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The attentional boost effect facilitates the encoding of contextual details: New evidence with verbal materials and a modified recognition task

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Abstract

In the attentional boost effect (ABE), words or images encoded with to-be-responded targets are later recalled better than words or images encoded with to-be-ignored distractors. The ABE has been repeatedly demonstrated to improve item memory, whereas evidence concerning contextual memory is mixed, with studies showing both significant and null results. The present three experiments investigated whether the ABE could enhance contextual memory when using a recognition task that allowed participants to reinstate the original study context, by simultaneously manipulating the nature of the instructions provided at encoding. Participants studied a sequence of colored words paired with target (gray circles) or distractor (gray squares) stimuli, under the instructions to remember either the words and their colors (Exps. 1–2) or only the words (Exp. 3) and simultaneously press the space bar whenever a gray circle appeared on the screen. Then, after a brief interval, they were administered a modified recognition task involving two successive stages. First, participants were presented with two different words and had to decide which word was originally encoded; second, they were presented with five colored versions of the (correct) old words and had to remember the color in which they were studied. Results converged in showing that the ABE enhanced contextual memory, although the effect was more robust with intentional encoding instructions.

Keywords Attentional boost effect · Recognition memory · Item memory · Contextual memory · Divided attention

The attentional boost effect (ABE) is a surprising phenomenon in which the detection of a target stimulus in a divided-attention condition benefits the encoding of co-occurring images or words (Swallow & Jiang, 2013). While the initial studies by Swallow and Jiang (2010, 2011) used images as the to-be-remembered stimuli, the ABE has been repeatedly demonstrated with verbal materials. Spataro et al. (2013), for example, presented participants with a sequence of words paired with red or green squares (placed immediately below the words). The instructions were to read aloud and study the words and simultaneously press the space bar whenever the associated squares were red (targets)—no response was required when the squares were green (distractors). The results of a later surprise recognition task showed that words encoded with target squares were recognized significantly better than words encoded with distractor squares.

Later research replicated and expanded these findings, by showing that the ABE with verbal materials represents a robust phenomenon (Mulligan & Spataro, 2015; Mulligan et al., 2014; Spataro et al., 2017). Furthermore, several regularities have been demonstrated. First, the effect has been reported in a wide variety of tasks, including free or cued recall (Mulligan et al., 2014; Spataro et al., 2017; Spataro et al., 2021) and implicit memory tests such as lexical decision and word-fragment completion (Spataro et al., 2013). Second, the ABE can be characterized as a relative facilitation, because the performance in the divided-attention condition (i.e., the condition in which participants must simultaneously study the words and monitor the target stimuli) is boosted to the same level of the full-attention condition (i.e., the condition in which participants must only study the words; Mulligan

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et al., 2014; Spataro et al., 2013); however, an absolute facilitation, in which the divided-attention performance exceeds the full-attention levels can be detected under specific conditions (Mulligan & Spataro, 2015; Prull, 2019). Third, the facilitation in the encoding of target-paired stimuli is not limited on the occurrence of an explicit motor response and is not specific to the detection of infrequent targets. In fact, the effect is robust even when participants are simply asked to count the number of targets and report it at the end of the encoding phase (Mulligan et al., 2016; Swallow & Jiang, 2010), and its magnitude is not reduced when targets and distractors appear with the same frequency (Swallow & Jiang, 2012). Finally, the effect is moderated by the frequency and orthographic distinctiveness of the studied words, since the size of the ABE is reduced for low-frequency and orthographically distinctive words (Mulligan et al., 2014; Spataro et al., 2015; but see Prull, 2019).

To account for the rapidly increasing number of findings related to the ABE, Swallow and Jiang (2013) proposed the *dual-task interaction model*. According to this model, the ABE would rely on a temporary increase in the release of norepinephrine (NE) from the locus coeruleus (LC). More specifically, on each trial, the two stimuli (the background words/images and the monitored stimuli) compete for representation within perceptual processing areas, producing dual-task interference. Dual-task interference also arises from the need to maintain two simultaneous goals: intentionally encoding the scene into memory and generating an appropriate response to the square. However, the categorization of the target stimulus as an item that requires an overt response produces a transient discharge of norepinephrine from the LC, which in turn triggers temporal selective attention. Swallow and Jiang (2013) proposed that temporal selective attention is temporally, but not modality or spatially, selective: Tt therefore enhances the perceptual processing of any stimulus occurring at the same time as the target.

Despite the rapidly increasing number of findings related to the ABE, an important limitation is that most of the available studies examined the effects of the ABE on item recognition, without considering the recall of the spatiotemporal context in which they were encoded. Since item and contextual memory can be dissociated in the medial temporal lobe (Davachi et al., 2003; Weis et al., 2004), an important issue is to determine whether the ABE can also enhance the recognition of the contextual properties of the studied words. In the case of verbal materials, the only exception of which we are aware is represented by a series of experiments reported by Mulligan et al. (2016). These authors performed four experiments in which the contextual properties of the words co-occurring with target and distractor squares were systematically varied. In Experiment 1, participants encoded words presented in different colors and different fonts (either in the Jokerman font in red or in the Bauhaus 93 font in green) and were later requested to determine whether a given word was old or new and, if old, to report the font-color combination in which it was originally studied. In Experiment 2, participants either saw or heard study words and were later given a context memory task in which they decided whether a test word was previously seen, previously heard or completely new. Finally, in Experiments 3 and 4, participants encoded two different study lists (L1 and L2) and were later asked to decide whether a test word came from List 1, List 2, or was a new word. The results of these experiments were surprising but clear. In all cases, the ABE produced a robust enhancement in item recognition. In contrast, the attentional boost manipulation had no effect on context memory, whether defined in terms of visual details, study modality or list membership. Mulligan et al. (2016) concluded that these results were consistent with the idea that the ABE with verbal materials has an abstract, amodal basis (Mulligan et al., 2014).

