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BRIEF REPORT

Concurrent target detection is associated with better memory for object exemplars

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Abstract

Under continuous dual-task conditions, participants show better memory for background information appearing at the same time as a response target in a concurrent task than for information appearing with a nontarget (the attentional boost effect, or ABE). While this effect has been demonstrated across a wide range of stimuli, few studies have examined the perceptual specificity of the memory difference. Here, we explored whether the ABE affects general category memory or perceptually specific exemplar memory. In an encoding phase, participants memorized images of objects presented in a continuous stream. At the same time, they pressed the space bar when a square appearing in the center of each image appeared in a target color, ignoring distractor-colored squares. The following four-alternative forced-choice memory test included the previously seen image, a perceptually distinct exemplar from the same category as the previously seen image, and two images from a new category. Regardless of whether images appeared during encoding three times (Experiment 1) or once (Experiment 2), participants recognized the correct exemplar more often during testing for images that had appeared with a target in encoding than for images that had appeared with a distractor. The difference in exemplar memory was not associated with a difference in false memories for within-category foils. This suggests that the ABE reflects modulation of perceptually detailed exemplar memory, which may be related to facilitation of pattern separation by detection-induced changes in cortical-hippocampal connectivity.

Keywords Attentional boost effect · Dual-task processing · Exemplar and category memory · Memory pattern separation

The visual world is complex, and only a subset of visible stimuli can be attended at once. Attention affects both which of these stimuli people perceive and which aspects of the environment they are likely to explicitly remember. When multiple stimuli or tasks occur concurrently, increasing attention in one task typically depletes resources available for processing of concurrent stimuli (Kinchla, 1992). Previous studies have shown that target detection exhausts attentional resources to a greater degree than rejection of a nontarget (Duncan, 1980; Raymond et al., 1992). More recent research has shown, however, that memory encoding of background information is paradoxically better at the attentionally demanding moment of target detection in a concurrent task than at the moment of distractor rejection.

In Swallow and Jiang (2010), participants memorized scenes presented in a continuous stream while monitoring squares appearing in the center, pressing the space bar for white target squares while ignoring black distractor squares. In a later memory test, participants better remembered scenes that had previously appeared at the same time as the target square. When baseline, image-only trials with no square are randomly intermixed with trials with target and distractor squares, the attentional boost effect (ABE) manifests primarily as a memory enhancement for target-paired images, rather than an impairment for distractor-paired images, relative to the baseline (Bechi Gabrielli et al., 2018; Rossi-Arnaud et al., 2018; Swallow & Jiang, 2014). This ABE has been observed across a wide range of background stimuli (scenes, words, faces), modalities (visual and auditory), and outcome measures (short-term memory, long-term memory, priming, subjective preference; Mulligan et al., 2014; Spataro et al., 2013; Spataro et al., 2020; Swallow & Atir, 2018; Swallow & Jiang, 2010, 2013). But does the ABE affect memory for perceptually specific exemplars, or does it influence abstract processing of the categories of target-concurrent stimuli?

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Researchers hypothesize that the ABE partly reflects a transient increase in the pool of attentional resources in response to target detection or action, potentially driven by a release of norepinephrine (Kinder & Buss, 2020; Swallow et al., 2019; Yebra et al., 2019). The norepinephrine response may influence functional network connectivity, as target detection not only increases frontoparietal activation (Swallow et al., 2012) but also strengthens the functional connectivity between the hippocampus and other brain regions (Moyal et al., 2020; Yebra et al., 2019). Similarly, conflict in a Stroop task both improves memory for background information and increases functional coupling of prefrontal and parietal regions with medial-temporal lobe regions (Krebs et al., 2015; Rosner et al., 2015). The increased connectivity provides an account for why target detection affects memory for concurrent background information. However, it does not provide a direct prediction regarding whether the ABE influences category memory or perceptually specific exemplar memory.

On the one hand, the ABE may primarily affect category memory, with little modulation of memory for perceptual details that distinguish different exemplars within a category. This hypothesis is consistent with prior studies showing a lack of a memory benefit for task-irrelevant context features that coincided with a detection target. For example, Mulligan et al. (2016) found that detecting a target had no effect on memory for concurrent perceptual details of background words. In their study, participants responded to red circles and ignored green circles while memorizing concurrently presented words. While target-colored circle detection improved memory for concurrently presented words, participants did not show improved memory for contextual properties of the target-paired words, such as their font, color, or sensory modality. In another study that tested memory for words presented either visually or auditorily, Mulligan et al. (2014) found that the ABE was unaffected by a change in sensory modality of the words between encoding and recognition, indicating that the ABE for verbal materials was amodal. That target detection modulates memory for words, regardless of modality, but not perceptual properties of text suggests that the ABE modulates abstract processing of words' meanings, not their perceptual features. Thus, target detection should influence one's ability to correctly identify a visual category that they have previously seen, but not a perceptually specific exemplar within that category.

