly defined on each trial (between 0° and 180°, with min. 15° distance). The priority signal and retrieval signal were the same, i.e., a white triangle presented in the fixation circle (filling about 1/3 of the circle). This triangle indicated which item had to be prioritized (priority signal) or reproduced (retrieval signal). The probe was always presented in the center of the screen (behind the retrieval signal) in a random orientation, on the condition that it differed at least 15° from any of the memory items.[11] The mask consisted of six black bars of the same measurements as the memory items, presented in six orientations (0°, 30°, 60°, 90°, 120°, 150°). In each interference display, three masks were presented in the three memory locations.

[9] Data of 30 participants was collected but one participant was excluded because they did not give permission for data use.

[10] The original authors kindly provided us with the original script of their experiment which was programmed in an early version of OpenSesame. For efficiency reasons, the program was recreated in PsychoPy.

[11] This was, to our knowledge, not included in the paradigm by van Moorselaar et al. (2015). However, we added this to avoid obtaining a correct response without any adjustment of the orientation.

Procedure

The experiments were run on a computer using Psychopy (v2022.2.4) with a default grey background ([0,0,0] in RGB color space). Participants were tested in small groups and sat at a comfortable distance from the screen (approximately 60 cm). They performed the following task (see Fig. 1, Panel D). Each trial started with a 500 ms display of only the fixation mark. The fixation mark remained on screen throughout the entire trial. This fixation display was followed by the three to-be-memorized orientations for 350 ms. At the end of the trial, one of these orientations had to be reproduced. The black bar in the test display was accompanied by a retrieval signal which indicated the location of the memory item that had to be reproduced. Participants were instructed to reproduce the probed orientation by using the buttons on screen: move bar to the left quickly, move bar to the left slowly, move bar to the right slowly, move bar to the right quickly, and submit (based on Zhang & Lewis-Peacock, 2023).[12]

In between memory encoding and test, there was a retention interval of 1400 ms. In all trials, the encoding display was followed by a 400 ms delay. What happened next depends on the type of trial. There were four types of trials: (1) Priority Signal – Interference, (2) Priority Signal – No Interference, (3) No Priority Signal – Interference, or (4) No Priority Signal – No Interference. In the Priority Signal – Interference trials, the 400 ms delay was followed by a 100 ms priority signal, another 400 ms delay, a 100 ms interference display, and again 400 ms delay (see Fig. 1, Panel D). In the Priority Signal – No Interference trials, the 400 ms delay is followed by a 100 ms priority, after which there was another delay for 900 ms. In the No Priority Signal – Interference trials, the 400 ms delay is followed by another delay for 500 ms (summing up to 900 ms) after which the interference display is presented for 100 ms, again followed by a 400 ms delay. In the No Priority Signal – No Interference trials, the screen

[12] This differed from the study by van Moorselaar et al. (2015) in which participants had to change the bar orientation by adjusting the mouse position. Because of the complexity to program the mouse response as used in the original study, we used an alternative approach.

remained empty for 1400 ms (except for the fixation mark). Furthermore, like in the original study by van Moorselaar et al. (2015), the No Priority Signal – No Interference trials were divided in short and long interval trials. The long interval trials correspond to the trials described above. In the short interval trials, the test display was presented at the time the interference display was presented in Interference trials, i.e. after 900 ms. This was done in the original study to have a measurement of the content of visual working memory at the moment the interference display was presented in interference trials. There was no inter-trial interval.[13]

The instructions associated with the priority signal varied between the different experiments such that participants were instructed that the priority signal corresponded to a 100%-valid retro-cue (4a), a 3-point high reward (4b), a 33%-valid retro-cue (4c), a 100-point high reward (4d), a 66%-valid retro-cue (4e), or a 1000-point high reward (4f). In the reward experiments (4b, 4d, and 4f), the unprioritized items always had a value of 1 point. Points were only assigned when the item was tested and responded to correctly. For this purpose, a response was considered correct when the error was less than 15 degrees. At the end of each trial, a feedback display was presented for 500 ms consisting of the correct orientation in white, overlaying the participants' response, and the obtained points on that trial.[14] To keep this the same between experiments, one point could be earned per correct response in the cue experiments (4a, 4c, and 4e). Additionally, participants received 1 point per correct response on trials without a priority signal. An incorrect response always resulted in 0 points. Instructions remained the same for all experiments except for the specifics about the priority signal (see Supplementary Materials for more information).

[13] This is not reported in the article by van Moorselaar et al. (2015), but we verified this with the original authors through e-mail correspondence.

[14] This feedback differed from the original study by van Moorselaar et al. (2015) in which no points were provided and in which feedback was displayed for only 100 ms. However, to allow participants to view the points as well as the correct response, the feedback presentation time was prolonged to 500 ms.

In each experiment, participants performed 8 blocks of 48 trials, resulting in a total of 384 trials. Within each block, there was an equal amount of (1) Priority Signal – Interference trials, (2) Priority Signal – No Interference trials, (3) No Priority Signal – Interference trials, (4) No Priority Signal – No Interference trials. Within the latter, half of the trials were presented with a short retention interval (i.e., 900 ms) and half of the trials with a long retention interval (i.e., 1400 ms). All other conditions had a retention interval of 1400 ms. Furthermore, within the Priority Signal – Interference and Priority Signal – No Interference trials, the number of times the high-priority item was tested, depended on the specific experiment (see Supplementary Materials for the trial proportions). Participants completed 48 practice trials before starting the experimental trials. After each block, participants were presented with their obtained points in that block[15] and were encouraged to take a short break.