Other studies have however provided conflicting results using pictorial stimuli (Broitman & Swallow, 2020; Swallow & Atir, 2019; Turker & Swallow, 2019). Turker and Swallow (2019) showed that the ABE enhanced the recognition of associations between a scene and the relevant and irrelevant features of the paired target-item. In their first experiment, participants encoded briefly presented scenes associated with target or distractor items that could vary for both color (the relevant features: e.g., yellow or red) and shape (the irrelevant feature; e.g., circles or stars). The instructions were to remember all the scenes and press the space bar when the superimposed item was a prespecified color (e.g., yellow). The encoding phase was followed by a recognition task that included three forced-choice questions. First, one old scene and one foil scene appeared on the screen and participants had to decide which scene was studied. Second, the old scene appeared in the center of the screen and was flanked by two colored squares (a neutral shape) and participants had to select the color that had been paired with the scene during the study phase. Third, the correct old scene was again displayed in the center of the screen and was flanked by one circle and one star in the correct color: participants had to select the shape of the item paired with the scene during the encoding phase. Using this paradigm, Turker and Swallow (2019) demonstrated that the recall of both relevant and irrelevant features was more accurate for scenes paired with target items than for scenes paired with distractor items.

Given the difference with the conclusions reached by Mulligan et al. (2016), it seems critical to further investigate which factors might explain the discrepancy. One such relevant factor might be the nature of the to-be-remembered stimuli: the ABE might enhance contextual memory with pictorial stimuli, but not with verbal stimuli. This possibility follows directly from previous evidence showing that the ABE with verbal material is based on the encoding of the abstract, amodal properties of the words, rather than on the encoding of their perceptual properties (Mulligan et al., 2014). It is also plausible that the positive effects of target detection might be limited to specific forms of contextual memory. Mulligan et al. (2016) assessed memory for associations between the words' identity and the perceptual properties in which they were presented, which were unrelated to the monitoring task; in contrast, Swallow and Atir (2019) and Turker and Swallow (2019) examined memory for associations between the background images and attributes of the monitored stimuli. It may be that the ABE enhances context memory only when the associations involve features of the monitoring task. Third, the discrepancy might be due to methodological factors, such as the number of presentations during the encoding phase or the method used to probe contextual memory during the retrieval phase. Mulligan et al. (2016) presented the study words only once during the encoding phase, whereas Swallow and Atir (2019) and Turker and Swallow (2019) repeated the same presentation several times (three or ten times, respectively). The effects of the ABE on contextual memory might unfold gradually over multiple presentations, such that they cannot be detected after a single presentation (Broitman & Swallow, 2020; Turker & Swallow, 2019). Regarding the method used to probe contextual memory, the aforementioned studies differed in terms of retrieval support, here defined as the extent to which the recognition task allowed the encoding context to be recreated or not (Naveh-Benjamin et al., 2002; Tulving & Thomson, 1973). Mulligan et al. (2016) used a recognition task in which participants had to mentally remember the properties, the modality, or the list in which the words were presented. In contrast, Turker and Swallow (2019) used a modified recognition task in which participants were always presented with the studied images and had to select the color and the shape of the items that were originally associated. Turker and Swallow (2019) speculated that this difference may be important and that the positive effects of the ABE on contextual memory might only be visible when retrieval support is high.

To further elucidate the roles of these factors, we performed three experiments investigating whether the ABE-related manipulation could enhance the encoding of the associations between the identity and the color of the background words. In designing these experiments, we introduced several modifications to the procedures previously used by Mulligan et al. (2016) that were aimed at maximizing the probability of obtaining significant effects of target detection on context memory.

Experiment 1

In Experiment 1 participants studied a sequence of colored words paired with target or distractor stimuli. Item and context recognition were later examined in a modified recognition task modeled after Turker and Swallow (2019). Besides replicating the classical ABE (target-paired words should be recognized more accurately than distractor-paired words), our primary aim was to determine whether the colors of target-paired words would be recognized better than the colors of distractor-paired words. If the critical factors in determining the effect of the ABE on context memory are the nature of the to-be-remembered stimuli, the number of presentations during the encoding phase, or the specific type of association investigated, then we should expect no significant difference in the recognition of the colors of target- and distractor-paired words, since we used verbal materials, the encoding phase was repeated only once and the to-be-tested associations did not involve features of the monitored stimuli. On the other hand, if the critical factor is retrieval support, then we should expect participants to recall the colors of target-paired words better than the colors of distractor-paired words, since our recognition task allowed them to reinstate the study context in which the words were originally encoded.

It should be noted that, in Experiment 1, the to-be-studied words could appear in five different colors (green, red, yellow, blue, purple), whereas only two colors were used in previous studies (red vs. green in Mulligan et al., 2016, and yellow vs. red in Turker & Swallow, 2019). This variation was simply aimed at increasing task difficulty and verifying whether target detection could still improve contextual memory in these challenging conditions. In addition, the color of target-paired words was maintained constant across trials (although it varied across participants). This choice was justified by the fact that, in previous studies showing a positive effect of the ABE on contextual memory (Swallow & Atir, 2019; Turker & Swallow, 2019), the color of monitored stimuli was maintained constant, since participants were required to press the space bar each time the central item was in the predefined target color. Turker and Swallow (2019) noted this point and suggested that, in these conditions, the relational memory advantage for items presented on target trials could reflect memory for the motor response, the status of the square as a target or distractor, or memory for the color of the square itself. Although we were aware of this confound, we nonetheless judged appropriate to begin our investigation by determining whether the ABE facilitated contextual memory in a condition in which the color of target-paired words was fixed, thus resembling as closely as possible previous studies reporting significant results.

