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The consequences of preparing for informative or distracting stimuli

Roy Shoval[1,2]✉ & Tal Makovski[1]

How do individuals prepare for impending distractors? It has been recently suggested that not only observers do not inhibit distractors before their appearance, but they are rather more alert at those moments. Interestingly, a similar effect emerged when observers prepared for task-relevant, informative stimuli, supporting a mandatory "attend-all" mechanism. However, the preparation effect was only demonstrated in speeded dot-probe tasks, and it is yet to be determined whether preparing for distractors merely facilitates motor preparation or extends to other outcomes, such as modifying early visual processes. In two experiments, we replaced the dot-probe task with a four-letter memory encoding task. Participants performed a change detection task that included Informative-display, Distractors-display, and No-display blocks. These displays appeared during the retention interval of the change-detection task. To probe attention, in 25% of the trials, four letters were displayed at the exact moment in which the Informative/Distractors display was expected, and participants were required to remember as many letters as possible. As expected, the performance in the change-detection task was best at the Informative- and worst at the Distractors-display condition. Importantly, participants recalled more letters when they appeared during the anticipation for both informative and distracting stimuli, and no meaningful difference was observed between these conditions. These findings suggest that the preparation effect extends beyond motor preparation, influencing visual processes at an early stage. They also support the notion that the preparation effect is not very flexible, yet further research is required to confirm this conclusion.

Keywords Preparation effect, Selective attention, Alertness, Distractors

When trying to maintain focus on a given task, individuals often encounter a continuous influx of irrelevant information that can potentially disrupt their performance. Thus, the ability to overcome distractors represents a fundamental function of our cognitive system, and as such, it has been the focus of attention research since its beginning[1–3].

However, much of the research on selective attention has focused on tasks in which both relevant and distracting stimuli appear simultaneously[4–12]. Consequently, distractors in these studies are often task-relevant, as they carry some information regarding the relevant targets[11]. Moreover, these studies primarily assess individuals' performance only after the appearance of distracting stimuli. Consequently, limited insight is available into the allocation of attention preceding the presentation of distractors as the cognitive processes occurring before distractors are presented may significantly differ from those arising after their appearance.

One might reasonably expect that when individuals know in advance that a distracting stimulus will appear, they would be capable of suppressing it before its occurrence. Indeed, there is some evidence that proactive suppression is possible under some conditions[4,6–11], yet this issue is still debated[13–17].

Other research suggests that instead of preemptively inhibiting anticipated interfering information, individuals may allocate more attention to the expected distractor[18–21]. This phenomenon is known as the "attentional white-bear effect" – just as individuals think of white bears when instructed not to[22], they are more inclined to attend to a stimulus's location or feature even when they are aware of its distracting nature. This phenomenon implies that the visual system prefers to first attend to an irrelevant stimulus and only then reject it ("search and destroy"[21]) rather than preemptively ignoring it. Importantly, attentional white-bear studies have employed selective attention tasks such as the Flanker task[2], where participants ignore distractors while simultaneously attending to targets. Consequently, these studies offer limited insights into how individuals prepare for the appearance of only distracting stimuli before they appear.

Recently, a novel paradigm has been developed specifically to investigate how the cognitive system prepares for the appearance of expected distractors[23]. In this paradigm, a Change-detection task was employed, and

[1]Department of Education and Psychology, The Open University of Israel, University Rd. 1, 4353701 Ra'anana, Israel. [2]Department of Psychology, Tel-Hai Academic College, Upper Galilee, Kiryat Shemona, Israel. ✉email: rshoval@gmail.com

participants' primary task was to remember a set of colors and to indicate whether a test probe was old (i.e., appeared in the memory display) or new (i.e., did not appear in the memory display). Critically, in one block of trials, no distractors appeared during the retention interval, while in another block, a set of distracting colors appeared at a fixed moment during the retention interval. Participants in this latter condition were forewarned that the distracting display would appear and that it might confuse them, and they were advised to ignore it. The pre-allocation of attention was evaluated using a Dot-probe task that occurred in 25% of trials precisely when the distracting display appeared in the Distractors condition. Upon the detection of the dot, the participant's task was to press the space bar as quickly as possible. The rationale of this paradigm is straightforward. If participants inhibit distractors before their manifestation, their response times to the dot probe should be slower in the Distractors condition compared to the No-distractors condition. In contrast, if participants allocate more attention to the impending distractors, their responses to the dot probe should be faster in the Distractors condition compared to the No-distractors condition.

The results of this study revealed faster detection of the dots in the Distractors condition compared to the No-distractors condition[23]. Consequently, it appears that participants allocated more attentional resources before the appearance of the distracting display, despite the detrimental impact of this display on their performance in the primary memory task. Furthermore, given that the effect was not spatially specific, it was suggested that the preparation effect reflects increased phasic alertness (a temporary, non-specific increase in alertness[24]) in the face of upcoming distractors.

The abovementioned study[23] tested an additional condition in which a task-relevant, informative display appeared during the retention interval instead of a distracting display. This informative display replicated the memory display, thereby offering participants the opportunity to refresh their memory. Thus, in this condition, it is beneficial for the participants to actively allocate their attention to the relevant, informative, display. Intuitively, it might be expected that participants would allocate more attentional resources to this informative display, given its memory-enhancing attributes, compared to the distracting display, which is confusing and performance-lowering. Surprisingly, however, the magnitude of the preparation effect (i.e., participants' performance in the Dot-probe task) did not differ between the Informative condition and the Distractors condition, suggesting that participants allocated attention to both informative and distractive information in a similar manner.

