Visual Memory of a Co-Actor's Target During Joint Search [1]

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Statements and Declarations

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Abstract

Studies on joint action show that when two actors turn-takingly attend to each other's target that appears one at a time, a partner's target is accumulated in memory. However, in the real world, actors may not be certain that they attend to the same object because multiple objects often appear simultaneously. In this study, we asked participant pairs to search for different targets in parallel from multiple objects and investigated the memory of a partner's target. We employed the contextual cueing paradigm, in which repetitive search forms associative memory between a target and a configuration of distractors that facilitates search. During the learning phase, exemplars of three target categories (i.e., bird, shoe, and tricycle) were presented among unique objects, and participant pairs searched for them. In Experiment 1, it was followed by a memory test about target exemplars. Consequently, the partner's target was better recognized than the target that nobody searched for. In Experiments 2a and 2b, the memory test was replaced with the transfer phase, where one individual from the pair searched for the category that nobody had searched for while the other individual searched for the category the partner had searched for in the learning phase. The transfer phase did not show search facilitation underpinned by associative memory between the partner's target and distractors. These results suggest that when participant pairs search for different targets in parallel, they accumulate the partner's target in memory but may not form its associative memory with the distractors that facilitates its search.

Keywords

joint action; task co-representation; incidental memory; contextual cueing effect

Visual Memory of a Co-Actor's Target During Joint Search

1. Introduction

People spend a great deal of time acting with others. Previous studies showed that when two persons cooperatively act toward a shared goal, their cognitive processes align with each other (e.g., Brennan et al., 2008; Dötsch et al., 2022; Niehorster et al., 2019; Szymanski et al., 2017; Towse et al., 2016). Even when they engage in seemingly independent tasks without a shared goal, their cognitive processes spontaneously align with each other (Becchio et al., 2010; Frith, 2012; Kampis & Southgate, 2020; Sebanz et al., 2003). Such spontaneous alignments have been principally shown in a situation where they act in turn-taking, and thus, they presumably focus their attention on each other's action/effector, such as hand actions (Frischen et al., 2009), trajectory of eye movements (Gobel et al., 2018), and action-directed stimuli (Sebanz et al., 2003). This turn-taking structure is considered to facilitate action coordination toward a shared goal (Meyer & Hunnius, 2020; Sebanz et al., 2006; Siposova & Carpenter, 2019; Sahaï et al., 2019). However, to understand how social interactions in broader situations change cognitions (Gallotti et al., 2017), investigation outside of this structure is required. Furthermore, there is a gap between the turn-taking structure and the real-world situation. In the real world, as multiple objects could appear simultaneously in a visual field, most behaviors involve search processes, although they may not always be regarded as searching (Wolfe, 2021). When two persons are searching, they may be unsure whether they attend to the same object simultaneously, unlike the turn-taking structure. Therefore, the present study investigated spontaneous alignments when two persons searched for different targets in parallel.

Evidence supporting spontaneous alignment in the absence of a shared goal is found in several paradigms (e.g., Atamaca et al., 2011; Böckler et al., 2012; Sebanz et al., 2003). In these paradigms, pairs of participants form shared attention, which refers to attending to the same object as a partner, based on knowledge about to which object the partner is attending (Böckler & Sebanz, 2013; Shyeynberg, 2010). In a study by Sebanz et al. (2003), a pair of participants sat alongside each other and were presented with two targets, which alternatingly appeared on the left or right side of the screen. One participant was assigned to one target while the other participant was assigned to the other target. They were asked to respond to the assigned target and ignore the other. The findings showed that the reaction time (RT) in this situation was similar to when the participants were assigned to both targets and responded on their own, but different from when they responded to one target and were alone. Existing literature suggests the idea of task co-representation, which is representation of some aspect of a partner's task (Knoblich et al., 2011; Sebanz et al., 2005; Vesper et al., 2017). In other paradigms, it has been observed that when two participants attend to each other's response target simultaneously, the partner's response target tends to be held in working memory (He et al., 2011; He et al., 2014), or it also tends to be accumulated in long-term memory (Elekes et al., 2016; Elekes & Sebanz, 2020; Eskenazi et al., 2013; Wagner et al., 2017). He et al. (2011) and He et al. (2014) demonstrated that after looking at a partner's to-be-remembered object (vs. nobody's to-be-remembered object) with the partner, the object was held in the participants' working memory and drew attention in a subsequent search task. Eskenazi et al. (2013) also showed that after looking at a partner's to-be-responded object (vs. nobody's to-be-responded object), that object was recalled better in a subsequent surprise recall test.