Method

Participants Twenty-five graduate and undergraduate students at the School of Medicine and Psychology of the University "La Sapienza" of Rome volunteered to participate in Experiment 1. They were eight females and 17 males (M_{age} = 23.04 years). Mulligan et al. (2016, Exp. 1) reported that the effect size associated with the ABE manipulation was $d = 0.72$ in a repeated-measures t test. Using the software G*Power3 (Faul et al., 2007), we determined that a sample size of 18 (increased to 20 for counterbalancing purposes) was sufficient to achieve a power of 0.90 (Test family: t test; Statistical test: means − difference between two dependent means; one-tailed; $\alpha = 0.05$). A slightly larger sample was recruited in order to have sufficient power to detect potentially smaller effects of target detection on context memory.

Design and material Trial type (target- vs. distractor-paired words) was manipulated within subjects. The critical items were 100 high-frequency words selected from the Italian adaptation of the Affective Norms for English Words (ANEW; Bradley & Lang, 1999; Montefinese et al., 2014). This original set was divided into five subsets of 20 words that were equated as closely as possible on the following variables: frequency (range: 320.8–342.1), familiarity (range: 7.26–7.39), imageability (range: 7.47–7.91), concreteness (range: 7.01–7.60), and length in letters (range: 6.25–6.60). Familiarity, imageability and concreteness were scored using 9-point Likert scales, where 1 indicated the lowest level and 9 indicated the highest level (see Montefinese et al., 2014). The words of each subset were shown in one of five different colors (green, red, yellow, blue, purple) and were paired with either gray squares (the distractor stimuli) or gray circles (the target stimuli). The assignment of the colors to the subsets of words was counterbalanced using a Latin square design, such that target words appeared once with each color: This resulted in the creation of five different encoding lists. Five participants were tested with each encoding list. An additional set of 100 words was selected from the same database to be used as foil items in the recognition task (frequency: 327.2; familiarity: 7.31; imageability: 7.68; concreteness: 7.30; length in letters: 6.33).

Procedure The experiment comprised an encoding phase, a short interval, and a recognition test. During the encoding phase, participants were presented with 100 words, at a rate of 1,000 ms per word. Twenty words were associated with gray circles (the target items) whereas the remaining 80 were associated with gray squares (the distractor items). On each trial, one word (Times New Roman, 44 points) and one circle (1 cm in diameter) or one square (1cm × 1cm) appeared simultaneously at the center of the screen for 250 ms, with a vertical distance of 1 cm between them, after which only the word remained visible for an additional 750 ms (there was no intertrial interval between two successive words). Unbeknownst to participants, the encoding list was divided into twenty blocks containing five words (one target word and four distractor words). Within each block, the exact position of the target-paired word was randomly chosen, with the constraint that target-paired words should occupy each position four times across the twenty blocks (see Fig. 1a). The organization of the encoding list was not apparent to participants, who saw a continuous sequence of items. The instructions were to remember the words and the colors in which they were presented and simultaneously press the space bar whenever a gray circle appeared on the screen (no response was required when the word was associated with a gray square).

The encoding phase was followed by a five-minute interval during which participants solved a series of arithmetical operations. Lastly, the test phase included a modified recognition task in which participants were asked, for each of 100 trials, two different questions (see Fig. 1b). First, they were shown two different words and had to decide which word was studied during the encoding phase. Each couple included an old word and a foil word, placed one below the other (the position of the old word was counterbalanced, so that 50 old words were shown in the upper position, whereas the remaining 50 old words were shown in the bottom position). Participants provided their responses by pressing one of two keys in the numerical keypad: either the "1" key (if the old word was the one shown in the bottom position) or the "7" key (if the old word was the one shown in the upper position). The second question involved the presentation of five different versions of the studied word, colored in green, red, yellow, blue, and purple. Each colored word was associated with a specific letter ("c," "v," "b," "n," and "m") and participants had to decide the color in which the word was presented at encoding by pressing the corresponding key. The five colored words were arranged into a single column (one below the other): the positions of the correct responses were randomized, with the constraint that they should appear in each position twenty times. Note that the word presented in the second phase was always the studied one, irrespectively of the accuracy of the responses provided by participants in the first phase. The task was self-paced.

Results

Encoding task Participants were accurate in detecting the target squares, $M = 97.1\%$ ($SD = 5.5\%$). The mean RT was 469.7 ms ($SD = 91.0$ ms).

Recognition task The mean proportions of old words correctly recognized are reported in Table 1. Since we did not expect significant differences in the recognition of distractor-paired words, the participants' performance was collapsed across the four distractor positions. A t test for dependent samples showed that target-paired words ($M = 0.67$) were recognized significantly better than distractor-paired words ($M = 0.58$), $t(24) = 2.70$, $p = .012$, Cohen's $d = 0.76$. Recognition memory was significantly greater than the chance performance (0.50) in both the target and distractor conditions, $t(24) = 5.84$, $p <$