On the other hand, several findings suggest a more perceptual basis underlying the ABE. Despite an ABE not occurring for task-irrelevant perceptual features like text color or modality, target detection does affect memory for task-irrelevant relational information. Turker and Swallow et al. (2019) asked participants to memorize scenes while pressing the space bar when a centrally presented shape appeared in one target color. Although only the *color* of the centrally presented stimulus was relevant to the detection task, participants showed better memory for which *shape* had appeared with which scene for target-concurrent pairings. Mulligan et al. (2021) extended these results to the verbal domain. Thus, target detection modulated the strength of some task-irrelevant perceptual memories. However, these perceptual details belonged to the detection stimulus, rather than the background images. When detailed memory for background scenes was tested, target detection did not consistently facilitate scene orientation memory (Swallow & Jiang, 2010).

Studies investigating memory for background images have found evidence for altered perceptual processing. In task-irrelevant perceptual learning, detecting a target in a rapid series enabled participants to acquire perceptual learning of task-irrelevant background motion or Gabor orientation (Nishina et al., 2007; Seitz & Watanabe, 2003). In addition, target detection increased the tilt aftereffect (Pascucci & Turatto, 2013). In the verbal domain, Spataro et al. (2017) presented participants with target- and distractor-paired words from the same semantic category. Later, when participants were given the category cue to recall the specific words they saw, memory was better for target-paired words than distractor-paired words. Together with studies that showed enhanced perceptual but not conceptual priming of words from the ABE (Spataro et al., 2013), these findings suggest that the ABE likely affects perceptual memory, over and above its impact on conceptual memory.

In addition to these behavioral findings, neuroscientific findings may also support a prediction of modulated exemplar memory. Target detection is associated with increased functional connectivity between the hippocampus and the visual cortex (Moyal et al., 2020), which may lead to the formation of more specific cortical and hippocampal representations of concurrent perceptual stimuli. Enhanced pattern separation—greater distinctions between neural representations of perceptually distinct stimuli—results in improved ability to distinguish between perceptually distinct exemplars within the same category (Pidgeon & Morcom, 2016). Importantly, pattern separation is associated with an increase in recognition of exemplars *without* an accompanying increase in false memory reports for foils from the same category (Wing et al., 2020). Thus, if target detection increases exemplar memory without increasing within-category errors—false memories for within-category foils—it may suggest target-enhanced pattern separation as a primary mechanism supporting the ABE.

To determine whether the ABE affects perceptual memory for exact exemplars or only more abstract category memory, we conducted a dual-task attentional boost experiment that probed both category and exemplar memory. Participants monitored a stream of squares, pressing the space bar for squares appearing in a target color. At the same time, they memorized the objects appearing behind the colored squares. In the subsequent memory test, participants were asked to select the exact image they had seen in encoding in a four-alternative forced-choice task (4AFC) including the target from encoding, one within-category foil, and two wrong-category foils. This allowed us to assess the extent to which the ABE influenced category and exemplar memory, as well as the extent to which target-concurrent images were more or less distinguishable from within-category foils than distractor-concurrent images.

Experiment 1

Method

Participants

Participants were recruited from Prolific.co, an online crowdsourcing platform designed for behavioral research. Experiment 1 includes data from 32 participants, including 16 females and 16 males, with a mean age of 25.4 years (range: 18–41 years; *SD* = 6.5). All participants who had access to the link to participate on Prolific.co met our inclusion criteria of being 18–45 years old, having normal or corrected-to-normal vision and normal color vision, being fluent in English, and having never participated in any previous iterations of this study before. Each participant was paid $1.34 for approximately 10 minutes of study participation. All study procedures were approved by the University of Minnesota Institutional Review Board.

Sample size determination Sample size was determined using G*Power analysis (Faul et al., 2007) with an effect size of d = 0.74 (Swallow & Jiang, 2010). The analysis suggests that a minimum of 17 participants would be needed to reach a power of .80 with an alpha level of .05 (two-tailed). To account for added noise due to testing participants online rather than in person, we tested to a sample size of 32, which achieves power of .98.

Equipment

Stimuli were presented online via Pavlovia.org, a website designed for conducting psychophysics experiments. Participants completed the experiment on their own devices with the constraint that they must complete the experiment on a laptop or desktop computer. Across both experiments, ten participants completed the experiment on a Mac OS, two on a Linux OS, and 64 on a Windows OS. Stimuli were presented at a frame rate of 60 fps for all participants.

The experiment was coded using PsychoPy (Version 2020.1.2; Peirce et al., 2019) with JavaScript adjustments implemented to make the code compatible with Pavlovia.org. Conditions were generated using MATLAB (www.mathworks.com) and read into PsychoPy.