Results and Discussion

To analyze Experiments 4a-4f, we applied similar analyses as in Experiments 1-3. However, we now followed the analysis plan by van Moorselaar and colleagues (2015) for the main analysis of the retro-cue experiments and for the exploratory analysis of the reward experiments. As such, the BANOVA and t-tests were executed three times: once for the full dataset, once for the dataset including only short trials for the No Priority Signal – No Interference trials, and once for the dataset including only long trials for the No Priority Signal – No Interference trials (see Supplementary Materials for an exploratory analysis using lmBF and an exploratory analysis on aggregated RTs).

As can be seen in Table 6, the results of the main BANOVAs were quite stable throughout the different experiments (regardless of the condition used as baseline). Following the conventional retro-cue comparison (high vs. equal priority), most of the retro-cue

[15] This differed slightly from the original experiment in which the average response error was presented following the completion of a block.

experiments (4a and 4e) demonstrated a retro-cue benefit, and following the conventional reward comparison (high vs. low priority), the reward experiments (4b, 4d, and 4f) displayed a reward benefit. In contrast, we did not observe a prioritization effect when a 33%-valid cue was used (4c), most likely because this was the only condition in which the prioritized item was linked to neither a higher chance of being tested nor a higher reward value.

Table 6

Results of main and exploratory Bayesian repeated measures ANOVA executed on absolute response error in Experiments 4a-4f.

Exp.	Analysis	Priority Status comparison	Interval	Priority Status	Interference	Priority Status *Interference
4a 100%-valid cue	**Main**	*High vs. Equal*	*All Trials*	6.40×10^{19}	0.20	0.05
			Short	4.43×10^{17}	0.23	0.06
			Long	1.25×10^{19}	0.22	0.06
4b 3-1-1 reward	**Main**	*High vs. Low*	*All Trials*	39.58	0.17	0.06
	Exploratory	*High vs. Equal*	*All Trials*	0.16	0.17	0.01
			Short	0.18	0.17	0.02
			Long	0.18	0.18	0.01
4c 33%-valid cue	**Main**	*High vs. Equal*	*All Trials*	0.93	0.31	0.10
			Short	0.41	0.50	0.05
			Long	1.86	0.23	0.12
	Exploratory	*High vs. Low*	*All Trials*	828.82	0.22	0.07
4d 100-1-1 reward	**Main**	*High vs. Low*	*All trials*	2.27×10^{5}	0.20	0.05
	Exploratory	*High vs. Equal*	*All Trials*	14.85	0.18	0.04
			Short	8.09	0.17	0.04
			Long	15.96	0.18	0.04
4e 66%-valid cue	**Main**	*High vs. Equal*	*All Trials*	987.80	0.22	0.06
			Short	94.16	0.37	0.12
			Long	4205.42	0.19	0.05
	Exploratory	*High vs. Low*	*All Trials*	3.56×10^{8}	0.36	0.15
4f 1000-1-1 reward	**Main**	*High vs. Low*	*All Trials*	6.33×10^{5}	0.20	0.07
	Exploratory	*High vs. Equal*	*Short*	150.01	0.19	0.11
			Long	1.74×10^{4}	0.37	0.10
			All Trials	2437.40	0.22	0.07

Note. Bayes factors (BFs) resulting from model comparison between het best model and the model excluding the effect/interaction (if it is included in the best model) or including the effect/interaction (if it is not part of the best model). The Bayes factors reflect evidence in favor of the tested effect (BF_{10}). When the BF presents conclusive evidence in favor of the tested effect ($BF_{10} > 3$), the text is presented in green; when the BF reflects conclusive evidence against the tested effect ($BF_{10} < 0.33$, which corresponds to $BF_{01} > 3$), the text is presented in red; inconclusive results are present in black ($0.33 < BF_{10} < 3$). When all BFs present evidence against the effect, this means that the null model best represented the data. The last column refers to the full model including the interaction between Priority Status and Interference.

Furthermore, in line with our findings in Experiments 1-3, none of the experiments displayed any evidence for an interference effect, or for an interaction between Priority Status and Interference.[16] Even more so, almost all results demonstrate moderate evidence (BF > 3) *against* an effect of interference (see Table 6). In line with this, the results of the Bayesian paired one-sided t-tests consistently did not show convincing evidence for higher response error when interfering stimuli were presented compared to when they were not presented, and thus, no convincing evidence for an interference effect in any of the different priority states (see Table 7). The lack of an interference effect in these experiments was unexpected, especially given that the paradigm was closely modeled after one that successfully detected a negative impact of perceptual interference on memory performance in the past (e.g., Barth & Schneider, 2018; Schneider et al., 2017; van Moorselaar et al., 2015).

Table 7

Results of the Bayesian paired one-sided t-tests (interference absent < present) on absolute response error in Experiments 4a-4f.

Interference Absent < Present (t-test)		**4a 100%-valid retro-cue**	**4b 3-1-1 reward**	**4c 33%-valid retro-cue**	**4d 100-1-1 reward**	**4e 66%-valid retro-cue**	**4f 1000-1-1 reward**
Priority Status	*High*	0.27	0.10	0.84	0.13	0.27	0.12
	Equal – all	0.18	0.72	0.21	0.12	0.42	0.22
	Equal – short	0.61	1.58	0.49	0.13	0.56	0.76
	Equal - long	0.10	0.24	0.11	0.12	0.15	0.09
	Low	/	0.83	0.12	0.07	2.85	0.28

Note. The Bayes factors reflect evidence in favor of the tested effect (BF_{10}). When the BF reflects conclusive evidence against the tested effect ($BF_{10} < 0.33$, which corresponds to $BF_{01} > 3$), the text is presented in red; inconclusive results are present in black ($0.33 < BF_{10} < 3$).