As Dötsch et al. (2022) pointed out, many previous studies, including those by He et al. (2011) and Eskenazi et al. (2013), made participants take turns in acting. This turn-taking structure had participants always attend to a partner's target at the same time as the partner. For instance, He et al. (2014) assigned a pair of participants (e.g., participants A and B) to one of three categories, respectively (i.e., animal, fruits, or musical instruments). In the beginning of a trial, an image of one category was presented and the corresponding participant (i.e., participant A) needed to remember it. Thus, this image was to be remembered by A and focused on by A and B simultaneously. Subsequently, a searcher (i.e., participant B) searched for a target circle that appeared near to or far from the to-be-remembered image for A. Next, A performed a memory recognition test. Although A's to-be-remembered image was not relevant to B, B's RT was shorter when A's to-be-remembered image was next to B's search target than when it was distant. This suggests that A's to-be-remembered object drew B's attention. This attention drawing was more evident than a priming effect, where the partner's to-be-remembered image was replaced with nobody's to-be-remembered image. He et al. (2014) suggested that the object that should be maintained in the partner's working memory was also maintained in that of the searcher since the latter represented the partner's task. In a study conducted by Eskenazi et al. (2013), two persons were separately allocated to one of three categories (i.e., animal, fruits/vegetables, or household items). They read words that appeared one by one and pressed a button when a word represented their own response category. Thus, they mutually attended to each other's target at the same time. In a subsequent memory recall test, not only one's responded words, but also their partner's responded words were better recalled than nobody's responded words (e.g., Elekes et al., 2016; Elekes & Sebanz, 2020; Eskenazi et al., 2013; Wagner et al., 2017).

Previous studies have mainly shown task co-representation and memory of the partner's target in the turn-taking structure. This may be due to these findings being involved in a line of research investigating how individuals coordinate actions to achieve a shared goal (Knoblich et al., 2011; Vesper et al., 2010; Vesper et al., 2017). This turn-taking structure may facilitate action coordination toward a shared goal. Simultaneously attending to the same object as the partner initiates and facilitates action coordination to achieve a shared goal (Sebanz et al., 2006). For instance, when two individuals move a two-handled picnic basket with each individual holding one handle and walking, attending to the same obstacle facilitates avoiding it. Attending to the same object or event also increases their tendency to care about one another (Knoblich et al., 2011; Siposova & Carpenter, 2019). For example, when one person slipped on the floor and when the slip was so loud that the person as well as another person standing near her/him are certain that both attend to it simultaneously, the standing person's tendency to help her/him stand up should increase (Siposova & Carpenter, 2019). Moreover, turn-taking actions are considered an important component of action coordination to achieve a shared goal (Meyer & Hunnius, 2020) and enhances the sense of joint agency (Sahaï et al., 2019; see also Zapparoli et al., 2022). However, to examine how social interactions in broader situations change cognitions, even without a shared goal (Gallotti et al., 2017), investigation outside of the structure that concerns a shared goal is required.

In the real world, multiple objects may appear simultaneously in a visual field. Therefore, individuals are often required to search for a relevant object, although it may not always be regarded as a search (Wolfe, 2021) because it happens so fast and/or is aided by the memory of the object or scene. Moreover, even if they know which object another person intends to act upon, they cannot keep track of the explicit moment-to-moment information about at which object another person is looking. When they find another's action object, they are not convinced that they are mutually attending to it at the same moment. While the previous studies (e.g., Eskenazi et al., 2013; He et al. 2011; He et al., 2014) indicate that two individuals exhibit task co-representation and memory of the partner's action object when they attend to it at the same moment as the partner, it is unclear whether they show the same effects when they attend to it that the partner attended at *some* moment. To understand how two individuals spontaneously align their cognitive processes in the presence of multiple objects even without a shared goal, the present study investigated a situation where two individuals search for different targets in parallel, that is, they are unsure whether they attend to the same object at the same time in such a situation.

While a partner's target may be attended and accumulated in memory, there is also an interplay between attention and memory (e.g., Awh et al., 2012). For instance, in a search task, repeatedly searching and attending to a target from the same layout forms an implicit associative memory between a specific target position and a specific layout of distractors (i.e., context), and this memory drives more efficient attention to the target. This effect is termed the contextual cueing effect (Chun & Jiang, 1998). When the same search layouts are presented repeatedly with random layouts in a random order, the contextual cueing effect is exhibited such that the RT in these repeated layouts gets shorter than that in the random layouts (Brady & Chun, 2007; Chun & Jiang, 1998; Sisk et al., 2019). To better understand the extent to which another person affects an individual's cognition, we investigated whether a partner's target draws attention more than other distractors, its position is associated with distractors in memory, and the associative memory guides attention to the partner's target.