Materials

A set of 200 images of everyday objects from Tim Brady's stimulus collection were used (Brady et al., 2008). The full set of 200 images was composed of 100 categories (e.g., butterflies, buttons, chess boards) with two perceptually distinct exemplars for each category (e.g., one orange butterfly and one blue butterfly). Of the 100 categories, 24 were randomly selected to appear with target-colored squares in encoding, 24 were randomly selected to appear with distractor-colored squares in encoding, 24 were randomly selected to appear as wrong-category foils in the testing phase on trials involving a target-concurrent image, and 24 were randomly selected to appear as wrong-category foils in the testing phase on trials involving a distractor-concurrent image. For the 48 categories that appeared during encoding, the exemplar selected to appear was counterbalanced between participants, so there was no regularity in the perceptual quality of target images relative to same-category foils during testing that would influence results.

During encoding, images appeared at a size of 256 × 256 pixels, regardless of screen size. During testing, each image appeared at a size of 150 ×150 pixels.

Design and procedure

Each experiment began with a practice phase followed by an encoding phase and a testing phase (see Fig. 1). In the practice phase, participants were assigned a target color, either blue or red, and instructed to respond to squares in that target color by pressing the space bar. They were told to refrain from responding to squares in the other color. The target color was counterbalanced between participants. Squares were presented one at a time for 200 ms each with an 800 ms interval between each square. Any space bar response within the 1,000-ms period between initial square onset and onset of the next square counted toward that trial. This practice lasted for 24 trials, and the order of targets and distractors was randomized with the constraint that the target-colored squares and distractor-colored squares each appeared equally often (12 trials total for each). If participants either correctly responded to the target color or correctly omitted a response to the distractor color, no feedback was presented. If participants either incorrectly omitted a response to the target color or incorrectly responded to a distractor color, a message saying "Wrong! Respond to [target color]" appeared for 1 second following the incorrect response. After this practice phase, a message appeared indicating the percentage of correct responses (both correct hits on targets and correct rejections on distractors) in that practice phase.

The encoding phase was similar in structure to the practice phase, but images of everyday objects were presented behind the small colored squares. Participants viewed a stream of