In another study that tested this preparation effect, a similar procedure was employed, but the distracting display featured natural or emotional images (threatening, joyful, or disgusting)[25]. The goal was to determine whether participants prepared for different distractors in different ways. Replicating Makovski's[23] findings, a preparation effect was observed in this study, with participants' response latencies in the Dot-probe task being faster in the Distractors condition compared to the No-distractors condition. Importantly, the preparation effect was comparable across the various distracting stimuli.

These results collectively suggest that the preparation effect is a general and hard-wired process that remains unaffected by the task relevance of the expected stimuli (whether distracting or informative) and their emotional valence. Indeed, a recent study provided further evidence of the generality of this effect, as it was shown that the magnitude of the effect was unrelated to relevant individual differences[26]. Specifically, it was reported that individual differences in memory capacity and the ability to suppress distractors were not correlated with the magnitude of the preparation effect.

This general and hard-wired preparation effect has so far only been demonstrated in studies employing speeded dot-probe tasks. Thus, the main objective of the present study was to ascertain whether preparing for distractors merely facilitates motor preparation or whether it has other outcomes. In the alertness literature, warning cues, which have been the typical manipulation for inducing phasic alertness, were initially associated with faster responses and response selection processes[27,28]. Later, however, it was found that phasic alertness has a wider impact. It affects both detection and discrimination tasks[29], and improves perceptual latency[30], temporal precision[31], and even executive functioning[32]. In this study, we aimed to investigate whether the preparation effect produces consequences beyond motor responses, specifically whether it influences early visual processes such as memory encoding.

A second goal of this study was to address the question of whether preparing for distractors is the same as preparing for informative stimuli. Indeed, in the speeded dot-probe task, no difference was found between preparing for distracting and informative displays. However, it is currently unknown whether this lack of difference is simply because the visual system prepares for all stimuli in the same manner or because the system becomes alert both before encountering relevant information and when preparing to avoid confusion from distractors (similar to the idea of "high-beams of attention"[33]). In addition, it is reasonable to assume that an efficient alert system will distinguish between relevant and irrelevant stimuli, particularly when preparing for distractors is costly[34]. Here, to probe attention, we used a memory encoding task that might be more sensitive for differentiating between informative and distracting stimuli than a speeded dot-probe task[35]. This is because improved perceptual processing seems important mainly for task-relevant informative stimuli but not for to-be-rejected, task-irrelevant distractors. Moreover, people may be more alert in the face of any upcoming stimulus, yet the visual system could still prioritize relevant stimuli over irrelevant stimuli[20Exp. 5].

To achieve these goals we modified the original task devised by Makovski[23]. Participants completed a Change-detection task with three conditions varying in the stimuli presented during the retention intervals. In one condition, no stimuli were presented during the retention interval. In the second condition, distracting stimuli that typically impair performance in the main task appeared, and in the third condition, informative stimuli that facilitate performance in the main task were presented. To minimize carry-over effects, in Experiment 1 each participant performed either the distractor-display and the no-display conditions or the informative-display and no-display conditions. Critically, to probe attention we replaced the speeded dot-probe task with a letters memory task, wherein four letters appeared at the exact moment when the distracting or informative stimuli would appear. Participants were instructed to remember as many letters as possible[7]. Note that according to experiments that compared different attentional probes[36], similar results are expected with these two measures.

Experiment 1
Method
Participants
Across both experiments, participants were between 18 and 40 years old, with normal or corrected-to-normal vision, normal color perception, and no reported attentional, psychiatric, or neurological disorders. Each participant completed only one experiment. The studies were approved by the Ethics Committee of the Open University of Israel (approval # 3308), and the experiments were conducted in accordance with the approved guidelines. Informed consent was obtained from all participants across both studies.

Seventy-one students (17 males, mean age = 25.31, $SD = 4.5$) from the Open University of Israel participated in Experiment 1 for course credit. The data of one participant was excluded from further analysis as she completed only a small portion of the experiment. Additionally, 5 participants were excluded from the analysis (as described in the results section), resulting in a final sample of 65 participants. After the application of these exclusions, 32 participants completed the distractor-display and no-display conditions, and 33 participants completed the informative-display and no-display conditions. These sample sizes have a statistical power of 0.87–0.89 to detect a medium-sized two-tailed effect ($d = 0.5$) in the dependent t-tests conducted within each of the within-subject conditions. They also have a power of 0.91 to detect a large-sized effect of 0.4 or higher in a mixed-design ANOVA.

Apparatus and stimuli
Participants were individually tested while seated approximately 58 cm from a 23.5-inch LCD screen (resolution 1,920 × 1,080). The experiment was programmed with MATLAB R2018a (www.mathworks.com) and PsychToolbox Version 3.0.14[37].

The memory display consisted of four colored circles (diameter 2.47˚(, randomly drawn without replacement from nine different colors (Red [255 0 0]; Green [0 255 0]; Blue [0 0 255]; Yellow [255 255 0]; Purple [127 0 127]; Orange [255 140 0]; Brown [115 58 0]; Azure [0 255 255]; White [255 255 255]). These circles were arranged on an imaginary circle located 6.51˚ from the center of the screen. In the informative-display, the previous memory display reappeared, allowing participants to utilize it as a reference to “refresh” their memory (Fig. 1b). In the distractor-display, the same circles appeared at the same locations as in the memory display, but their colors were shuffled (Fig. 1c).