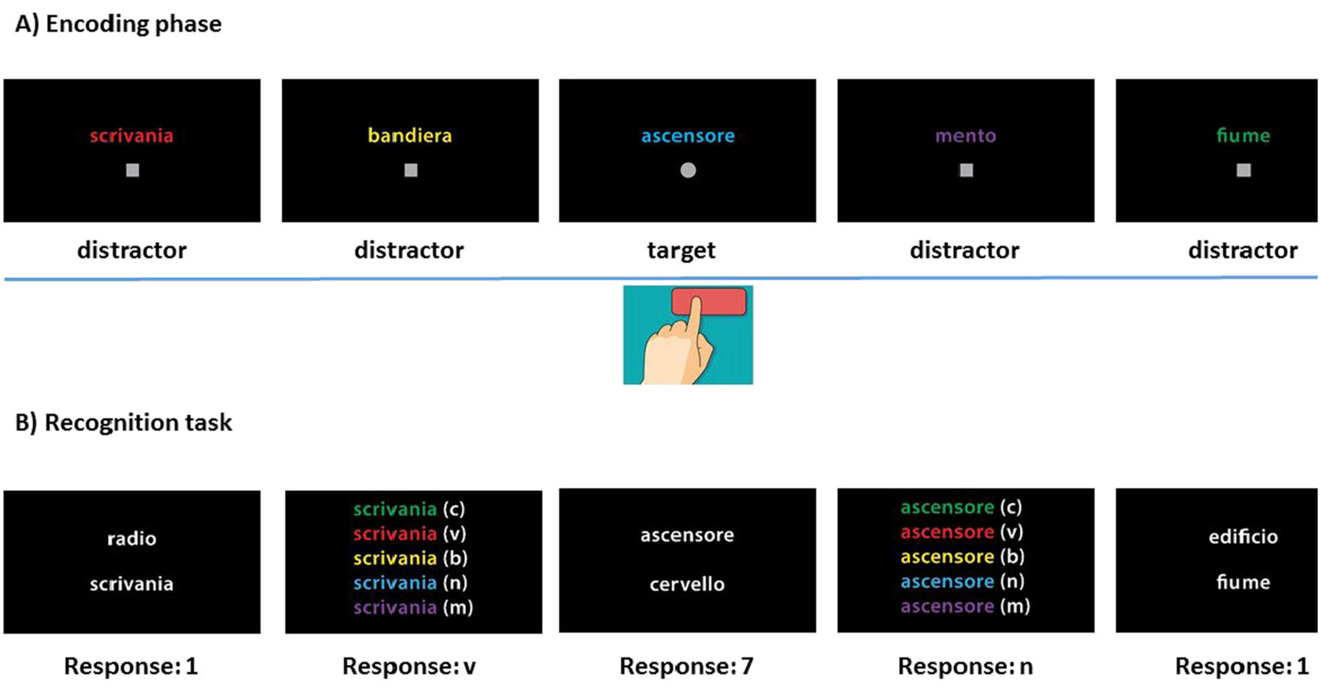

Fig. 1 Example of the encoding phase and recognition task used in Experiments 1–3. **a** Each block in the encoding phase contained five words, four paired with gray squares (the distractor stimuli) and one with a gray circle (the target stimulus). Participants were instructed to study the words and their colors and press the space bar whenever the associated stimulus was a gray circle. **b** In the recognition task, participants were first asked to determine which of two words was presented during the encoding phase; then, the correct old word was shown in five different colors and participants had to indicate in which color the word was presented during the encoding phase, by pressing the corresponding key. (Color figure online)

.001, and $t(24) = 4.26$, $p < .001$, respectively. Thus, the standard ABE was successfully replicated in Experiment 1.

Context memory was assessed with the *identification-of-origin* scores (IO; Johnson et al., 1993; Mulligan et al., 2016), defined as the proportions of words correctly recognized as old that were attributed to the correct colors. We used this conditionalized measure because we wanted to avoid the possibility that the context memory results could be influenced by the differential recognition rates of target- and distractor-paired words (see Mulligan et al., 2021, for an extensive discussion of this point). As in the previous analysis, the IO scores of distractor words were collapsed into a single score. A *t* test for dependent samples showed that the IO scores of target words ($M = 0.32$) were significantly greater than the IO scores of distractor words ($M = 0.24$), $t(24) = 2.66$, $p = .014$, Cohen's $d = 0.68$ (see Table 1). Context memory was significantly greater than the chance performance (1/5 = 0.20, because words could assume five different colors) for both target and distractor words, $t(24) = 4.30$, $p < .001$, and $t(24) = 2.26$, $p = .033$, respectively.

In sum, Experiment 1 found that the ABE-related manipulation was effective in increasing the participants' ability to

Table 1 Mean proportions of words correctly recognized (item memory) and mean identification-of-origin scores (contextual memory) in Experiments 1–3 (standard deviations are reported in parentheses)

	Experiment 1 ($N = 25$)	Experiment 2 ($N = 25$)	Experiment 3 ($N = 65$)	Experiment 3* ($N = 39$)
Item memory				
Target-paired words	0.67 (0.15)	0.69 (0.16)	0.67 (0.17)	0.71 (0.15)
Distractor-paired words	0.58 (0.10)	0.63 (0.12)	0.58 (0.13)	0.63 (0.14)
Contextual memory				
Target-paired words	0.32 (0.14)	0.37 (0.19)	0.23 (0.16)	0.31 (0.16)
Distractor-paired words	0.24 (0.09)	0.27 (0.13)	0.22 (0.11)	0.26 (0.13)

Note. * = subsample of participants having IO scores greater than 0.20.

form associations between the identity and the colors of the encoded words. This result is unprecedented and important from a theoretical perspective, because it demonstrates that the positive effects of target detection on context memory are not limited to pictorial stimuli, multiple-presentation paradigms or associations involving features of the monitoring task. Rather, it suggests that the nature of the recognition task, and specifically the degree of retrieval support, might represent the critical factor in determining the significance of the effects of the ABE on contextual memory.

Experiment 2

Although novel and interesting, the data presented in Experiment 1 are not sufficient to conclude that target detection facilitates the encoding of the associations between different features of background words. This is because the color of the target words did not vary across trials (i.e., all the target words were presented in the same color). As mentioned above, the consequence is that increased contextual memory might reflect memory for the motor response or for the target status of the words, rather than memory for their colors (see Turker & Swallow, 2019, for discussion). The aim of Experiment 2 was to rule out these alternative explanations, by varying the color of target-paired words.

Method

Participants A new sample of twenty-five graduate and undergraduate students of the School of Medicine and Psychology of the University "La Sapienza" of Rome volunteered to participate in Experiment 2. They were 11 females and 14 males (M_{age} = 24.80 years).

Design and material Trial type (target- vs. distractor-paired words) was manipulated within subjects. The critical items were the same 100 high-frequency words selected for Experiment 1, which were again divided into five subsets of 20 words. Critically, the words of each subset were shown in one of five different colors (green, red, yellow, blue, purple; four words were associated with each color, with the pairings being fixed for all participants) and were paired with either gray squares (the distractor stimuli) or gray circles (the target stimuli). The foil words used in the recognition task were the same as in Experiment 1.