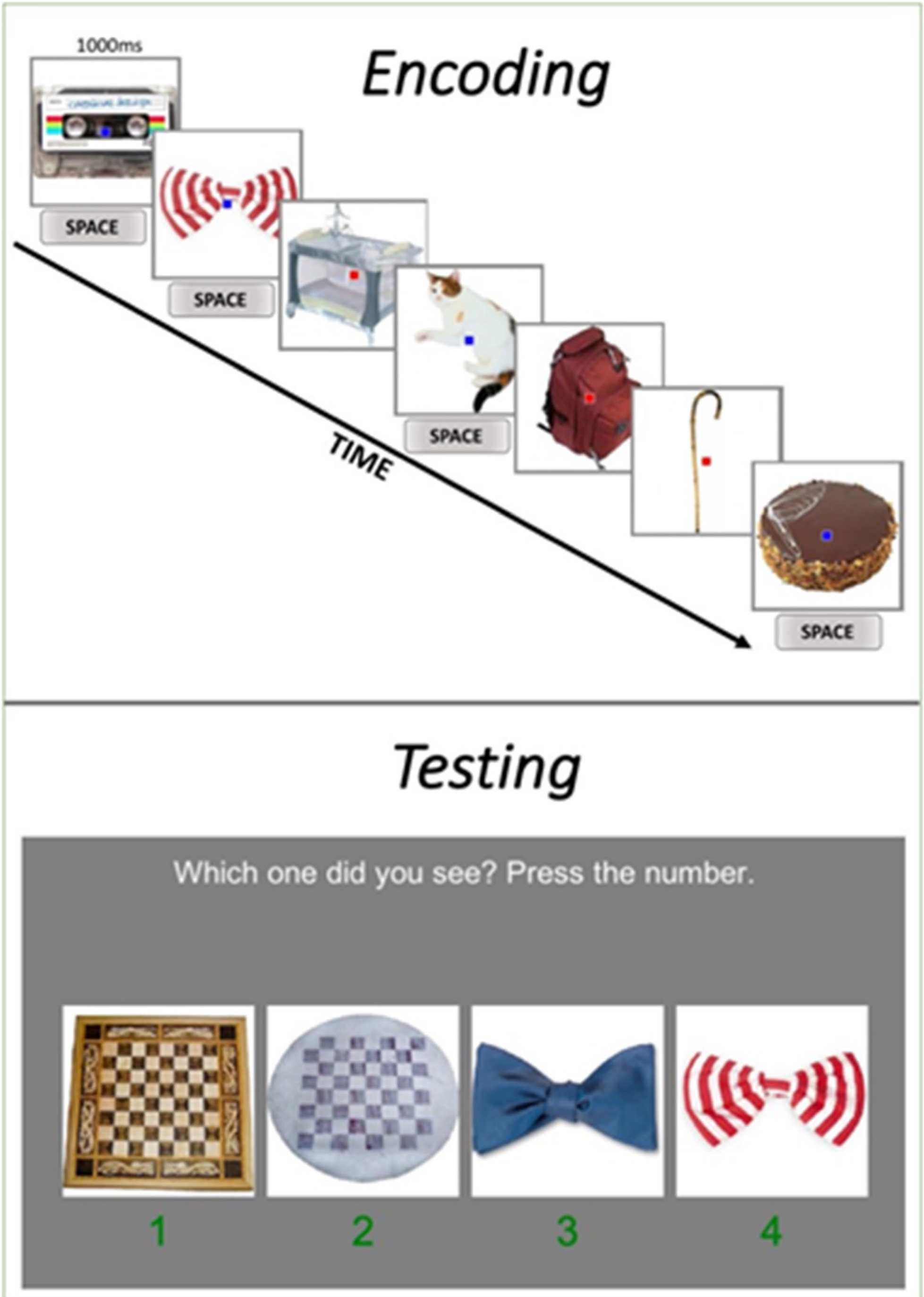

Fig 1 Schematic of the study design for the encoding and testing phases. In encoding, images of objects were presented one at a time in a continuous stream for 500 ms followed by a 500-ms mask. Participants were instructed to memorize the images. There was also a red- or blue-colored square in the center of each image. Participants were assigned a target color, such as blue, and they were to press the space bar whenever a target-colored square appeared and refrain from pressing the space bar for the distractor-colored squares. In the testing phase, participants were shown four images: two from a different category than any of the images presented in encoding, one previously unseen exemplar from the same category as one of the items presented in encoding, and one exemplar that had been shown during encoding. Participants were instructed to choose the exact image they had seen during encoding by pressing the corresponding keyboard key (1, 2, 3, or 4). Feedback was given on each trial. (Color figure online)

everyday objects presented one after another at a pace of 1 second per image. In the second 500 ms of each 1,000-ms trial, the image was replaced by a mask, which was created by scrambling the pixels in the original image.

A small, colored square appeared in the center of each image, with onset at the same time as the background image and offset 200 ms after onset. As in practice, the square could be either blue or red, and each participant was assigned one target color and instructed to press the space bar only when the square appeared in that color. The target color and distractor color appeared equally often. The same target color that participants had been assigned during practice was the target color during encoding. In addition to the space-bar response task from practice, participants were given a concurrent memory task. They were told to memorize all of the images behind the target squares for a later memory test.

Each image in encoding was presented three times. Trials were blocked into three 48-trial blocks with no breaks or any other indication of transitions between blocks for participants. Each image appeared once per block. The order of the images was randomized within each block with the constraint that any image that had appeared with a target-colored square in one block always appeared with a target-colored square in every other block, and those that appeared with a distractor-colored square in one block always appeared with a distractor-colored square. As in practice, participants received feedback at the end of encoding indicating the percent of correct responses in the space bar response task during encoding.

Following encoding, the testing phase consisted of a four-alternative forced-choice task. In the testing phase, participants were presented with four images and were asked to select the image that they had seen before in the encoding phase. A number appeared below each image, running from 1 to 4, from left to right. Participants indicated their choice by pressing the corresponding number on their keyboards. If the participant selected the exact exemplar that had been shown during encoding, they received feedback in the form of the word "correct" appearing briefly for 300 ms, followed by a 300-ms blank interval. If they selected any of the other three items, the word "incorrect" appeared for 300 ms, followed by a 300-ms blank interval. The four images remained visible until a response was made.

In this four-alternative forced-choice task, the four images on each trial consisted of one "target" that had appeared during encoding, one same-category foil that was from the same category as the target, but was a perceptually distinct exemplar, and two wrong-category foils. The wrong-category foils were always from the same category as each other, but neither of them nor any other item within their category had been presented during encoding. The use of two wrong-category foils instead of one prevents participants from strategically choosing only images from categories represented by two exemplars instead of responding based on memory. Presenting the four images at the same time similarly prevented participants from using strategies related to category repetition to guide their responses. The locations of the four images were counterbalanced. Each image from encoding was tested once in the testing phase, resulting in 48 testing trials.

Immediately following the 48 testing trials, participants were redirected to Prolific.co, where they received payment for participation.

Results

Practice phase

Accuracy during practice was high, especially considering the small number of trials, $M = 91.67\%$, $SD = 11.54\%$.

Encoding phase

Accuracy during encoding was also high, $M = 94.94\%$, $SD = 8.76\%$. One participant was excluded for only achieving 50% accuracy (they made no space-bar responses). All other participants were above 85% accuracy. All further analyses therefore include 31 participants.

Testing phase

First, we can consider the percentage of trials in which participants selected the exact exemplar during testing that had previously been shown during encoding. Accuracy was high, $M = 82.33\%$, $SD = 11.71\%$. If online testing still yields an ABE, we would expect a higher percentage of "hits," or remembered exemplars, for images that had coincided with a target-colored square in encoding, compared with images that had coincided with a distractor-colored square. Indeed, participants better remembered exemplars shown in encoding when they had coincided with target-colored squares ($M = 85.48\%$) than when they had coincided with distractor-colored squares ($M = 79.17\%$), $t(30) = 4.16$, $p < .001$, Cohen's $d = 0.76$ (see Fig. 2a–b).