For experiments 4b-4f, we also analyzed the data following the alternative comparisons (cue: high vs. low priority, reward: high vs. equal priority; see ‘Exploratory’ in Table 6). The results of these analyses were consistent with the main analysis, such that none of the exploratory analyses showed any evidence for an interference effect, nor for an interaction

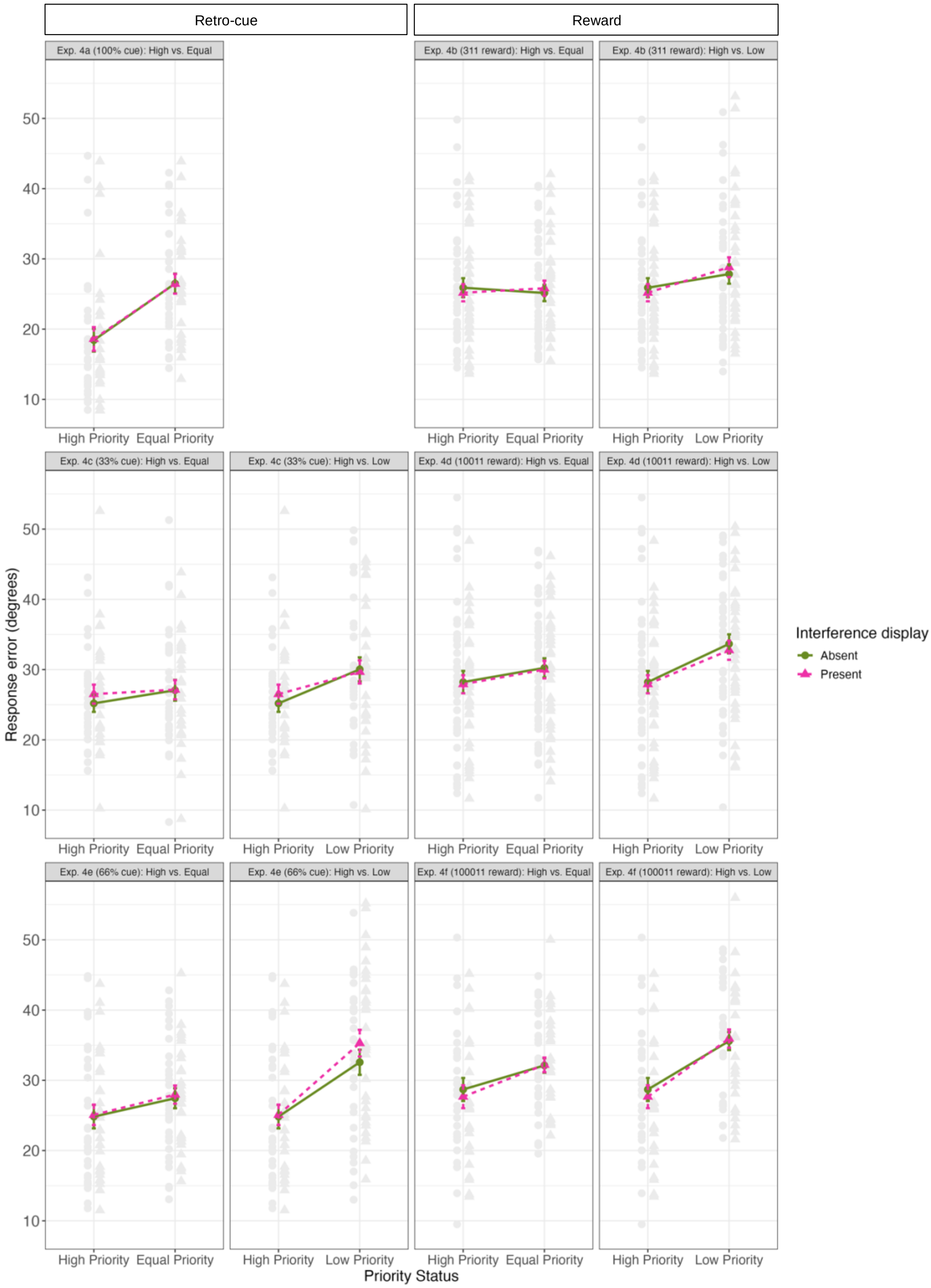
[16] The evidence for or against served as our preregistered stopping rule in each experiment. For all experiments, except 4d, the BF against the interaction surpassed 10 after the first batch of 30 participants. In Experiment 4d, this was the case after one additional batch of 10 participants.

between Interference and Priority Status. Furthermore, all experiments resulted in a prioritization effect, except when a 3-1-1 reward pattern was used (4b). The lack of a prioritization effect, here, can most likely be explained by the fact that the conventional comparison for the reward experiments entails the benefit for the prioritized item (high vs. equal priority) as well as the cost for the unprioritized item (equal vs. low priority), whereas the alternative comparison only reflects the benefit for the prioritized item. This demonstrates that, in Experiment 4b, using a reward pattern does not result in a substantive benefit for the prioritized item. Similarly, the 33%-valid retro-cue (4c) did result in a prioritization effect when applying the alternative comparison, while this was not the case for the conventional comparison. Here, the exploratory analysis entails the benefit for the prioritized item (high vs. equal priority) as well as the cost for the unprioritized item (equal vs. low priority), whereas the main analysis only reflects the benefit for the prioritized item. This again suggests that, in this experiment, there seems to be a cost for the unprioritized items but no, or only a small, benefit for the prioritized item. The differences in cost and benefits will be further discussed in the General Discussion.

Overall, the results from Experiments 4a-4f demonstrated that, in most cases, participants use the priority signal to prioritize information in working memory, resulting in a performance benefit for this prioritized item, for both cue-based and reward-based prioritization (see Figure 5). This is line with previous studies using retro-cues (see Souza & Oberauer, 2016 for a review) or reward patterns (see Allen et al., 2024 for a review). The only exception here is when a 33%-valid retro-cue was used. Here, the cued item did not have a higher chance of being tested nor did it result in a reward when tested and responded to correctly. Thus, although participants were still asked to attend to the cued item, the item did not have enough behavioral relevance to result in a prioritization effect. Furthermore, and importantly, across 6 experiments, we did not observe any evidence in favor of an interference effect on memory performance. Instead, the data was inconclusive in some conditions, but in most conditions and experiments, the evidence was conclusively against an interference effect. These findings are in line with our first set of experiments, but go against previous studies that *did* observe an impact of perceptual interference on working memory performance. The lack of an interference effect in these experiments prevents us from drawing firm conclusions regarding the distractor susceptibility of information in the focus of attention and what might determine this susceptibility.