Procedure The procedure of Experiment 2 was similar to that illustrated for Experiment 1. During the encoding phase, participants were presented with 100 colored words, of which 20 associated with gray circles (the target items) and 80 associated with gray squares (the distractor items). As noted above, both the target and distractor words could assume one of five different colors. As in Experiment 1, the encoding list was divided into twenty blocks containing five words (one target word and four distractor words). Participants were instructed to remember the words and the colors in which they were presented and simultaneously press the space bar whenever the associated item was a gray circle. No response was required when the item was a gray square. The encoding phase was followed by a 5-min interval (filled with simple arithmetic tasks) and by the same two-stage recognition task illustrated in Experiment 1.

Results and discussion

Encoding task Participants were very accurate in detecting the target stimuli, M = 99.3% (SD = 1.2%). The mean RT was 421.5 ms (SD = 92.9 ms).

Recognition task The mean proportions of target- and distractor-paired words correctly recognized during the recognition task are reported in Table 1. As in the previous experiments, the participants' performance was collapsed across the four distractor positions. A t test for dependent samples showed that target-paired words (M = 0.69) were recognized significantly better than distractor-paired words (M = 0.63), $t(24) = 2.78$, p = .010, Cohen's d = 0.42. Recognition memory was significantly greater than the chance performance (0.50) in both the target and distractor conditions, $t(24) = 5.96$, $p < .001$, and $t(24) = 5.51$, $p < .001$, respectively. Thus, the standard ABE was replicated in Experiment 2.

Context memory was again assessed with the *identification-of-origin* (IO) scores. A t test for dependent samples showed that the IO scores of target words (M = 0.37) were significantly greater than the IO scores of distractor words (M = 0.27), $t(24) = 3.02$, $p = .006$, Cohen's $d = 0.61$ (see Table 1). Context memory was significantly greater than the chance performance (1/5 = 0.20) for both target and distractor words, $t(24) = 4.30$, $p < .001$, and $t(24) = 3.01$, $p = .006$, respectively.

To conclude, Experiment 2 replicated the main conclusions of Experiment 1 in a condition in which the effects of the ABE on contextual memory were unlikely to be confounded by the recall of either the press responses or the target status of the words.

Experiment 3

While Experiments 1 and 2 provided initial evidence showing that target detection could benefit the recognition of the perceptual details of encoded words when the retrieval task allowed participants to reinstate the same context experienced during the study phase, there is a second factor that could potentially account for the difference with previous studies—namely, the use of intentional instructions. In fact, in Experiments 1 and 2 we instructed participants to consciously attend to and remember both the identity and the colors of the studied words. This is an important departure from the study reported by Mulligan et al. (2016), in which participants were only instructed to remember the words. While the use of intentional instructions does not represent an essential element for obtaining the ABE (the effect has been replicated with incidental instructions: Broitman & Swallow, 2020; Spataro et al., 2013; Swallow & Jiang, 2014; but see Hutmacher & Kuhbandner, 2020), it may be instead crucial for revealing the influence of target detection on contextual memory when using verbal materials. Specifically, Broitman and Swallow (2020) showed that both recollection and familiarity estimates were greater for target-paired faces than for distractor-paired faces, regardless of whether the faces were encoded incidentally or intentionally. Since recollection estimates are often taken to reflect the subjective experience of remembering contextual details, the authors concluded that attending to relevant targets facilitated both intentional and incidental memory for the background image and the context in which it occurred. However, there are relevant differences in the processes that underlie the encoding of images and words. First, previous studies found that long-term memory is capable of storing a massive number of objects with perceptual details from the corresponding images (Brady et al., 2008; Kuhbandner et al., 2017). Second, there is evidence that, when attended, pictures may be processed and remembered more readily than words because they engage more effectively and automatically areas important for visual memory. In contrast, the encoding of words is typically associated with increased activity in prefrontal and temporoparietal regions related to language function, suggesting that they rely more heavily on the analysis of abstract semantic meaning (Grady et al., 1998). Third, even when unattended in a dual-task paradigm, pictures were recognized at high rates regardless of their association with to-be-detected items during the primary task, whereas words were later recognized at higher rates only if they had previously been aligned with primary task targets (Walker et al., 2017). Taken together, these findings suggest that the elaboration and the retention of the perceptual details of attended and unattended items may be easier and more direct for pictures than for words and that the positive effects of the ABE on the recognition of words' colors might be only evident when participants are explicitly instructed to pay attention to these details. Sisk and Lee's (2021) recent study supports these contentions. They reported clear evidence showing that the ABE affected memory for perceptually specific images. In this study, the authors used a four-alternative recognition task including a previously seen image, a perceptually distinct exemplar from the same category as the previously seen image, and two images from a new category. Results showed that participants recognized the correct exemplar more often for target-paired than for distractor-paired images; critically, this positive effect was not accompanied by a difference in false memories for within-category foils, suggesting that participants were able to encode the perceptual details of target-paired images.

To further verify the role of encoding instructions, Experiment 3 used the same materials and procedures of Experiment 2, with the exception that participants were told to pay attention to the words but no mention was made of the colors. Thus, instructions were intentional for the encoding of words' identity but incidental for the encoding of words' colors. If retrieval support is the critical factor for obtaining the positive effects of the ABE on contextual memory, then the results of Experiment 3 should be similar to those obtained in Experiments 1 and 2. Otherwise, if the use of intentional instructions is the key factor, then target detection should have no effects on the recognition of words' colors when using incidental instructions.