Improved category memory could create this effect—when participants remember the target-concurrent category, their selection is narrowed from four to two objects, thus improving the odds of selecting the correct exemplar even if only category memory is improved. To control for this, we ran a second analysis, which only considered trials in which the correct category was chosen [i.e., P(correct exemplar | correct category)]. To correct for multiple comparisons, we used the Bonferroni-corrected $p < .025$ as the critical alpha level for statistical inference. Participants still showed a higher proportion of correct exemplar selections for target-concurrent objects ($M = 90.22\%$), compared with distractor-concurrent objects ($M = 86.71\%$), $t(30) = 2.88$, $p = .008$, Cohen's $d = 0.51$. This finding demonstrates that the ABE indeed enhanced exemplar memory over and above its influence on category memory.

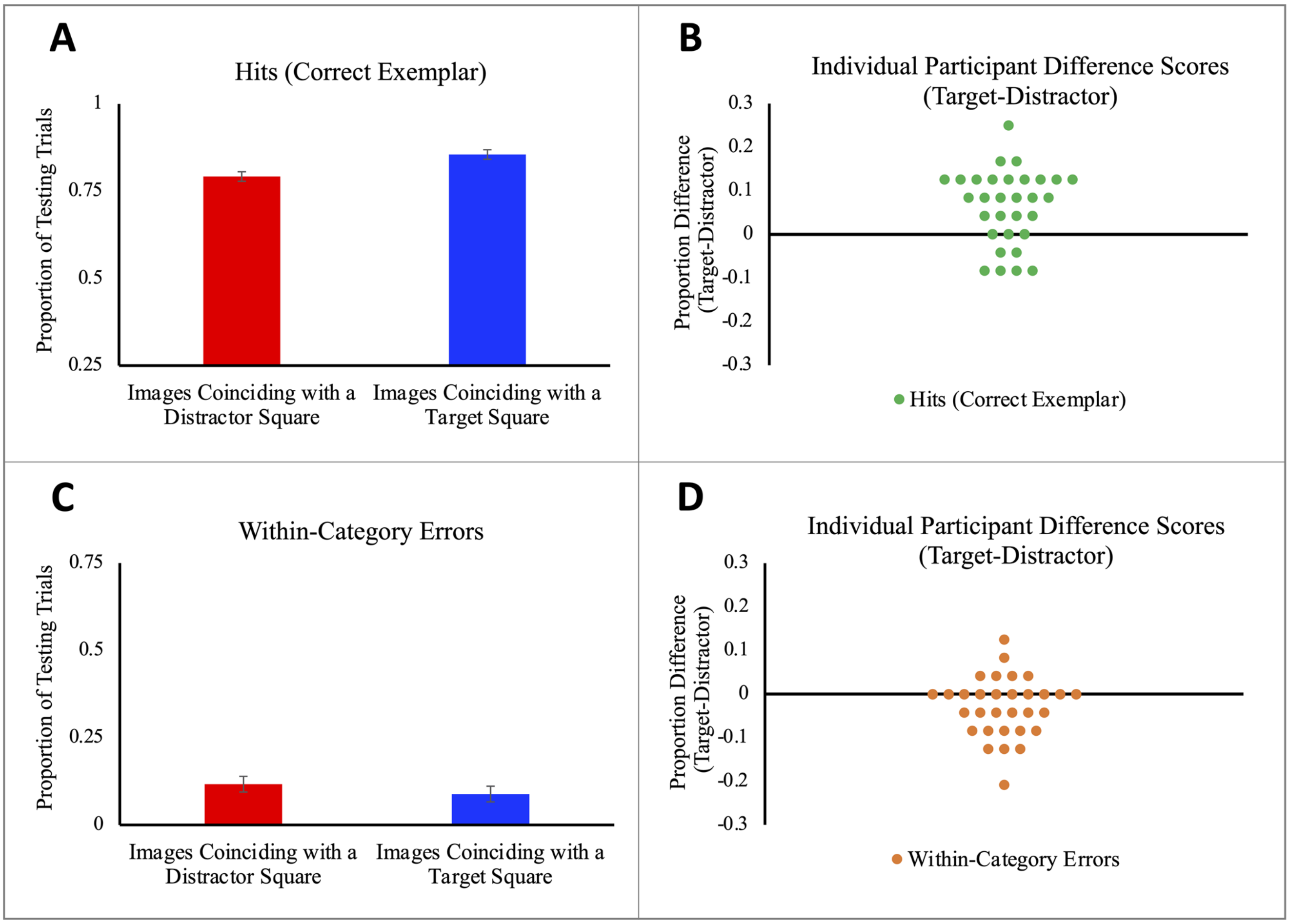

Fig. 2 **a** Proportion of testing trials in Experiment 1 categorized as hits, where participants selected the exact exemplar that had been shown during encoding, presented separately for images that had coincided with a distractor square in encoding (red) and images that had coincided with a target square (blue). The scale runs from chance performance (0.25) to perfect performance (1.00). **b** Individual participants' data points for the difference in the proportion of hits between target-concurrent images and distractor-concurrent images. Positive scores indicate a higher proportion of hits for target-concurrent images (a standard ABE effect), and negative scores indicate a higher proportion of hits for distractor-concurrent images. Each point is the difference score for one of the 31 participants in Experiment 1 **c** Proportion of testing trials in Experiment 1 categorized as within-category errors, where participants selected the within-category foil of the image that had been shown during encoding, presented separately for distractor- and target-concurrent images. Error bars represent standard error of the mean. **d** Individual participants' data points for the difference in the proportion of within-category errors (false alarms for within-category foils) between target-concurrent images and distractor-concurrent images. Positive scores indicate a higher proportion of within-category errors for target-concurrent images, and negative scores indicate a higher proportion of within-category errors for distractor-concurrent images. Each point is the difference score for one of the 31 participants in Experiment 1. (Color figure online)

Even though target detection was associated with more hits, we must also determine whether this increase in hits is paired with an increase in within-category errors (trials in which participants incorrectly chose the within-category foil). If the ABE primarily reflects a change in category memory, then target-concurrent images should yield both more hits and more within-category errors. If, however, the ABE reflects modulation of exemplar memory, perhaps via pattern separation, we should expect more hits and equal or fewer within-category errors for target-paired images, as perceptual distinctiveness would be enhanced to a degree that participants would not be enticed by the familiarity of the category identity of within-category foils. The percentage of within-category errors out of all testing trials shows that there were significantly fewer within-category errors for target-concurrent (M = 8.87%) than distractor-concurrent images (M = 11.49%), $t(30) = 2.30$, $p = .03$, Cohen's $d = 0.41$ (see Fig. 2c–d).