Figure 5

Mean response error (in degrees) for Experiments 4a-4f presented with standard error bars and individual scores (grey).



General discussion

The current study aimed to investigate the distractor susceptibility of information in the focus of attention. Specifically, we examined whether information in the focus of attention is protected from or (particularly) vulnerable to perceptual interference in comparison to other information in working memory, outside the focus of attention. Across ten experiments involving 451 participants, we did not observe any convincing or consistent evidence for a negative impact of perceptual interference on memory performance, regardless of the priority status of the information. Visual information in working memory was thus found to be largely robust against irrelevant visual stimuli of the same class.

The absence of an interference effect prevents us from drawing firm conclusions regarding our main research question: whether information in the focus of attention is protected from or (particularly) vulnerable to perceptual interference. Moreover, our findings suggest that working memory representations can not be considered vulnerable to perceptual interference by default.[17] This challenges the necessity of mechanisms, like the focus of attention, for protecting information in working memory against interference. Instead, these findings suggest that the more relevant question is under what conditions memory representations become vulnerable to interference from irrelevant information, rather than whether and how focused attention influences distractor susceptibility in working memory.

Furthermore, our experiments allow for a direct comparison between cue-based and reward-based prioritization within the same paradigm, demonstrating that the effects of these two prioritization modes differ, with cue-based prioritization appearing more effective than

[17] One could argue that when multiple items are prioritized simultaneously, the prioritized items will become highly susceptible to perceptual interference, whereas this impact will no longer or barely be traceable for the unprioritized items (Experiments 2-4, Allen & Ueno, 2018; Hu et al., 2014; Hitch et al., 2018). Still, even when only one item is prioritized, previous studies have found that all items in working memory were equally vulnerable to perceptual interference (e.g., Experiment 1, Allen & Ueno, 2018; Vergauwe et al., 2025), which was not the case in our study as none of the items were impacted by perceptual interference.

reward-based prioritization. The implications of our results for the focus of attention, and for working memory more broadly, are discussed below.

Working memory representations are quite resilient to irrelevant perceptual distractors

Using different types of interference displays, we did not observe any convincing evidence for an interference effect in working memory. These findings contradict several studies reporting a detrimental effect of perceptual interference on working memory performance (see Lorenc et al., 2021 for a recent review), despite using experiments that were either similar (Experiments 1-3) or closely modeled after paradigms that previously detected such effects (Experiment 4). The fact that an interference effect was largely absent in our experiments strongly suggests that memory representations are not vulnerable to perceptual interference by default. Despite the fact that protection against interference is a key characteristic of the focus of attention in working memory, we are not the first to observe that information in working memory is not consistently impacted by perceptual interference (e.g., Bettencourt & Xu, 2016; Clapp et al., 2010; Feredoes et al., 2011; Jeanneret, Vergauwe, et al., 2024; Rademaker et al., 2019; Sreenivasan & Jha, 2007; Zhang & Lewis-Peacock, 2022; Zickerick et al., 2020; Zimmer & Speiser, 2002; see also Xu, 2017 for a review). This raises the question under what conditions working memory is affected by perceptual interference and when it remains unaffected.

When comparing our study to the relevant ones in the literature, there are some task aspects that differ, that could make a critical difference in observing an interference effect or not. For one, it could be that perceptual interference does not impact memory in an all-or-nothing fashion, such that only part of the representation gets lost (see Schneider et al., 2017 for a similar reasoning). Indeed, in most of the studies that did observe an interference effect, participants were asked to recall or reproduce the probed memory item rather than simply recognize it (Allen & Ueno, 2018; Hautekiet et al., 2025; Hu et al., 2023; Saito et al., 2024; Schneider et al., 2017; Ueno, Allen, et al., 2011; Ueno, Mate, et al., 2011; van Moorselaar et al., 2015; Vergauwe et al., 2025; Zhang & Lewis-Peacock, 2022, 2023). In our Experiments 1-2, we used a recognition task, and we did not observe any negative impact of perceptual interference on memory performance. This could be because enough of the representation remained to recognize it, but perhaps not to recall or reproduce it. In Experiment 3, we addressed this by making our recognition task more similar to a recall task. Specifically, rather than presenting participants with a probe, we asked participants to select their answer from a 12-item list. In this experiment, we observed a glimpse of an interference effect as there was some very modest evidence for a main effect of Interference (BF_{10} = 3.02). This suggests that recall or reproduction might be better suited for detecting interference effects. However, in Experiments 4a-4f, we still found no negative impact of perceptual interference on memory performance, even though information had to be reproduced rather than rcognized (see also e.g., Rademaker et al., 2019; Zimmer & Speiser, 2002; Zhang & Lewis-Peacock, 2022 for similar findings1/22/2025 1:43:00 PM). This indicates that using recall or reproduction alone is not sufficient to detect an interference effect.