Procedure
Change-detection task. Each trial began with the appearance of a white fixation cross (0.08˚ × 0.08˚) at the center of the screen (800 ms), followed by the memory display (250 ms) and a second fixation cross (700 ms; Fig. 1). At this point, different displays were presented, pending on the experimental block.

In the no-display block, a blank screen, devoid of a fixation cross, was presented for 250 ms (Fig. 1a). In the Informative block, the informative-display appeared for 250 ms (Fig. 1b), while in the Distractors block, the distractor-display appeared (250 ms; Fig. 1c). After these displays, a fixation cross appeared for a randomized interval of 500, 600, 700, or 800 ms, followed by the presentation of a test probe at a randomly selected location, corresponding to the location of one of the circles from the memory display. Randomly, in half of the trials, referred to as Old trials, the color of the test probe matched the color that had originally appeared at the same location during the memory display. In the remaining half of the trials, referred to as New trials, the test probe was a color presented at a different location during the memory display. Participants were required to report as accurately as possible whether the test probe was old (indicated by the "H" key) or new (indicated by the "J" key). Following a correct response, a yellow smiley face was displayed for 250 ms, while an incorrect response prompted the presentation of a yellow sad face for 600 ms. An inter-trial interval of 200 ms followed before the initiation of the subsequent trial. After every set of 20 trials, a short break was incorporated to update participants on their progress in the experiment (e.g., "You have completed X trials out of 320").

Letters task. Participants were informed that, on occasion, four letters would appear during the retention interval. When these letters were detected, participants were required to remember as many of them as possible and to press four keys for the trial to end. Four Hebrew letters, sampled without replacement out of 21 letters, appeared for 90 ms, in the four locations of the circles from the memory display. The letters were followed by a 400 ms visual mask and a 400 ms blank screen (Fig. 1d). The letters appeared 700 ms after the offset of the memory display – a timing that corresponded to the moment at which the distractor-display or the informative-display appeared during the retention interval. These letter trials occurred unexpectedly in 25% of the trials in each block, with the constraints that they could not be in the first trial following a break and that two letter trials could not take place consecutively. Upon pressing four keyboard letters, feedback was given, indicating that “you recognized X out of 4 letters”, and was presented until participants pressed the space bar. At this point, the current trial concluded, and the subsequent trial commenced after an inter-trial interval of 200 ms.

Design
A mixed design was employed, with each participant undertaking two distinct experimental conditions. All participants completed the no-display block, and in addition, they were randomly assigned to either the distractor-display or informative-display block (order counterbalanced). Each experimental block consisted of 160 trials (40 Letters and 120 Change-detection trials).

Practice. To familiarize themselves with the task, before commencing the experiment participants underwent two practice phases. In the first phase, only Letters' trials were presented, amounting to a total of 32 trials. The