Discussion

The findings from Experiment 1 suggest that the ABE affects perceptually specific exemplar memory. Participants were more likely to remember the exact exemplar of an encoded category, and not more likely to falsely remember the within-category foil for target-concurrent images. These findings support the hypothesis that target detection facilitates pattern separation.

However, each image was seen multiple times during encoding. Repeated exposure to multiple different exemplars from within a single category may influence category memory, while repeated exposure to the same exemplar may influence exemplar memory instead (Homa et al., 2019; Manelis et al., 2011). This could lead to complex interactions between the ABE and exemplar repetition.

Experiment 2

Experiment 2 aimed first to determine whether the ABE can affect exemplar memory without repeated exposure to each exemplar. Second, Experiment 2 aimed to ensure that the ABE does not reflect a learned association between certain images and the detection target following several repetitions of the pairing. This experiment was the same as Experiment 1, except that each image appeared only once during encoding.

Method

Participants

We tested 44 participants, including 14 females and 30 males, with a mean age of 24.9 years (range: 18–41 years; $SD = 6.0$).

Sample size determination Sample size was determined using G*Power (Faul et al., 2007) based on the effect size of 0.76 observed in Experiment 1. This analysis suggests a minimum sample size of 25, but given the decrease in the number of repetitions, we increased the intended sample size to 44. A sample of 44 achieved power of 0.998.

Design and procedure

The design and procedure were identical to that of Experiment 1, with one exception: The encoding phase only consisted of one 48-trial block, so each image appeared only once during encoding.

Results

Practice phase

Accuracy during practice was again very high, $M = 93.58\%$, $SD = 11.17\%$.

Encoding phase

Accuracy during encoding was also high, $M = 94.65\%$, $SD = 7.89\%$. One participant was excluded for only achieving 50% accuracy. All other participants were above 85% accuracy. All further analyses therefore include 43 participants.

Testing phase

Accuracy, in terms of percentage of trials in which the correct exemplar was selected was 63.18% ($SD = 14.40\%$). This was considerably lower than that observed in Experiment 1, $F(1, 72) = 37.10$, $p < .001$, $\eta_p^2 = 0.34$. Nonetheless, the pattern of results was similar. In Experiment 2, participants better remembered exemplars that had coincided with a target-colored square ($M = 67.93\%$,) versus a distractor-colored square ($M = 58.43\%$) in encoding (see Fig. 3, left), achieving more hits for target-concurrent objects, $t(42) = 3.82$, $p < .001$, Cohen's $d = 0.58$. As before, this effect held when considering only trials in which participants selected the correct category, $t(42) = 2.17$, $p = .04$, Cohen's $d = 0.33$.