A second factor that might be of importance is that the distraction should be disruptive enough such that it cannot easily be ignored. Given that working memory is severely limited, it would be most efficient to ignore irrelevant information and not let it disrupt the information that is being maintained, except when the distractor stimulus is too attentionally captivating and cannot easily be ignored (e.g., Bonnefond & Jensen, 2012; Jeanneret et al., 2024; Rademaker et al., 2019). For example, in the study by Rademaker et al. (2019), participants were shown a to-be-memorized oriented grating and reproduced its orientation at the end of the trial, with a sequence of contrast-reversing visual distractors presented in between on some trials. The results showed no negative impact of perceptual interference on memory performance (see also Bettencourt & Xu, 2016 for the same result using a similar paradigm). In a follow-up experiment, Rademaker et al. (2019) used the same paradigm but flickered the visual distractors on and off the screen during the delay. This time, memory performance was negatively impacted by the interference. This suggests that increasing the salience of the stimulus to make it more attentionally captivating can induce an interference effect.

Thus, our findings, along with previous literature, show that representations in working memory are not vulnerable to perceptual interference by default. Instead, certain task parameters, such as the type of memory test and the attentional salience of the distractors, may be critical for observing a negative impact of interference. Future studies should systematically investigate the differences between studies that did and did not observe a negative impact of irrelevant perceptual distractors during maintenance to pinpoint the precise task conditions that make working memory representations vulnerable to interference.

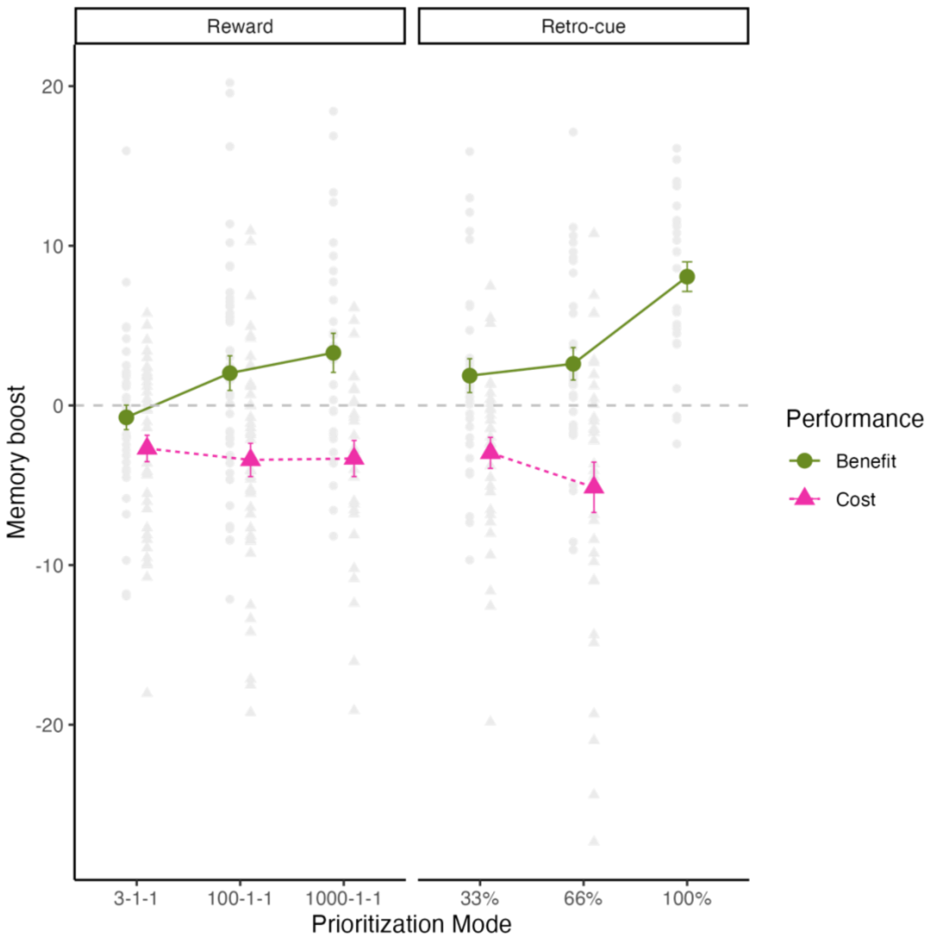
The costs and benefits associated with prioritization in working memory

In addition to the investigation of our main research question, our paradigm allowed for an exploratory investigation of prioritization effects across different prioritization modes (retro-cue vs. reward). In the past literature, studies that have directly compared retro-cue and reward prioritization found the memory boost resulting from reward-based prioritization to be smaller and less consistent than the memory boost resulting from cue-based prioritization (Jeanneret et al., 2023; Vergauwe et al., 2025; Zhang & Lewis-Peacock, 2022 in visuo-spatial working memory; but see Jeanneret et al., 2024 in verbal working memory). Our findings align with the literature, in that (1) we did not observe a memory boost for reward-based prioritization in Experiment 1b and (2) we did observe a smaller memory boost for reward-based prioritization than for cue-based prioritization in Experiment 4. Moreover, the reaction times (RTs) in Experiments 1-2 showed faster responses for prioritized information than for unprioritized information for both prioritization modes, with a larger boost in RTs for cue-based prioritization (Experiment 1a) than for reward-based prioritization (Experiment 1b; see Supplementary Materials for more details). Thus, in line with recent literature, our findings demonstrate that the memory boost induced by cue-based prioritization is larger and more consistent than the boost induced by reward-based prioritization.

Experiments 4a-4f allowed us to further compare different levels of relevance for these two prioritization strategies. Specifically, we varied the validity of the retro-cue (100%, 66%, and 33%) as well as the value of the high reward (3 points, 100 points, and 1000 points). To get a better understanding of what the associated memory boosts are reflecting, we performed an additional, cross-experiment analysis, to evaluate the benefits and costs for prioritized and unprioritized items, respectively, across prioritization modes and their variations. For each experiment, we calculated the increase in memory performance between the high priority items and the equal priority items, which corresponds to the *benefit* for prioritized items. In the same way, we calculated the decrease in memory performance between the equal priority items and the low priority items, which corresponds to the *cost* for the unprioritized information. A visualization of the performance costs and benefits of the different prioritization strategies and their variations is displayed in Figure 6.