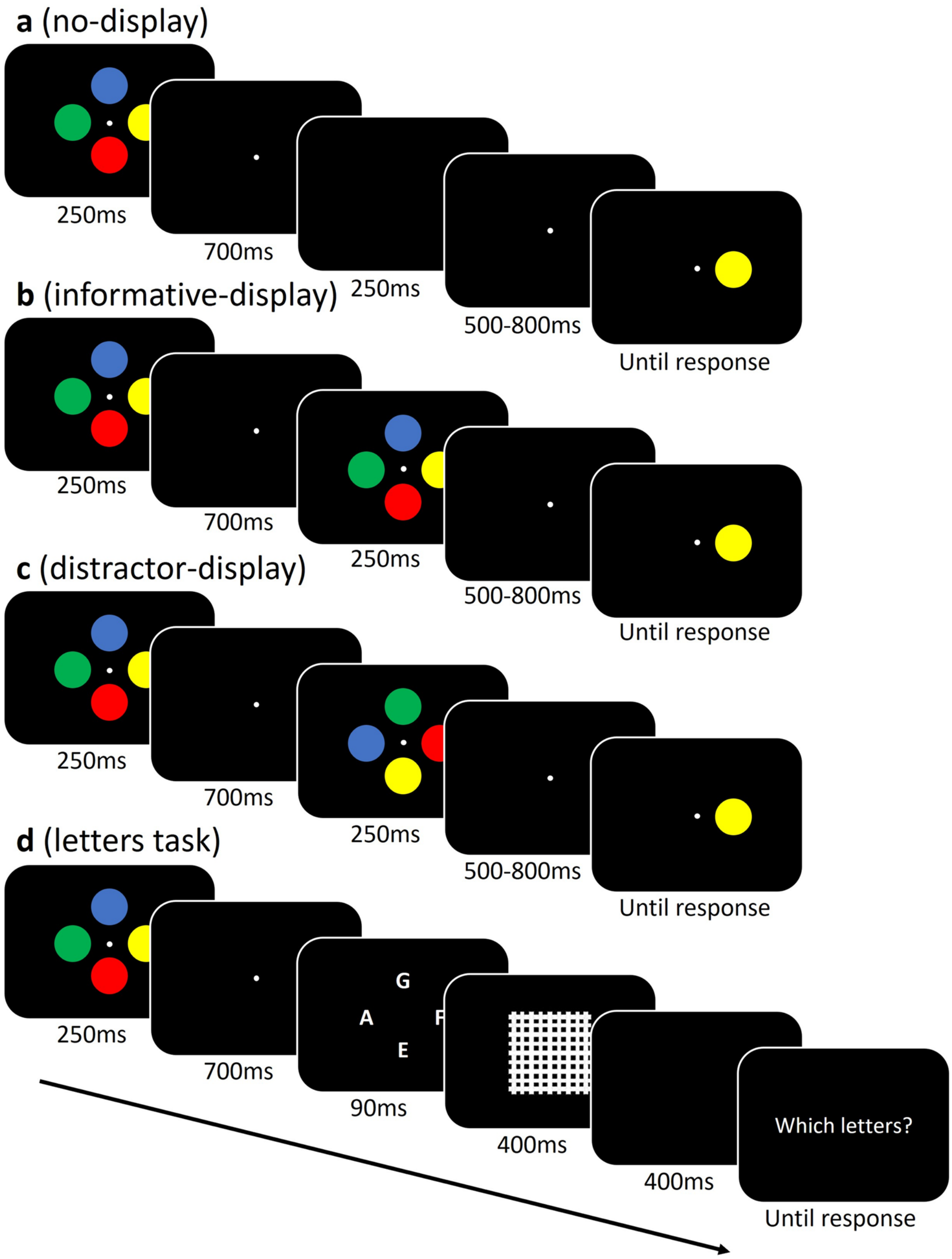

Fig. 1. Experimental schema. Illustration of the four distinct experimental trials – no-display trial (**a**), informative-display trial (**b**), distractor-display trial (**c**), and Letters trial (**d**). The letters in the letters task were in Hebrew in Experiment 1, and in English in Experiment 2.

second practice phase included 16 trials that were divided into two blocks of 8 trials (a no-display block and an informative or a distractor-display block). In each block, as in the actual experiment, 25% Letters trials were intermixed with 75% Change-detection trials.

Results

The data of both experiments are publicly available at https://osf.io/sc23d.

We initially assessed participants' memory task accuracy rates in the no-display block, by employing z tests, with $\alpha = 0.05$, to each participant's performance. Five participants whose performance did not deviate significantly from the chance level (50%) were excluded from further analysis. In addition, one participant who did not complete the entire experiment was excluded from further analysis, resulting in a final sample of 65 participants.

We then conducted two mixed-design analyses of variance (ANOVAs) to examine performance in the Change-Detection task and the Letters task. The between-subjects factor for these analyses was the two blocks participants completed (No-display and Informative-display, or No-display and Distractor-display), and the within-subject factor was the absence or presence of a display, regardless of whether it was an informative or destructive one.

For the Change-Detection task performance, the overall model was significant, $F(66,63) = 8.67$, $p < 0.001$, $\eta_p^2 = 0.9$. There was a significant main effect of the presence of a display, $F(1,63) = 8.53$, $p < 0.005$, $\eta_p^2 = 0.12$, and two pairwise comparisons were conducted to investigate the source of this effect. The first comparison revealed that performance in the Informative-display condition was higher than in the No-display condition, $t(63) = 2.96$, $p < 0.005$, with a medium effect size ($d = 0.52$, based on $n = 33$). The second comparison showed that performance in the No-display condition was higher than in the Distractor-display condition, $t(63) = 7.02$, $p < 0.001$, with a large effect size ($d = 1.24$, based on $n = 32$). The main effect of the between-subjects conditions was significant as well, $F(1,63) = 18.45$, $p < 0.001$, $\eta_p^2 = 0.22$. Pairwise comparisons revealed that performance in the No-display and Informative-display condition was better than in the No-display and Distractor-display condition, both when no display appeared, $t(63) = 2.94$, $p = 0.005$ (medium effect size of $d = 0.36$, based on $n = 65$), and when a display did appear, $t(63) = 7.44$, $p < 0.001$ (large effect size of $d = 0.92$, based on $n = 65$). The interaction between the within- and between-subjects factors was significant as well, $F(1,63) = 50.09$, $p < 0.001$, $\eta_p^2 = 0.44$ and stemmed from the fact that the Informative-display improved memory performance while the Distractor-display impaired it (Fig. 2a). Therefore, our basic manipulation of the Change-Detection task was successful.

For the Letters task performance, the overall model was significant, $F(66,63) = 17.66$, $p < 0.001$, $\eta_p^2 = 0.95$. However, both the main effect of the presence of a display, $F(1,63) = 1.76$, $p = 0.19$, and the main effect of the between-subjects condition, $F(1,63) = 3.18$, $p = 0.08$, were insignificant. The interaction of the ANOVA model was significant, $F(1,63) = 4.37$, $p = 0.04$, $\eta_p^2 = 0.06$, and stemmed from the fact that the informative display somewhat improved letters' memory performance while the Distractor-display slightly impaired it, compared to the no-display condition (Fig. 2b).

Because our primary interest was to find a preparation effect within each group, and the sample sizes were not powerful enough to detect small-to-medium effects in a mixed ANOVA model, two pairwise comparisons were conducted to further evaluate the difference between the No-display condition and the Informative- or Distractor-display conditions. The first comparison revealed that performance in the Informative-display condition was higher than in the No-display condition, $t(63) = 2.44$, $p = 0.02$, with a medium effect size ($d = 0.42$, based on $n = 33$). The second comparison showed no difference between the No-display and the Distractor-display conditions, $t(63) = 0.53$, $p = 0.6$.