In our prior study (Sakata et al., 2021), we examined whether a partner's attended distractors can be associated with the participants' own target. We presented two color sets of objects (i.e., blue and red sets of rotated T and Ls), and asked pairs of participants to search for different targets (a blue T and a red T, respectively). We did not find evidence of a partner's attended set of distractors (e.g., blue Ls) drawing attention and being associated with the participants' own target, but there were some limitations. First, the memory of the partner's target was not investigated, however, the distractors were. Second, as the participants' own target and their partner's attended distractors were divided by color throughout the experiment, the partner's distractors were easily filtered out (Wolfe, 2021). The contextual cueing effect is difficult to be observed when a target and distractors are separated by color (Jiang & Chun, 2001; Jiang & Leung, 2005; Vadillo et al., 2020). Zang et al. (2022) recently overcame these two limitations. Participant pairs searched for different targets (i.e., a black T and a white T) among black and white Ls in each trial. They were instructed which target each participant should search for in each trial (i.e., words “black” and “white” presented on the left and right side of the screen) and the target colors frequently changed across trials. Therefore, participants experienced searches of both target colors. However, the target color assignment for a specific configuration remained consistent throughout the learning phase. In the middle of the experiment, unbeknownst to the participants, Zang et al. (2022) swapped the instruction words for each configuration; that is, the participant was asked to search for a white T in the configuration in which they had searched for a black T and vice versa. As a result, the contextual cueing effect was found after swapping the instruction words. This was not found when the participants performed the entire experiment alone. These results suggested that participant pairs attended to both their own and their partner’s targets. However, unlike Eskenazi et al. (2013) or He et al. (2011), an undesignated target was not included, and thus it was unclear whether the partner’s target was prioritized more than other targets.

As an alternative way to assess whether a given distractor (and a partner’s target) can be associated with distractors, the present study used the paradigm of Conci and Müller (2012). Conci and Müller (2012) presented a distractor that had a similar physical feature to a target and told participants that it would become the target later in the experiment. As instructed, the participants searched for the target at first and then searched for the distractor from the middle of the experiment. The contextual cueing effect was observed for the distractor, as the RT for layouts repeatedly shown was still shorter than that for random layouts after the distractor became the new target (Conci et al., 2011; Conci & Müller, 2012); this suggested that a distractor that was attended more than others was associated with a context in memory. In the present study, to prevent a partner’s target from being filtered out easily by color and investigate whether the partner’s target draws attention more than other distractors and is associated with a context, we used real-world objects that could not be clearly determined by one specific feature (e.g., color). Moreover, using real-world objects also made the experiment setting more like real-world environments than using T and Ls. In such a search task, all the objects in the search field are not pre-attentively identified, nor do participants need to move their eye gaze serially to each object (Zelinsky, 2013). The objects in the peripheral area are pre-attentively judged both semantically (Zelinsky, 2013) and perceptually (Alexander & Zelinsky, 2011) to some extent.

The present study focused on a situation where participant pairs performed seemingly independent tasks without a shared goal in the presence of multiple objects. The aim was to investigate whether participant pairs spontaneously pay attention to the partner's target more than other distractors, remember it, and utilize the memory for subsequent behavior in such a situation. We hypothesized that even when participants are not certain about simultaneously attending to a partner's target, participants would pay more attention to and form a better memory of it than other distractors, which facilitates the subsequent search. Therefore, participant pairs were asked to simultaneously search for different objects from the same display while they were informed about each other's target category. Subsequently, In Experiment 1, a surprise memory recognition test was conducted regarding the target exemplars to investigate whether participants attended to a partner's target and formed a memory of the partner's target itself. In Experiments 2a and 2b, instead of the memory recognition test, the participants' targets were changed in the middle of the experiment to investigate whether they formed associative memory of the partner's target that would facilitate the search for it. It was predicted that a greater contextual cueing effect would be observed when participants searched for a partner's target as compared to another distractor as a new target[2].