Method

Participants Sixty-five graduate and undergraduate students of the faculty of Economy of "Mercatorum" University volunteered to participate in Experiment 3. They were 43 females and 22 males, with a mean age of 30.94 years. A larger sample was recruited because we expected that the use of incidental instruction should decrease the probability of observing a significant effect of the ABE on contextual memory. Thus, we wanted to ensure that we had sufficient power to detect effects that were substantially smaller than those obtained in the first two experiments. The age discrepancy with the samples recruited in Experiment 1 and 2 is due to the fact that the students enrolled at Mercatorum University (a telematic university) are typically older than those recruited in public universities (such as the University "La Sapienza" of Rome).

Design and material Trial type (target- vs. distractor-paired words) was manipulated within subjects. Materials were the same as those used in Experiment 2.

Procedure Owing to the restrictions imposed by the Covid-19 health emergency, Experiment 3 was carried out remotely. Stimuli were delivered, and the participants' responses recorded, online, through a classic 3-tier Web application. Participants were recruited by e-mail and accessed the experiment as a web page, via an URL and a Web browser, with no additional requirements (e.g., downloading and installing software on their devices was not necessary). Experimental parameters (i.e., presentation times and the visual characteristic of the stimuli) were the same as in previous experiments; to prevent participants from running the experiment on undersized screens, the use of the software on tablets and smartphones was forbidden. No personal data, other than those reported here (i.e., age, gender, and education), were collected. The software allows the experiment to be coded in a subset of the JavaScript language, entered in an online editor. It is based on common open- source tools, such as the Django framework, jQuery, and PegJS, and can be hosted by any provider; here, the Python Anywhere free service was chosen for its ease of use. All other technical details are available upon request.

In addition to the difference in the online format of the experiment, the instructions were also modified. Prior to the study phase, participants were only asked to try to remember the words for a later test. No mention was made of remembering the colors of the words. Otherwise, the instructions were identical to Experiment 2. During the 5-minute retention interval, participants were presented with a total of 30 arithmetical operations (additions and subtractions). Each operation remained on the screen for a fixed time of 10 seconds. Participants typed their responses into a small blank box located just below the operation.

Results and discussion

Encoding task Participants were very accurate in detecting target stimuli, $M = 98.4\%$ ($SD = 3.7\%$). The mean RT was 481.0 ms ($SD = 102.3$ ms).

Recognition task The mean proportions of target- and distractor-paired words correctly recognized during the recognition task are reported in Table 1 (third column). A *t* test for dependent samples showed that target-paired words ($M = 0.67$) were recognized significantly better than distractor-paired words ($M = 0.58$), $t(64) = 5.25$, $p < .001$, Cohen's $d = 0.59$. Recognition memory was significantly greater than the chance performance (0.50) in both the target and distractor conditions, $t(64) = 7.99$, $p < .001$, and $t(64) = 5.19$, $p < .001$, respectively. Thus, the standard ABE was replicated in Experiment 3.

Context memory was again assessed with the *identification-of-origin* (IO) scores. A *t* test for dependent samples showed that the IO scores of target-paired words ($M = 0.23$) did not differ from the IO scores of distractor-paired words ($M = 0.22$), $t(64) = 0.28$, $p = .77$, Cohen's $d = 0.07$ (see Table 1).[1] However, context memory did not differ from chance performance (0.20) for both target- and distractor-paired words, $t(64) = 1.49$, $p = .14$, and $t(64) = 1.83$, $p = .07$, respectively. This raises the possibility that, in the overall sample, the lack of a significant ABE might be the consequence of a floor effect. To address this issue, we computed the mean IO scores (by averaging the IO scores of target- and distractor-paired words) and performed a median split by selecting a subsample of participants having IO scores equal or greater than the median value (which was 0.20; $N = 39$). In this subgroup, the IO scores of target-paired words ($M = 0.31$) were significantly higher than the IO scores of distractor-paired words ($M = 0.26$), $t(38) = 2.41$, $p = .021$, Cohen's $d = 0.34$. In addition, replicating the results obtained in the whole sample, recognition memory was also better for target words ($M = 0.71$) than for distractor words ($M = 0.63$), $t(38) = 4.35$, $p < .001$, Cohen's $d = 0.55$ (see the fourth column of Table 1). The same conclusions were obtained when we selected participants having IO scores equal or greater than the mean values of target- and distractor-paired words ($M = 0.22$ in both cases; $N = 26$). In this subgroup, we found that (a) the IO scores of target-paired words ($M = 0.37$) were significantly higher than the IO scores of distractor-paired words ($M = 0.27$), $t(25) = 6.43$, $p < .001$, Cohen's $d = 0.67$, and (b) recognition memory was better for target-paired words ($M = 0.73$) than for distractor-paired words ($M = 0.65$), $t(25) = 3.43$, $p = 0.002$, Cohen's $d = 0.64$.

In summary, Experiment 3 indicates that the use of intentional instructions was not the key factor in producing the beneficial effects of the ABE on contextual memory in Experiments 1 and 2. Target detection increased the recognition of words' colors even when participants were instructed to pay attention only to the words during the encoding phase (although the use of incidental instructions had the consequence of reducing the overall recognition of contextual details). These results suggest that, when retrieval support is high, the ABE-related manipulation enhances contextual memory in both intentional and incidental conditions.