Figure 6

Memory performance costs and benefits for the different prioritization strategies.



Note. Overview of the performance benefit and cost (in terms of difference in response error) for the '3-1-1' reward pattern condition (Experiment 4b), the '100-1-1' reward pattern (Experiment 4d), the '1000-1-1' reward pattern (Experiment 4f), the 33%-valid retro-cue condition (Experiment 4c), the 66%-valid retro-cue condition (Experiment 4e), and the 100%-valid retro-cue condition (Experiment 4a), presented with standard error bars and individual distribution. The grey dotted line represents baseline performance (i.e., equal priority items).

When comparing the costs and benefits, it seems that in some cases, the benefit for the prioritized item is non-existing or descriptively smaller than the cost for the unprioritized item. Indeed, exploratory analyses confirmed that, whereas prioritization consistently results in a cost for unprioritized information, the benefit for prioritized information is less consistently observed and is not larger than the cost observed for unprioritized information (see Supplementary Materials for more details). Thus, the consequences of prioritization seem to be more important for the information that is not prioritized than for the information that is assumed to be brought into a privileged state within working memory.

Conclusion

The current study aimed to investigate the distractor susceptibility of information in the focus of attention, by examining whether the prioritized item is protected from or (particularly) vulnerable to perceptual interference in comparison to unprioritized information in working memory. Across ten experiments, rather than finding evidence for reduced or heightened distractor susceptibility, we observed no convincing evidence for a detrimental impact of perceptual interference on memory performance, despite our efforts to optimize our paradigm and closely model our experiments after previous studies. As a result, we could not determine if or how distractor susceptibility of information in working memory is modulated by its priority state. However, our findings clearly show that memory performance is not affected by perceptual interference by default. Moreover, we uncovered that the cost to unprioritized information often outweighs the benefits for prioritized information, regardless of prioritization mode. If (1) information in working memory is not highly vulnerable to interference, and (2) the costs of attention-based prioritization to unprioritized information exceed the benefits for prioritized information, then some of the key advantages of the focus of attention are not supported, casting some doubt on the need to assume this privileged state in working memory.

References

Allen, R. J., Atkinson, A., & Hitch, G. J. (2024). Getting value out of working memory through strategic prioritisation; implications for storage and control. *Quarterly Journal of Experimental Psychology*, 17470218241258102. https://doi.org/10.1177/17470218241258102

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

Atkinson, A. L., Berry, E. D. J., Waterman, A. H., Baddeley, A. D., Hitch, G. J., & Allen, R. J. (2018). 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*, *29*(3), 891–900. https://doi.org/10.3758/s13423-022-02056-6

Baddeley, A. D., & Hitch, G. (1974). Working memory. *The Psychology of Learning and Motivation: Advances in Research and Theory*, *8*, 47–89. https://doi.org/10.1016/S0079-7421(08)60452-1

Baddeley, A., Hitch, G., & Allen, R. J. (2021). Chapter 2: A Multicomponent Model of Working Memory. In R. Logie, V. Camos, & N. Cowan (Eds.), *Working Memory: State of the Science* (pp. 10–43). Oxford University Press.

Barth, A., & Schneider, D. (2018). Manipulating the focus of attention in working memory: Evidence for a protection of multiple items against perceptual interference. *Psychophysiology*, *55*(7), e13062. https://doi.org/10.1111/PSYP.13062

Bettencourt, K. C., & Xu, Y. (2016). Decoding the content of visual short-term memory under distraction in occipital and parietal areas. *Nature Neuroscience*, *19*(1), 150–157. https://doi.org/10.1038/nn.4174

Bonnefond, M., & Jensen, O. (2012). Alpha oscillations serve to protect working memory maintenance against anticipated distracters. *Current Biology: CB*, *22*(20), 1969–1974. https://doi.org/10.1016/j.cub.2012.08.029

Brady, T. F., Konkle, T., Alvarez, G. A., & Oliva, A. (2008). Visual long-term memory has a massive storage capacity for object details. *Proceedings of the National Academy of Sciences*, *105*(38), 14325–14329. https://doi.org/10.1073/PNAS.0803390105

Clapp, W. C., Rubens, M. T., & Gazzaley, A. (2010). Mechanisms of Working Memory Disruption by External Interference. *Cerebral Cortex*, *20*(4), 859–872. https://doi.org/10.1093/cercor/bhp150

Cowan, N. (2011). The focus of attention as observed in visual working memory tasks: Making sense of competing claims. *Neuropsychologia*, *49*(6), 1401–1406. https://doi.org/10.1016/J.NEUROPSYCHOLOGIA.2011.01.035

Cowan, N., Johnson, T. D., & Scott Saults, J. (2005). Capacity limits in list item recognition: Evidence from proactive interference. *Memory*, *13*(3–4), 293–299. https://doi.org/10.1080/09658210344000206

Endo, N., Saiki, J., Nakao, Y., & Saito, H. (2003). Perceptual judgments of novel contour shapes and hierarchical descriptions of geometrical properties. *The Japanese Journal of Psychology*, *74*(4), 346–353. https://doi.org/10.4992/jjpsy.74.346

Feredoes, E., Heinen, K., Weiskopf, N., Ruff, C., & Driver, J. (2011). Causal evidence for frontal involvement in memory target maintenance by posterior brain areas during distracter interference of visual working memory. *Proceedings of the National Academy of Sciences*, *108*(42), 17510–17515. https://doi.org/10.1073/pnas.1106439108

Griffin, I. C., & Nobre, A. C. (2003). Orienting Attention to Locations in Internal Representations. *Journal of Cognitive Neuroscience*, *15*(8), 1176–1194. https://doi.org/10.1162/089892903322598139