2. Experiment 1

As memory formation during a search, incidental visual memory of attended objects has been shown (Castelhano & Henderson, 2005). In a study by Williams et al. (2005), a participant searched for a target determined by a specific color-category combination (e.g., white telephone) from an array containing real-world objects. In a subsequent surprise memory recognition test, the targets or distractors related to the targets (i.e., in the same color or category) were recognized better than the distractors unrelated to the targets (Williams et al., 2005). That is, if a partner's target draws attention, participants' own target, as well as their partner's target, may be memorized better than other distractors. Experiment 1 investigated whether a partner's target drew attention and whether its identity was memorized.

2.1. Materials and methods

We preregistered our hypotheses, primary analyses, and sample size. The preregistrations are available online (https://osf.io/e476t). Non-preregistered and exploratory analyses were indicated as exploratory. The study was conducted following the Declaration of Helsinki, and the procedure was approved by the Ethics Committee of the Unit for Advanced Studies of the Human Mind, Kyoto University, No. 30-P-17. Written informed consent was obtained from all participants prior to the experiment.

2.1.1. Participants

Thirteen pairs of university students (i.e., 26 participants) were recruited as strangers (*M*

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[2] Preregistered documents of hypotheses, primary analyses, and sample size for each experiment are available online in the Open Science Framework repository. The data and analyses codes in Experiments 2a, and 2b are also available on the OSF repository (https:// osf. io/2tf43/).

= 21.15 years old, *SD* = 3.08, females = 12). Participants were told their partner's name and affiliation in the university before coming to the experiment room, to check if they knew each other. We aimed to collect data from 24 participants based on the study of Williams et al. (2005), which recruited 24 participants. When we looked at the descriptive data of twelve pairs, we found that one participant did not follow the instruction (i.e., he/she pressed only one key in some trials and never pressed the other key). Therefore, we added one pair of participants. Consequently, we conducted the statistical tests with data from 25 participants (*M* = 21.24 years old, *SD* = 3.11, females = 12).

2.1.2. Apparatus and stimuli

The stimuli were presented on an LCD monitor (SHARP, LC-40DX2, 25.1° × 39.7° for visual angle). The experiments were operated with MATLAB (www.mathworks.com) and the Psych toolbox extension (Brainard, 1997; Kleiner et al, 2007; Pelli, 1997). A table was placed such that the edge of participants' sitting side was 110 cm away from the monitor. Two keyboards were on the table for recording the participants' responses. Two chairs' heights were adjusted in the beginning of the experiment to level the participants' eyes with the center of the monitor. The distance between the centers of two chairs was 60 cm. The distance between the center of the monitor and the participants' eyes was about 114 cm. We placed a transparent partition between each pair as a safety precaution due to the outbreak of COVID-19 (Fig 1). Pairs could clearly see each other, and the clear partition did not overlay the monitor from their viewpoint.

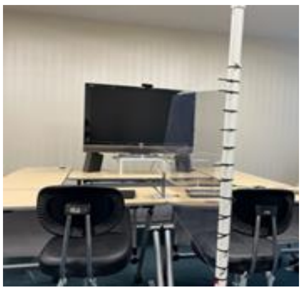

Fig. 1 The transparent partition was placed such that it did not overlay the monitor from the participants' viewpoint

We used the MIT dataset (Konkle et al., 2010; http://konklab.fas.harvard.edu/#) as target and distractor stimuli. For target categories, we chose a bird, shoe, and tricycle. We chose them because these images in the dataset were photographed from the side and participants could respond according to its orientation. Specifically, we used the original and mirror-reflected images and required participants to press a left or right button according to whether the beak, toe, and handle were facing the left or right of the bird, shoe, and tricycle, respectively. We selected 16 exemplars of each target category from the dataset and generated the mirror-reflected images to be the identical size as the original images. We also added 16 different target objects of each category collected from the BOSS dataset (Brodeur et al., 2010, https://sites.google.com/site/bosstimuli/download) and the Internet using Google image search and generated the mirror-reflected versions. Therefore, there were 32 target objects for each category. Before each run, half of them were randomly selected and used for both the search task and the subsequent memory test (i.e., old objects). The other half were used only for the memory test (i.e., novel objects). In the search task, one exemplar from each target category was presented in each trial. Similar to Makovski (2016), 350 unique objects were randomly selected from the dataset in the beginning of the running program and used as distractors for the search task. Thirteen distractors among them were presented with the targets in each trial. In the memory test, in addition to the 32 objects of each target category, 16 distractors that were used in the search task and 16 that were not used in the search task also appeared in the memory test.