It was recently claimed that the preparation effect is stronger for participants who begin the experiment with the No-display condition[38].In the current design, half of the participants started while the other half ended the experiment with the No-display condition. Thus, to test the possibility of an order effect, we conducted an additional mixed ANOVA. In this model, the block number (first vs. second) served as the within subject factor and the display type (Informative/Distractor) as the between-subject factor. This model was significant, $F(66,63) = 20.31$, $p < 0.001$, $\eta_p^2 = 0.96$, as well as the main effect for block number, $F(1,63) = 15.82$, $p < 0.001$, $\eta_p^2 = 0.2$. Additionally, the display type factor was marginal, $F(1,63) = 3.18$, $p = 0.08$ and no interaction between these factors emerged, $F(1,63) = 0.3$, $p = 0.59$. The group means were higher in the second compared to the first block for both display types (Distractor display – block 1: M = 55.1%, SD = 13.5, block 2 M = 58.24, SD = 14.64; Informative display – block 1: M = 61.02, SD = 11.75, block 2: M = 63.41, SD = 11.32). This suggests that a temporal order effect can account for most of Experiment 1's findings although display type might still have an effect.

To further investigate the preparation effect beyond the order effect we examined it separately for participants who completed the No-display block *before* the Distractor- or Informative-display block. Two within-subject t-tests were conducted, one for each of the between-subjects conditions (note that for this relatively small sample size, mixed ANOVA models do not have enough power to produce meaningful results). The first t-test reaffirmed the superior performance in the Informative-display block in comparison to the No-display block,

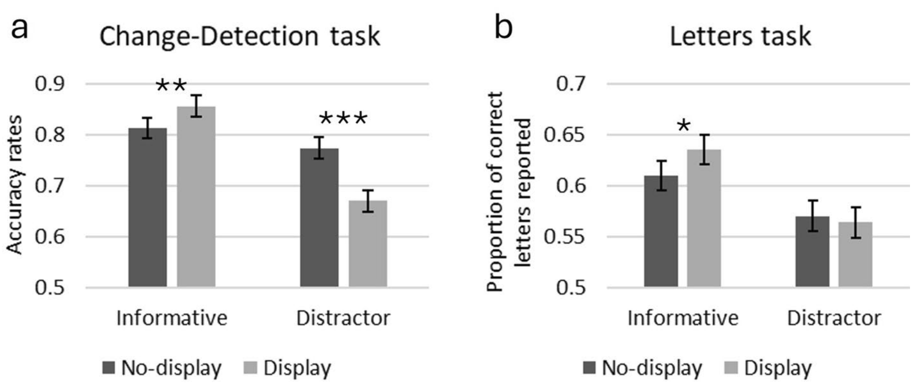

Fig. 2. Mixed-ANOVA results of experiment 1 for the three experimental conditions clustered by the two between-subjects conditions (No-display and Informative-display; No-display and Distractor-display). Change-Detection task performance (**a**) and Letters task performance (**b**) for the entire sample of participants. Error bars represent the 95% CI around the means of the pairwise comparisons, while * represents p < 0.05, ** represents p < 0.01, and *** represents p < 0.001.

$t(16) = 4.71$, $p < 0.001$, $d = 1.14$ (Fig. 3a). Additionally, performance was better in the Distractor-display block in comparison to the No-display block, $t(15) = 2.14$, $p = 0.049$, $d = 0.53$ (Fig. 3b). For completeness, a similar analysis was conducted for participants who completed the No-display block *after* the Distractor- or Informative-display block. This analysis revealed no difference between the Informative-display to the No-display block, t(15) = 0.12, p = 0.91 (Fig. 3c). Surprisingly, performance was somewhat better in the No-display in comparison to the Distractor-display block, t(15) = 2.15, p = 0.049, d = 0.54 (Fig. 3d).

To directly compare the preparation effect for distracting and informative stimuli, we calculated the differences between the informative- and distractor-display conditions and the no-display condition in percentages. Specifically, we used the formulas

$$\frac{InformativeDisplay - NoDisplay}{NoDisplay} \times 100 \text{ and } \frac{DistractorDisplay - NoDisplay}{NoDisplay} \times 100$$

Participants' performance in the letters task was higher by 4.78% in the informative- compared to the no-display condition, and lower by 0.67% in the distractor- compared to the no-display condition, $t(63) = 2.06$, $p = 0.04$, $d = 0.51$. When analyzing the data of the Letters task solely for participants who completed the no-display block before the distractor- or informative-display block, no significant difference was observed, $t(31) = 1.39$, $p = 0.17$, $BF_{01} = 1.44$ (performance was higher in 8.81% in the informative- compared to the no-display condition, and higher in 4.61% in the distractor- compared to the no-display condition).

Discussion

Our basic manipulation was proven successful as memory performance was the highest in the informative-display condition and the lowest in the distractor-display condition. Regarding the preparation effect, it was notably pronounced in the informative-display condition, where participants exhibited enhanced performance in the Letters task compared to the no-display condition. This result suggests that the preparation effect, at least for informative stimuli, is not restricted to motor responses, and preparing for task-relevant information can enhance early processes such as memory encoding.