Hautekiet, C., Langerock, N., & Vergauwe, E. (2023). Accessibility of working memory representations in the focus of attention: Heightened or reduced? *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 50(4):562-579. https://doi.org/10.1037/xlm0001223

Hautekiet, C., Langerock, N., & Vergauwe, E. (2025). *Prioritization in Visual Working Memory: An Investigation of Distractor Susceptibility and Different Prioritization Modes*. OSF page: https://doi.org/10.17605/OSF.IO/5DCZ8

Hautekiet, C., Niklaus, M., & Oberauer, K. (2025). *Susceptibility to Visual Interference in Working Memory: Different Results Depending on the Used Prioritization Strategy?* https://doi.org/10.31234/osf.io/hn9wp

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, and 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, & 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

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*. https://doi.org/10.3758/s13414-023-02706-4

Jeanneret, S., Vergauwe, E., Hautekiet, C., & Langerock, N. (2024). What are the benefits of directed attention within verbal working memory? Quarterly Journal of Experimental Psychology, 0(0). https://doi.org/10.1177/17470218241299918

Jonides, J., Lewis, R. L., Nee, D. E., Lustig, C. A., Berman, M. G., & Moore, K. S. (2008). The Mind and Brain of Short-Term Memory. *Annual Review of Psychology*, *59*(1), 193–224. https://doi.org/10.1146/annurev.psych.59.103006.093615

Landman, R., Spekreijse, H., & Lamme, V. A. F. (2003). Large capacity storage of integrated objects before change blindness. *Vision Research*, *43*(2), 149–164. https://doi.org/10.1016/S0042-6989(02)00402-9

Logie, R. H., Zucco, G. M., & Baddeley, A. D. (1990). Interference with visual short-term memory. *Acta Psychologica*, *75*(1), 55–74. https://doi.org/10.1016/0001-6918(90)90066-O

Lorenc, E. S., Mallett, R., & Lewis-Peacock, J. A. (2021). Distraction in Visual Working Memory: Resistance is Not Futile. *Trends in Cognitive Sciences*, *25*(3), 228–239. https://doi.org/10.1016/J.TICS.2020.12.004

Makovski, T., & Jiang, Y. V. (2007). Distributing versus focusing attention in visual short-term memory. *Psychonomic Bulletin and Review*, *14*(6), 1072–1078. https://doi.org/10.3758/BF03193093

Makovski, T., & Pertzov, Y. (2015). Attention and memory protection: Interactions between retrospective attention cueing and interference. *Quarterly Journal of Experimental Psychology*, *68*(9), 1735–1743. https://doi.org/10.1080/17470218.2015.1049623

Makovski, T., Sussman, R., & Jiang, Y. V. (2008). Orienting attention in visual working memory reduces interference from memory probes. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *34*(2), 369–380. https://doi.org/10.1037/0278-7393.34.2.369

Mallett, R., & Lewis-Peacock, J. A. (2019). Working memory prioritization impacts neural recovery from distraction. *Cortex*, *121*, 225–238. https://doi.org/10.1016/j.cortex.2019.08.019

Morey, R. D., & Rouder, J. N. (2011). Bayes factor approaches for testing interval null hypotheses. Psychological Methods, 16(4), 406–419. https://doi.org/10.1037/a0024377

Noonan, M. P., Adamian, N., Pike, A., Printzlau, F., Crittenden, B. M., & Stokes, M. G. (2016). Distinct Mechanisms for Distractor Suppression and Target Facilitation. *Journal of Neuroscience*, *36*(6), 1797–1807. https://doi.org/10.1523/JNEUROSCI.2133-15.2016

Oberauer, K. (2002). Access to Information in Working Memory: Exploring the Focus of Attention. *Journal of Experimental Psychology: Learning Memory and Cognition*, *28*(3), 411–421. https://doi.org/10.1037/0278-7393.28.3.411

Oberauer, K. (2009). Chapter 2 Design for a Working Memory. *Psychology of Learning and Motivation - Advances in Research and Theory*, *51*, 45–100. https://doi.org/10.1016/S0079-7421(09)51002-X

Oberauer, K., Farrell, S., Jarrold, C., & Lewandowsky, S. (2016). What limits working memory capacity? *Psychological Bulletin*, *142*(7), 758. https://doi.org/10.1037/bul0000046

Oberauer, K., & Lin, H.-Y. (2017). An interference model of visual working memory. *Psychological Review*, *124*(1), 21–59. https://doi.org/10.1037/rev0000044

Peirce, J. W., Gray, J. R., Simpson, S., MacAskill, M. R., Höchenberger, R., Sogo, H., Kastman, E., Lindeløv, J. (2019). PsychoPy2: experiments in behavior made easy. Behavior Research Methods. 10.3758/s13428-018-01193-y

R Core Team. (2014). *R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. 2013*.

Rademaker, R. L., Chunharas, C., & Serences, J. T. (2019). Coexisting representations of sensory and mnemonic information in human visual cortex. *Nature Neuroscience*, *22*(8), 1336–1344. https://doi.org/10.1038/s41593-019-0428-x

Rerko, L., Souza, A. S., & Oberauer, K. (2014). Retro-cue benefits in working memory without sustained focal attention. *Memory and Cognition*, *42*(5), 712–728. https://doi.org/10.3758/s13421-013-0392-8

Ricker, T. J., & Cowan, N. (2010). Loss of visual working memory within seconds: The combined use of refreshable and non-refreshable features. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *36*(6), 1355. https://doi.org/10.1037/a0020356

Ricker, T. J., & Vergauwe, E. (2020). Consistent Failure to Produce a Cognitive Load Effect in Visual Working Memory Using a Standard Dual-Task Procedure. *Journal of Cognition*, *3*(1), 15. https://doi.org/10.5334/joc.108