Search objects subtended approximately a visual angle of 1.7° width × 1.7° height. They were presented against a white background on an invisible 12 × 8 grid (26.4° width × 17.6° height, with a jitter between 0 and 0.24° within each cell to reduce collinearity). Therefore, object locations were selected from 96 possible locations. Each block contained 16 trials.

Within each block, 16 target objects of each category were all different. However, the same target objects appeared once in every block. There were two conditions concerning the search array: one condition was referred to as the repeated trial, and the other was the control trial (see Fig 2).

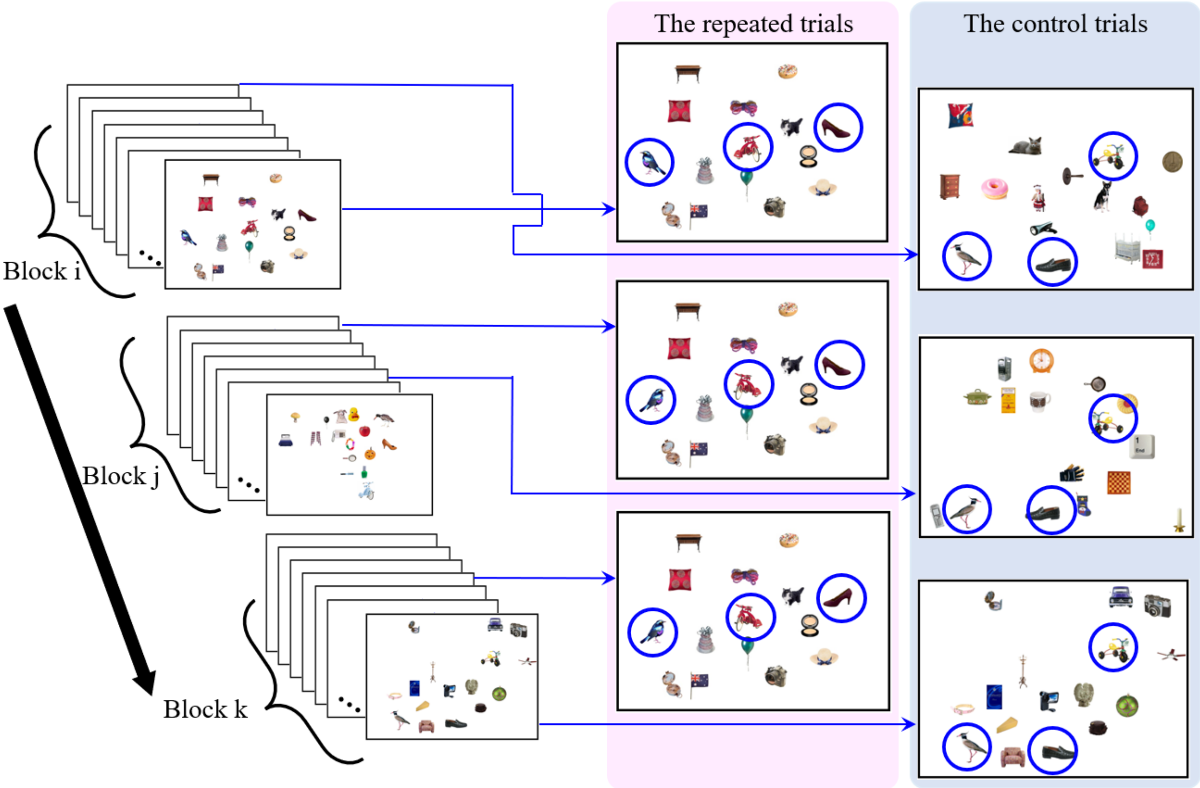

Fig. 2 The target categories were birds, shoes, and tricycles. Pairs of participants were introduced with all categories and allocated to different categories. They were asked to search for their own category and press a left or right key according to whether the beak, toe, or handle were facing the left or right of the bird, shoe, or tricycle, respectively. The original target images of the dataset or the mirror-reflected images were randomly selected for each trial. Identities and locations of the targets and distractors in the repeated trials were repeated once per block. Only identities and locations of targets in the control trials were repeated once per block. After 25 blocks, participants performed a surprise memory recognition test regarding the target exemplars

Each block contained eight repeated and eight control trials. At the beginning of each experiment, the program randomly selected eight target objects of each category for the repeated trials and the other eight for the control trials. The program also selected eight target locations for each category for the repeated and control trials (i.e., 16 target locations total). These locations were selected such that they were equally presented in each quadrant of the screen. In the repeated trials, both identities and locations of the targets as well as distractors were maintained. Therefore, 13 locations were randomly determined to be used for eight times as the distractor configurations of the repeated trials. These locations, as well as the target locations, were repeated once every block as the repeated trials. In the control trials, only the identities and locations of the targets were maintained, while those of the distractors were randomly selected for each trial. Within each block, the repeated and control trials were presented in a randomized order. Either the original or mirror-reflected images of each target object was randomly presented for each trial.