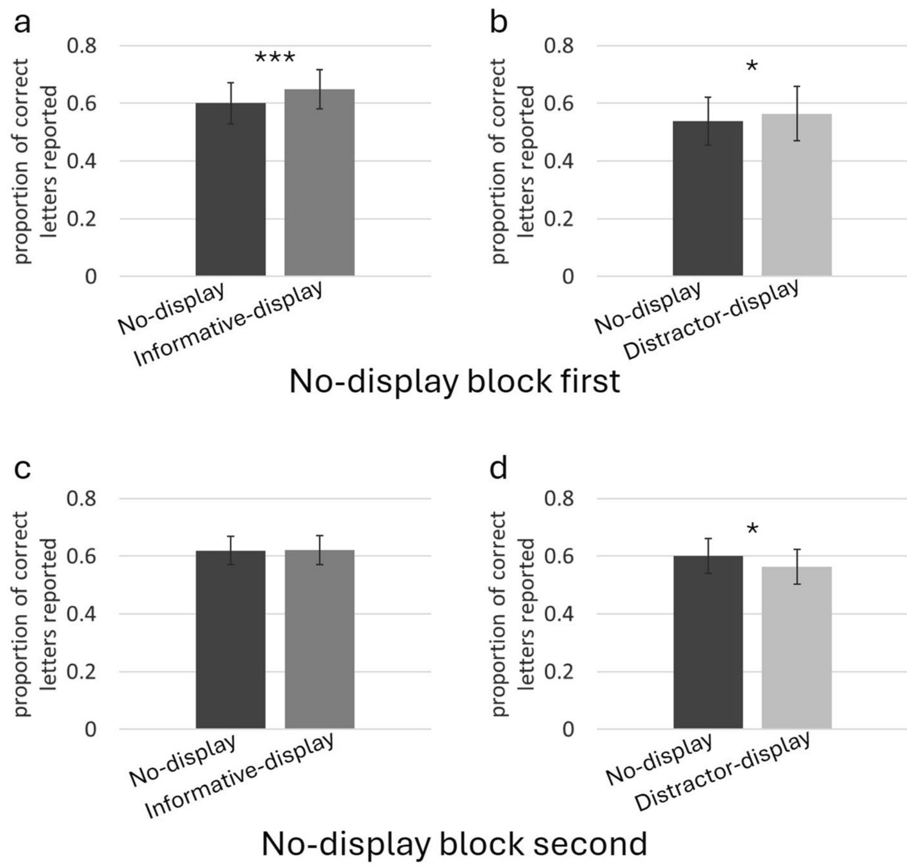

Fig. 3. Within-subject t-tests results pending on the order of the experimental blocks. A comparison between the No-display and the Informative-display blocks (**a**) and between the No-display and Distractor-display blocks (**b**) when the No-display block appeared first, and the same comparisons (**c** & **d**) when the No-display block appeared second. Error bars represent the 95% CI around the means, while * represents p < 0.05 and *** represents p < 0.001.

In contrast, in the distractor-display condition, the preparation effect appeared less consistent, with the presence of an order effect. Participants' performance in the Letters task was superior in the distractor-display condition than the no-display condition, but only when the distractor-display block was performed after the no-display block. Chen et al.[38], reported a similar pattern with a speeded dot-probe task and claimed it was the result of an adaption of an attention control strategy, which suggests, in turn, that the preparation effect is somewhat under attention control. Yet, it could also be the case that the preparation is smaller for participants who begin the experiment with the distractors condition because of a carry-over effect (i.e., they kept expecting distractors at a particular moment in time even in the no-display condition). Be that as it may, the next experiment aimed to investigate the preparation effect without the possible interference of an order effect.

Experiment 2

The goal of the second experiment was to re-test the preparation effect without the influence of an order effect. Thus, we used a large sample of participants and a between-subject design in which each participant completed only one out of the three experimental conditions.

Method

Participants

A total of 306 individuals (188 males, one individual preferred not to indicate their gender; mean age = 28.15, *SD* = 5.6, the age of 2 individuals is unknown) were recruited online through Prolific (www.prolific.co) and completed the experiment on their desktop computers for a payment of 2.55–3.45 pounds. 103 of these participants completed the no-display condition, 100 completed the informative-display condition, and 103 completed the distractor-display condition. This sample size provided a power of 0.98 to detect a between-subject effect (η_p^2) with a size of 0.25 or larger in a one-way analysis of variance (ANOVA).

Apparatus and stimuli

The experiment was programmed using Psychopy[39] and executed on the Pavlovia (www.pavlovia.org) server. Overall, this experiment resembled Experiment 1, but with the following changes. As in Experiment 1, the memory display consisted of four colored circles, which were randomly selected without replacement from a pool of nine different colors. However, the colors utilized in this experiment differed from those in Experiment 1. Specifically, to address the possibility that the colors used in experiment 1 are not sufficiently distinct and might cause some confusion, particularly in an online experiment that has no control over the lighting conditions, the color palette for the current experiment was selected using https://mokole.com/palette.html, an algorithm that identifies the most distinguishable color scheme for a given set size.

The final selection comprised nine distinct colors: dark slate gray [47 79 79], green [0 128 0], red [255 0 0], yellow [255 255 0], blue [0 0 255], deep pink [255 20 147], aqua [0 255 255], dodger blue [30 155 255] and Navajo white [255 222 173]. The informative-display and the distractor-display were consistent with those in Experiment 1 but featured the colors specified here. An additional change was that participants used different keyboard keys to indicate if a test probe was old or new (specifically, the "S" key indicated an old color while the "D" key indicated a new one). Finally, differing from Experiment 1, the letters in the Letters task were English letters ("A", "B", "C", "E", "G", "H", "J", "K", "L", "M", "N", "P", "R", "S", "T", "X", "Y", "Z").

Procedure and design

The main difference between Experiment 2 and Experiment 1 was in their design. In the current experiment, a between-subject design was used, and each participant completed only one of the three experimental conditions.