General discussion

Three experiments investigated the question of whether the ABE-related manipulation could enhance the encoding of the associations between the identity and the colors of the background words. As briefly reviewed in the Introduction, previous studies investigating the effects of target detection on contextual memory had reached different conclusions. Swallow and Atir (2019) and Turker and Swallow (2019, Exp. 1) found that the participants' ability to report the relevant (i.e., color) and irrelevant (i.e., shape) features of the monitored items was significantly better when they appeared with target- rather than with distractor-paired scenes. In contrast, Mulligan et al. (2016, Exp. 1) showed that the ABE did not benefit the recognition of the features (e.g., colors and fonts) of background words. We hypothesized that at least four different factors could be at the origin of this

[1] Note that similar results were observed when statistical analyses were limited to participants aged 18 to 30 years ($N = 37$; $M_{age} = 24.1$). In this subsample, target-paired words ($M = 0.66$) were again recognized significantly better than distractor-paired words ($M = 0.58$), $t(36) = 3.96$, $p < .001$, Cohen's $d = 0.51$; in contrast, as in the full analysis, the IO scores of target-paired words ($M = 0.25$) did not differ from the IO scores of distractor-paired words ($M = 0.24$), $t(36) = 0.29$, $p = .76$, Cohen's $d = 0.06$.

discrepancy, namely: (a) the nature of the to-be-remembered stimuli (images vs. words); (b) the type of association assessed (associations involving features of the monitored stimuli vs. associations involving features of the background stimuli); (c) the number of presentations of the study stimuli at encoding (single vs. multiple presentations); and (d) the characteristics of the recognition task in terms of retrieval support (whether it allowed the reinstatement of the encoding context or not).

The results obtained in the present experiments help us evaluate the respective roles of these four factors. More specifically, we can now confidently conclude that the discrepant outcomes were not due to differences in the nature of the to-be-remembered stimuli or in the number of presentations during the encoding phase. We showed that the ABE can boost the encoding of contextual details when participants studied words rather than images and the stimuli were presented only once rather than repeated several times. A recent study by Mulligan et al. (2021) reached similar conclusions with respect to source memory. Participants studied a sequence of words paired with red (target) or green (distractor) circles, with the instructions to remember the words and press the space bar whenever the circle below the word was red. After a five-minute delay, the recognition task involved the presentation of both old and new words. For each trial, participants were required to judge whether the word was studied or not, and if studied, to indicate whether it was presented with a red or a green circle. Across three experiments, the analyses showed that the ability to report the circles' color was significantly more accurate for target than for distractor trials, thus replicating the results illustrated by Swallow and Atir (2019) and Turker and Swallow (2019) by using verbal materials and a single encoding presentation.

The most important contribution of the present experiments concerns the possibility of excluding the nature of the associations being tested as an explanation for the discrepancy between previous studies. As illustrated above, the positive effects of the ABE were to date demonstrated for associations involving features of the monitored items, but not for associations involving features of the background items. In this respect, our data demonstrate for the first time that target detection can increase the recognition of the associations between the words' identity and their colors. When compared with the experiments illustrated by Mulligan et al. (2016), we modified both the nature of the task used to assess recognition memory and the intentionality of the encoding instructions. While Mulligan et al. (2016) asked participants to remember the color of the studied words, we asked them to select the correct response among an array of five colored words. One possibility, then, was that a high level of retrieval support was necessary to uncover the positive impact of the ABE-related manipulation on some forms of contextual memory. However, in addition to modifying the retrieval task, participants in Experiments 1 and 2 were also required to attend to and remember both the identity and the colors of the studied words—a procedure that was not adopted by Mulligan et al. (2016). Thus, an alternative possibility is that the use of intentional instructions was necessary for revealing the influence of target detection on the recognition of the perceptual details of studied words. To adjudicate between these two possibilities, we performed a third experiment in which we used the same recognition task as in Experiments 1 and 2 but modified the encoding instructions. Specifically, we asked participants to memorize the words, but made no mention about the necessity to remember their colors. In this condition, the results showed that, in the whole sample, the ABE was significant for the recognition of words' identity (participants recognized target-paired words better than distractor-paired words), but not for the recognition of their colors. However, performance in the color recognition task was at chance for both target- and distractor-paired words, suggesting a potential floor effect. Critically, when statistical analyses were restricted to participants having IO scores greater than 0.20 (i.e., the median value of the averaged IO scores) or 0.22 (i.e., the mean value of the IO scores of target- and distractor-paired words), it turned out that the ABE had a clear, positive effect on contextual memory: the colors of target-paired words were recognized significantly better than the colors of distractor-paired words. Thus, when not obscured by floor effects, a positive ABE was found in context memory even under incidental instructions. A caveat to this conclusion is that, by selecting participants having IO scores above the median, we potentially restricted statistical analyses to participants who were more likely to exhibit a significant ABE on contextual memory. This possibility is supported by the finding that, for participants having IO scores below the median, the numerical tendency was reversed, showing that IO scores were higher for distractor- than for target-paired words. Such a result suggests that the conclusions emerging from Experiment 3 should be regarded with caution, as they were less clear than those obtained in Experiments 1 and 2: additional studies using a simplified condition with two or three colors should be conducted to clarify the issue of whether intentional instructions are always necessary to uncover the effects of the ABE on the recognition of contextual details.

Thus, the overall conclusion from our set of experiments is that, when using verbal materials, the positive effects of the ABE on contextual memory can be best detected when retrieval support is high (i.e., when the recognition task allows the reinstatement of the original encoding conditions) and participants are explicitly required to encode the perceptual details of the studied words. A significant ABE can also be detected when the instructions are incidental (i.e., when participants are not explicitly instructed to memorize the words' colors), but in the experimental conditions used in the present study the difficulty of the recognition task masked the beneficial impact of target detection, such that the advantage of target-associated words was only observed on participants having high IO scores. When compared with previous studies (Swallow & Atir, 2019; Mulligan et al., 2016; Turker & Swallow, 2019), the task employed in the present study was indeed quite difficult, because participants were required to discriminate between five different colors—rather than between two colors. Our data suggest that, in these specific conditions, both retrieval support and intentional instructions may be necessary to most clearly observe the beneficial impact of target detection on contextual memory.