Saito, J. M., Printzlau, F., Yeo, Y., & Fukuda, K. (2024, October 20). Working Memory Prioritization Changes Bidirectional Interactions with Perceptual Inputs. https://doi.org/10.31234/osf.io/2f7mp

Schneider, D., Barth, A., Getzmann, S., & Wascher, E. (2017). On the neural mechanisms underlying the protective function of retroactive cuing against perceptual interference: Evidence by event-related potentials of the EEG. *Biological Psychology*, *124*, 47–56. https://doi.org/10.1016/J.BIOPSYCHO.2017.01.006

Schneider, D., Göddertz, A., Haase, H., Hickey, C., & Wascher, E. (2019). Hemispheric asymmetries in EEG alpha oscillations indicate active inhibition during attentional orienting within working memory. *Behavioural Brain Research*, *359*, 38–46. https://doi.org/10.1016/j.bbr.2018.10.020

Shimi, A., & Scerif, G. (2015). The interplay of spatial attentional biases and mental codes in VSTM: Developmentally informed hypotheses. *Developmental Psychology*, *51*(6), 731. https://doi.org/10.1037/a0039057

Souza, A. S., & Oberauer, K. (2015). Time-based forgetting in visual working memory reflects temporal distinctiveness, not decay. *Psychonomic Bulletin & Review*, *22*(1), 156–162. https://doi.org/10.3758/s13423-014-0652-z

Souza, A. S., & Oberauer, K. (2016). In search of the focus of attention in working memory: 13 years of the retro-cue effect. *Attention, Perception, & Psychophysics*. https://doi.org/10.3758/s13414-016-1108-5

Souza, A. S., Rerko, L., & Oberauer, K. (2016). Getting more from visual working memory: Retro-cues enhance retrieval and protect from visual interference. *Journal of Experimental Psychology: Human Perception and Performance*, *42*(6), 890–910. https://doi.org/10.1037/xhp0000192

Sreenivasan, K. K., & Jha, A. P. (2007). Selective Attention Supports Working Memory Maintenance by Modulating Perceptual Processing of Distractors. *Journal of Cognitive Neuroscience*, *19*(1), 32–41. https://doi.org/10.1162/jocn.2007.19.1.32

Ueno, T., Allen, R. J., Baddeley, A. D., Hitch, G. J., & Saito, S. (2011). Disruption of visual feature binding in working memory. *Memory and Cognition*, *39*(1), 12–23. https://doi.org/10.3758/S13421-010-0013-8/FIGURES/8

Ueno, T., Mate, J., Allen, R. J., Hitch, G. J., & Baddeley, A. D. (2011). What goes through the gate? Exploring interference with visual feature binding. *Neuropsychologia*, *49*, 1597–1604. https://doi.org/10.1016/j.neuropsychologia.2010.11.030

van Moorselaar, D., Gunseli, E., Theeuwes, J., & Olivers, C. N. L. (2015). The time course of protecting a visual memory representation from perceptual interference. *Frontiers in Human Neuroscience*, *8*(JAN), 1–9. https://doi.org/10.3389/fnhum.2014.01053

van Moorselaar, D., & Slagter, H. A. (2019). Learning What Is Irrelevant or Relevant: Expectations Facilitate Distractor Inhibition and Target Facilitation through Distinct Neural Mechanisms. *Journal of Neuroscience*, *39*(35), 6953–6967. https://doi.org/10.1523/JNEUROSCI.0593-19.2019

Vergauwe, E., Hautekiet, C., & Langerock, N. (2025). *Distractor susceptibility in visual working memory: No evidence for particularly vulnerable mnemonic representations in the focus of attention*. https://doi.org/10.31234/osf.io/4yqjt

Vergauwe, E., & Langerock, N. (2017). Attentional refreshing of information in working memory: Increased immediate accessibility of just-refreshed representations. *Journal of Memory and Language*, *96*, 23–35. https://doi.org/10.1016/j.jml.2017.05.001

Wickham, H., Averick, M., Bryan, J., Chang, W., McGowan, L. D., François, R., Grolemund, G., Hayes, A., Henry, L., Hester, J., Kuhn, M., Pedersen, T. L., Miller, E., Bache, S.

M., Müller, K., Ooms, J., Robinson, D., Seidel, D. P., Spinu, V., … Yutani, H. (2019). Welcome to the Tidyverse. *Journal of Open Source Software*, *4*(43), 1686. https://doi.org/10.21105/joss.01686

Willroth, E. C., & Atherton, O. E. (2024). *Best Laid Plans: A Guide to Reporting Preregistration Deviations*. https://doi.org/10.31234/osf.io/dwx69

Xu, Y. (2017). Reevaluating the Sensory Account of Visual Working Memory Storage. *Trends in Cognitive Sciences*, *21*(10), 794–815. https://doi.org/10.1016/j.tics.2017.06.013

Zhang, Z., & Lewis-Peacock, J. A. (2022). Prioritization sharpens working memories but does not protect them from distraction. *Journal of Experimental Psychology: General*, *152*(4), 1158–1174. https://doi.org/10.1037/xge0001309

Zhang, Z., & Lewis-Peacock, J. A. (2023). Bend but don’t break: Prioritization protects working memory from displacement but leaves it vulnerable to distortion from distraction. *Cognition*, *239*, 105574. https://doi.org/10.1016/j.cognition.2023.105574

Zickerick, B., Thönes, S., Kobald, S. O., Wascher, E., Schneider, D., & Küper, K. (2020). Differential Effects of Interruptions and Distractions on Working Memory Processes in an ERP Study. *Frontiers in Human Neuroscience*, *14*. https://doi.org/10.3389/fnhum.2020.00084

Zimmer, H. D., & Speiser, H. R. (2002). The irrelevant picture effect in visuo-spatial working memory: Fact or fiction? *Psychologische Beiträge*, *44*(2), 223.