Additionally, the practice phase that preceded the experiment was different from that of Experiment 1. In the initial practice phase, participants completed 20 Letters trials. The second practice phase consisted of 20 trials, comprising 15 Change-detection trials and 5 Letters trials. To proceed to the actual experiment, participants were required to achieve a performance level of 60% or higher in the Change-detection task. If a participant did not meet this 60% threshold, they were instructed to repeat the second practice phase. All participants were able to meet the 60% performance threshold during their first or second attempt in the second practice phase.

Results

In the previous experiment, participants were excluded from the analysis based on their performance in the no-display block. However, in the current experiment, this procedure was not applicable due to the different design. Consequently, no filters were applied to the data.

As in Experiment 1, we initially assessed participants' performance in the Change-detection task to ensure the effectiveness of our basic manipulation. A one-way ANOVA revealed a significant main effect for the display condition, $F(2,303) = 78.77$, $p < 0.001$, $\eta_p^2 = 0.34$. As illustrated in Fig. 4a, two independent t-tests indicated that performance in the informative-display condition ($M = 85\%$, $SD = 8.32$) was significantly higher compared to the no-display condition ($M = 79.17\%$, $SD = 11.93$; $t = 4.03$, $p < 0.001$, $d = 0.57$), which, in turn, was higher compared to the distractor-display condition ($M = 66.45\%$, $SD = 11.68$; $t = 7.74$, $p < 0.001$, $d = 1.08$).

Next, we focused on participants' performance in the Letters task, and again, a one-way ANOVA revealed a significant main effect for the display condition, $F(2,303) = 6.45$, $p = 0.002$, $\eta_p^2 = 0.041$. Two independent t-tests were conducted, revealing that performance was higher in the informative-display condition ($M = 64.24\%$, $SD = 12.34$; $t = 3.48$, $p < 0.001$, $d = 0.49$) and in the distractor-display condition ($M = 61.68\%$, $SD = 12.65$; $t = 2.13$, $p = 0.03$, $d = 0.3$) in comparison to the no-display condition ($M = 57.62\%$, $SD = 14.64$; Fig. 4b). No significant difference was observed between the informative-display and distractor-display conditions, $t(201) = 1.46$ $p = 0.15$, $BF_{01} = 2.43$.

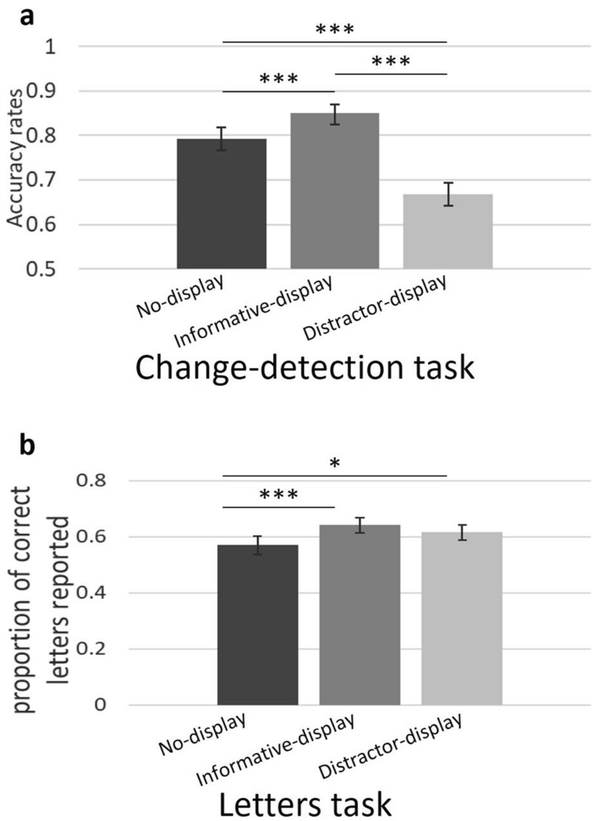

Fig. 4. Experiment 2's results. Change-detection (**a**) and Letters task (**b**) performance for the three between-subject experimental conditions. Error bars represent the 95% CI around the means, while * represents $p < 0.05$ and *** represents $p < 0.001$.

Discussion

Similar to Experiment 1, the basic manipulation in this experiment was successful – Change-detection performance exhibited its highest levels in the informative-display condition and its lowest levels in the distractor-display condition. More importantly, the preparation effect was evident in both the informative-display and distractor-display conditions. Participants displayed enhanced performance in the Letters task in both conditions in comparison to the no-display condition, while there was no significant difference in the magnitude of the effect. These findings were found even though we used a between-subject design, a noisier online experiment[40], and most importantly, a non-speeded probe task. Thus, the preparation effect seems general and robust, and its implications go beyond the facilitation of motor responses.

General Discussion

Overcoming distraction is an endless task for our cognitive system that has vast implications for numerous aspects of our daily lives. Extensive experimental efforts have been devoted to studying selective attention mechanisms and how they are affected by top-down knowledge. In contrast to most of the past research, the preparation effect focuses on the way attention is allocated before the distractors are presented and demonstrates that observers allocate more attentional resources when expecting distracting stimuli to appear. Studies revealed that people are more alert and faster to detect probes when distractors are expected to appear[23,25,38]. Here, we showed that the preparation effect is not limited to speeded motor responses and can affect early visual processes as well. Specifically, encoding letters to memory was enhanced when those appeared when observers expected either informative or distracting stimuli.