More broadly, our data support the idea that the processes underlying the encoding of words and pictures differ from each other in multiple respects (Brady et al., 2008; Grady et al., 1998; Kuhbandner et al., 2017; Walker et al., 2017). Perceptual details such as color are better encoded in the ABE paradigm when participants are explicitly told to direct their attention to these features. This does not mean that the perceptual details of target- and distractor-paired words are not at all encoded when using the standard incidental instructions (i.e., when participants are only told to memorize the background stimuli): simply, our results suggest that, for verbal materials, the positive consequences of the ABE on the encoding and the retention of multiple contextual details can be better uncovered through the use of intentional instructions. In contrast, for images, there is evidence indicating that perceptual details are easily encoded with both incidental and intentional instructions. For example, Leclercq et al. (2014) found that both 'remember' and 'familiar' responses were higher for target- than for distractor-paired images (see also Broitman & Swallow, 2020); furthermore, remember responses were associated with the recall of unattended contextual details, since participants reported the correct spatial location of target-paired images better than that of distractor-paired images. This occurred even if participants were only asked to remember the identity of the images (i.e., even if spatial location was not intentionally encoded). In these experiments, however, the difficulty of the task was relatively low, because participants were requested to discriminate between two spatial positions (right vs. left). Additional studies are needed to examine the potential interaction between task difficulty and encoding instructions in the ABE with visual images.

From a theoretical perspective, the present data provide valuable insights into the nature and the bases of the ABE. Previous studies using visual materials contended that the effect was primarily driven by an improvement in the perceptual processing of target-paired stimuli (Swallow & Jiang, 2010, 2013). Such a conclusion is supported by multiple evidence showing that target detection (a) facilitates pattern separation by increasing the recognition of correct old images in a four-alternative forced-choice memory test (Sisk & Lee, 2021), (b) increases activity in the primary visual cortex (Swallow et al., 2012) and enhances functional connectivity between the ventral visual cortex and the hippocampus (Moyal et al., 2020), and (c) facilitates the encoding and retention of color-shape associations in short-term memory (Spataro et al., 2020). For verbal materials, however, current evidence is mixed. On the one hand, Spataro et al. (2013) found that the ABE increased repetition priming in two perceptually-driven implicit tasks (lexical decision and word-fragment completion), suggesting that the effect could enhance the implicit elaboration of the orthographic features of studied words. On the other hand, the study by Mulligan et al. (2014) proposed a different account, by showing that the ABE was not modality-specific. In particular, these authors found that the positive effects of target detection on recognition tasks were not reduced when participants studied visual words but were tested on auditory words, or vice versa, and concluded that the ABE facilitated the processing of abstract, amodal representations, an idea also supported by the finding the ABE in free recall. The results of the present set of experiments contribute to this ongoing debate by showing that the ABE with verbal materials can benefit the encoding of the perceptual details of background words, at least when retrieval support in the test phase is sufficiently high and participants are explicitly aware of the need to focus their attention on these details and memorize them.

On a related note, we must note that our data should not be generalized to all forms of contextual memory. In fact, while the ABE facilitated the encoding of the associations between the identity and the colors of background words in the present study, the effect proved to be nonsignificant when participants were asked to maintain in memory the associations between successive words. More specifically, Spataro et al. (2017) found that the ABE enhanced explicit memory in a category-cued recall task in which participants were asked to produce exemplars that belonged to a given category and that were also appeared in the study phase; in contrast, it did enhance repetition priming in a category-exemplar generation task in which participants were simply told to generate exemplars from a given category. The well-known distinction between item-specific and relational encoding suggests that performance in the category-cued recall task requires the encoding of features that are unique to a given exemplar, whereas performance in the category-exemplar generation task requires the encoding of features that are shared with other to-be-retrieved exemplars (i.e., their categorical relationships; Hunt & McDaniel, 1993). Thus, the finding that the ABE did not increase repetition priming in the latter task indicates that the effect had no positive effect on the processing of between-item relations. A recent study by Spataro et al. (2021) reached similar conclusions by showing that, in a multiple-recall paradigm, the ABE enhanced item gains (i.e., the number of items recalled on later tests that were not reported in earlier tests), but failed to reduce item losses (i.e., the number of items lost on later tests that were successfully retrieved in earlier attempts). Previous research assumed that, when participants study lists of semantically associated stimuli, relational information is used to guide retrieval and to generate potential responses, resulting in the development of stable retrieval strategies that minimize item losses (Burns, 1993; Klein et al., 1989). According to this view, if the ABE facilitated relational processing, then item losses should have been significantly lower for target- than for distractor-paired items—a prediction that was not supported by Spataro et al. (2021). The discrepancy with the current results might be understood within the framework proposed by Piekema et al. (2010), who distinguished between *intra-item* and *interitem* relational processes. Intra-item processes refer to associations between different features of a single item (e.g., color-identity or color-shape associations) or between the item and its location, whereas interitem processes refer to associations between different items. The provisional conclusion, therefore, is that the ABE enhances the encoding of intra-item associations but may have small or no effect on the encoding of interitem associations.

In conclusion, the present study provides novel evidence in support of the claim that the positive effects of the ABE generalize to contextual memory, here defined as the recognition of the perceptual details of background words. The dual-task interaction model suggests that target detection in the ABE paradigm operates via a mechanism of temporal attention that boosts perceptual processing at behaviorally relevant moments by transiently increasing the release of norepinephrine from the locus coeruleus (Swallow & Jiang, 2013). Turker and Swallow (2019) proposed that this mechanism might be extended to incorporate the effects of temporal selection on spatiotemporal context, because the locus coeruleus projects to a wide variety of cortical regions, including the hippocampus (Sara, 2009). In support of this view, a recent study revealed that the ABE-related enhancement might be mediated by a cerebral circuit connecting the locus coeruleus to the parahippocampal gyrus (Yebra et al., 2019), a structure which plays a critical role in contextual associative processing (Aminoff et al., 2013). Similarly, Moyal et al. (2020) found that auditory target detection was accompanied by a widespread enhancement in functional connectivity between the ventral visual cortex and the hippocampus. Future neuroimaging studies should determine whether these same circuits underlie the effect of target detection on forms of contextual memory such as those investigated in the present experiments.

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Code availability Not available.

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Declarations

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