As in Experiment 1, there were fewer within-category errors for target-concurrent ($M = 15.21\%$) than distractor-concurrent images (17.64%), though the effect was not significant, $t(42) = 1.37$, $p = .18$, Cohen's $d = 0.21$ (see Fig. 3, right). Because the purpose of this analysis is to ensure that within-category errors did not increase for target-concurrent images, these nonsignificant findings are still entirely in line with the pattern of findings from Experiment 1 and the predictions one would make if pattern separation were facilitated in the ABE.

Discussion

Despite presenting each image only once during encoding, participants demonstrated an ABE, showing better memory for target-concurrent objects. This demonstrates that the ABE does not rely on strategically formed associations between images and the response target. Instead, the results point to a causal relationship between detection stimulus category (target or distractor) in one task and encoding of background information in a concurrent task.

Furthermore, these findings demonstrate that the target-related change in exemplar memory observed in Experiment 1 does not depend on repeated exposures to each exemplar. Under single exposure conditions, participants demonstrated the same pattern of exemplar memory as in Experiment 1. This again was not accompanied by a change in within-category errors.

General discussion

In a 4AFC recognition test with both within-category and wrong-category foils, participants were more likely to select the exact exemplar for images that had coincided with a detection target during encoding. This improved exemplar memory was maintained regardless of the number of exposures