Whether preparing for distractors involves a unique mechanism or does the mechanism underlying the preparation effect applies to all stimuli, is an important, unresolved question. Using a speeded dot-probe task, Makovski[23] found that the effect of preparing for informative and distracting information was similar. We speculated that a non-speeded probe task might be more sensitive to detect differences between the stimulus types. Yet, we observed no significant difference in the preparation for task-relevant and task-irrelevant stimuli in our memory encoding probe task. This is consistent with the finding that the preparation effect is not modulated by the valence of the upcoming stimuli[25] nor by individual differences in working memory capacity and the ability to filter our distractors (Lindzen et al., 2024). Taken together, these findings provide strong evidence in support of a mandatory 'process-all' mechanism[20] according to which distractors are not unique and the visual system prepares for all expected stimuli in the same manner.

Chen et al[38] recently suggested that the preparation effect might be under attentional control, as they found it to be larger when the main task required remembering only a single color in memory and for participants who started with the no-display condition. It is important to note, however, that a process-all mechanism does not necessarily contrast with the notion that some control over the effect is possible and that under some conditions, observers can allocate more rather than less attention to the distractors. That is, to undermine the idea that the visual system prepares for all upcoming stimuli, one needs to show conditions under which the effect is eliminated, and participants do not allocate attention to upcoming distractors. Furthermore, the finding that the preparation effect is reduced when working memory load is high seems to suggest that the current paradigms that measure the preparation effect underestimate the magnitude of the effect as they all involve some working memory load.

The lack of difference between the distracting and informative conditions seems to suggest that the preparation effect is rigid and does not readily differentiate between the relevance of the upcoming stimuli. This conclusion, however, should be taken with caution as in both experiments there was at least a numerical trend for the preparation effect to be somewhat larger in the informative condition than in the distracting condition. Thus, it is still possible that more sensitive measurements would be able to detect subtle differences between preparing for informative stimuli and distracting stimuli. Accordingly, we have tried testing several other probe tasks that we had reason to believe could detect perceptual effects due to increased alertness when observers were expecting distractors and examined whether these tasks revealed differences between preparing for informative and distracting stimuli. Specifically, we tried several versions of an orientation judgment task of briefly presented Gabors and a same-different task of two Gabors. Unfortunately, however, those attempts were unsuccessful because there was no difference in performance between the No-display and the Informative-display conditions. That is, even though there was a large benefit in the Change-detection performance for the Informative task compared to the No-display task, indicating that observers were efficiently utilizing this relevant information, the probe tasks that were used to detect an increase in alertness failed to do so. We also tested another experiment that employed the Letters task to probe attention but used only 3 colored circles in the Change-detection task. This attempt was also unsuccessful because participants' Change-detection performance was unaffected by our basic manipulation. That is, their change-detection performance did not differ between the No-display and the Informative-display conditions.

In addition, we used a temporal order judgment as the probe task. In this task, two dots appeared one after the other at the same time in which the informative/distractor stimuli should appear, and the participant's task was to determine which dot appeared first[31]. However, when this task was used a preparation effect was detected only in the distractor condition, but not in the informative condition. That is, when an informative-display was expected, there was no difference in participants' performance in the temporal order task. Yet, a preparation effect was found in the distractor-display condition as participants' performance in the temporal order task was better when the distractor-display was expected in comparison to when no display was expected.

Taken together, these attempts suggest first that the perceptual outcomes of the preparation effect found in this study are limited and subtle, unlike the robust facilitation of motor responses that were observed in previous studies[23,25]. Second, although no strong difference was found between preparing for informative and distracting information, it is still difficult to determine whether there is a qualitative difference between preparing for these types of information and further research is needed to resolve this issue.

Finally, an alternative explanation for the results should be considered. One could argue, for instance, that given the differences between conditions in the change-detection task, it is possible that working memory was in different states across the experimental conditions at the critical moment when the attentional probe was expected. Specifically, participants in the Informative-display condition might have experienced a lower working memory load at this critical moment. However, we find it unlikely that merely expecting to see the colors again in the informative block altered the state of working memory to the extent that it affected working memory capacity for encoding new letters. To our knowledge, there is no evidence suggesting that working memory can be controlled in a way that allows observers to "free up" resources for future encoding or refreshing of information. Furthermore, once the letters appeared, participants knew they no longer needed to retain the colors for the color memory task. If working memory was indeed that flexible, they could potentially have "reset" their memory across all blocks to a similar degree. Finally, even if this unlikely possibility was true, it cannot account for the higher performance in the Distractors-display condition compared to the No-display condition, nor for the absence of significant differences between the Informative- and Distractors-display conditions.

To conclude, while considering the above caveats, this research provides evidence that the preparation effect is not limited to speeded motor responses, and it also affects early visual processes such as memory encoding. In addition, the present data seem to suggest that the visual system prepares for all expected stimuli (informative and destructive) in a similar manner – evidence that supports a mandatory 'process-all' mechanism[20] of the visual system.

Data availability

The data of both experiments are publicly available at https://osf.io/sc23d.

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Author contributions
Both authors developed the study concept and contributed to the study design. RS programmed Experiment 1, analyzed both experiments results, and drafted the manuscript, while TM provided critical revisions and suggested critical improvements for this draft. The authors then exchanged several versions of the manuscript until

its final version was approved by both.

Declarations

Competing interests
The authors declare no competing interests.

Additional information
Correspondence and requests for materials should be addressed to R.S.

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