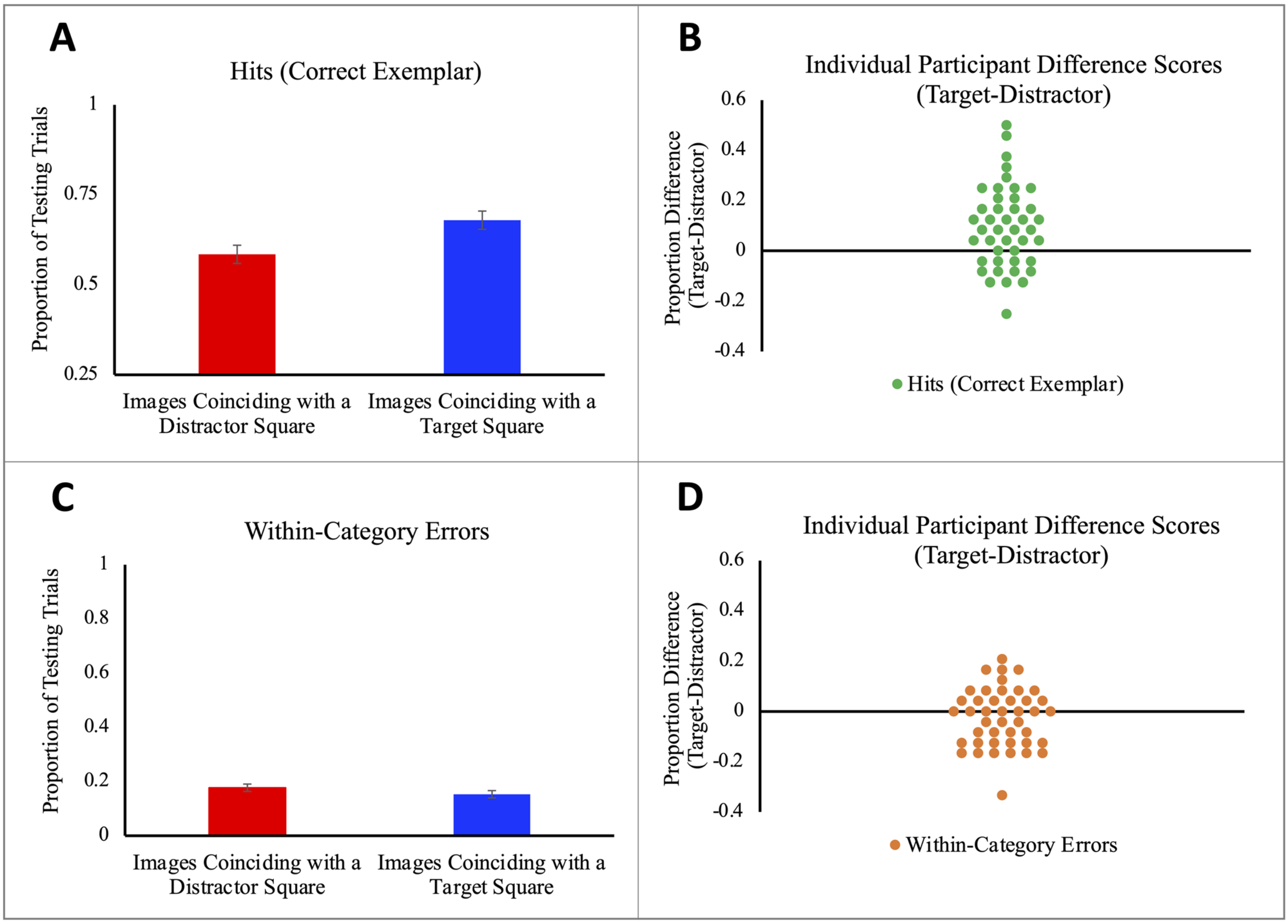

Fig. 3 **a** Proportion of testing trials in Experiment 2 categorized as hits, where participants selected the exact exemplar that had been shown during encoding, presented separately for images that had coincided with a distractor square in encoding (red) and images that had coincided with a target square (blue). The scale runs from chance performance (0.25) to perfect performance (1.00). **b** Individual participants' data points for the difference in the proportion of hits between target-concurrent images and distractor-concurrent images. Positive scores indicate a higher proportion of hits for target-concurrent images (a standard ABE effect), and negative scores indicate a higher proportion of hits for distractor-concurrent images. Each point is the difference score for one of the 43 participants in Experiment 2. **c** Proportion of testing trials in Experiment 2 categorized as within-category errors, where participants selected the within-category foil of the image that had been shown during encoding, presented separately for distractor- and target-concurrent images. Error bars represent standard error of the mean. **d** Individual participants' data points for the difference in the proportion of within-category errors between target-concurrent images and distractor-concurrent images. Positive scores indicate a higher proportion of within-category errors for target-concurrent images, and negative scores indicate a higher proportion of within-category errors for distractor-concurrent images. Each point is the difference score for one of the 43 participants in Experiment 2. (Color figure online)

during encoding and when taking into account benefits to category memory. Thus, the ABE does reflect improved fidelity of encoding at a perceptual, exemplar level at the moment of concurrent target detection.

Does the difference in exemplar memory between target- and distractor-paired images reflect an enhancement for the former, a suppression for the latter, or both? Because we did not include a no-square baseline in the current study, we cannot address this question definitively. Some studies suggest that the inhibition accompanying no-go responses impairs memory (Chiu & Egner, 2015a, 2015b), but these studies did not include a neutral baseline, and they conflict with studies showing superior memory on infrequent no-go trials (Makovski et al., 2013). When Yebra et al. (2019) examined the inhibition hypothesis by analyzing the number of go trials preceding a no-go response, they did not find evidence for inhibition. Furthermore, when a no-square baseline was included along with target- and distractor-paired trials, researchers observed memory enhancement for target-paired trials, without a memory deficit for distractor-paired trials (Bechi Gabrielli et al., 2018; Swallow & Jiang, 2014). While it is possible that both target-related enhancement and distractor-related inhibition contribute to the effect, prior research suggests that enhancement at least partly explains the pattern of results observed in the ABE (Lin et al., 2010; Meng et al., 2019; Mulligan et al., 2014; Spataro et al., 2013). The current study helps clarify the nature of that enhancement in terms of its perceptual specificity.

Our finding is consistent with previous studies that showed perceptual enhancement from the ABE, as demonstrated by observations of an increased tilt aftereffect (Pascucci & Turatto, 2013), improved relational memory (Turker & Swallow, 2019), and enhanced category cued recall (Spataro et al., 2017). However, these results appear to conflict with the absence of a memory benefit for the perceptual details of background words in an ABE task (Mulligan et al., 2016). This conflict may be resolved by drawing upon a distinction that Garner (1974) made regarding the perceptual separability of different stimulus dimensions. Distinct perceptual dimensions, such as the font or color of words versus the meaning of words, may yield separable memories. The encoding of a word's meaning does not depend on identifying the color or font of that word, making it possible to remember just its meaning but not its perceptual features. In contrast, recognizing and encoding a visual object requires perceptual analysis of its shape, color, and other features. Because object recognition in an ABE with nonverbal background stimuli necessarily involves processing of perceptual features, it follows that modulation of memory for background information will influence memory at a perceptual, exemplar level. Yet when the background information is verbal, as in Mulligan et al. (2016), the same perceptual analysis is not required during encoding, so task-irrelevant perceptual details may escape the influence of target detection.

Beyond the observation that target detection boosts memory for background images at a level that is selective for perceptually distinct exemplars within a category, our findings yield important insights into the mechanisms of encoding facilitation by concurrent target detection. Wing et al. (2020) explored category and exemplar memory as a function of the overlap in the evoked cortical and hippocampal representations of images of objects within a category. They found that greater distinctiveness or pattern separation in the hippocampus was associated with fewer within-category errors. Extending these findings to the present study, this alludes to a potential mechanism for the ABE whereby concurrent target detection facilitates pattern separation in the hippocampus. Target detection in the ABE has been associated with increased connectivity between the hippocampus and other parts of the brain, including the visual cortex (Moyal et al., 2020) and the locus coeruleus (Yebra et al., 2019). In light of this, our findings suggest that the ABE occurs when attentional selection of a target facilitates pattern separation. By including exemplar and category foils in our 4AFC recognition test, we provide a novel experimental paradigm for examining the nature of visual memory in the ABE that controls for order effects that may influence selection strategies. Future studies may seek converging support by using other experimental paradigms, such as that used by Stark et al. (2013), to examine the role of pattern separation in the ABE.

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