2.1.3. Design and procedure

The experiment consisted of the learning phase and the surprise memory test. Importantly, at the beginning of the learning phase, participants of all groups were introduced with all target categories and told that all of them would appear in every trial. An example of a search array composed of objects that were never used in the experiment was shown to the participants. Participants were explained the task for each target category (e.g., if a participant was assigned the bird category, the participant should search for and find the bird, and press the left or right button according to which side its beak is on). Subsequently, participants in pairs were told the category for which they and their partner were required to search. Therefore, they knew each other's category.

At the start of every trial, the fixation appeared in the center of the display for 1,000 ms. Subsequently, a search array was presented, and participants searched for their own target, pressing the left or right key as quickly and accurately as possible. We fixed the presentation duration of a search array to 2,500 ms in every trial, independent of participants' responses. Thereafter, a blank screen was shown for 1,000 ms. When participants made an error (i.e., improper key press, or either participant did not press the key within 2,500 ms), a beep sound occurred as an auditory error feedback. The pairs of participants were instructed not to speak to each other during the trials. They could take a short rest between the blocks and talk to each other just to check whether they wanted to take a short break or restart. The learning phase had 400 trials divided into 25 blocks.

After the learning phase, the pairs called the experimenter and took a rest for two minutes. Subsequently, they were told about the surprise memory recognition test. During the memory test, they were presented with 64 objects that appeared in the search task (i.e., old objects) and 64 that never appeared in the search task (i.e., new objects). Out of the old objects, 16 were participants' own targets, 16 were the partner's targets, and 16 were nobody's targets (eight were from the repeated trials and the other eight were from the control trials). Those 48 target objects were all presented 25 times during the search task. The remaining 16 objects were distractors that appeared at least once during the search task. Every object was presented for three seconds, alternating with a fixation image, which was presented for one second. Participants in pairs sat next to each other again, judged whether each object was new or old, and pressed the left or right key, respectively. Key assignment was counterbalanced across pairs. They were instructed that the memory test would take about five minutes without rest or any feedback and asked to press the button as accurately and quickly as possible. They were also told to respond with intuition within three seconds if they were unsure.

2.1.4. Analysis

Trials where the RT was shorter than 200 ms were excluded. Five blocks were collapsed into one epoch for further analysis based on previous studies (Makovski, 2016;

Makovski, 2018). R software (R Core Team, 2020) was used for all the analyses. For the learning phase, we carried out a two-way ANOVA, entering the configuration and epoch to examine the contextual cueing effect. For the memory test, we calculated the sensitivity to discriminate between the old and new objects based on the signal-detection theory (Hautus et al., 2021): d′ = z(hit rate) – z(false alarm rate), separately for each category. There were a few trials wherein the participant gave no response (0.2 %), and they were excluded from the analysis.

2.2. Results

2.2.1. The learning phase

The results of RTs and error rates in the learning phase are shown in Fig 3a. A two-way ANOVA, in which categorical independent variables were configuration (repeated vs. control trials) and epoch (from 1st to 5th epochs), and the dependent variable was RT, was conducted. A significant main effect of the configuration was found, $F(1, 24) = 7.41$, $p = .012$, $\eta_p^2 = .24$, as the repeated trials were faster than the control trials. The main effect of the epoch was also significant, $F(4, 96) = 86.20$, $p < .001$, $\eta_p^2 = .78$, due to RT decreasing with increasing epochs. A significant interaction between the configuration and epoch was also found, $F(4, 96) = 4.39$, $p = .003$, $\eta_p^2 = .16$. Multiple comparisons using Holm's Sequentially Rejective Bonferroni Procedure revealed that the first epoch did not show a significant difference between the trials, $F(1, 24) = 0.07$, $p = .792$, $\eta_p^2 = .00$, but the others showed, $F(1, 24) > 4.44$, $p < .046$, $\eta_p^2 > .16$. These indicate a contextual cueing effect. The error rate yielded a significant main effect of the epoch, $F(4, 96) = 25.80$, $p < .001$, $\eta_p^2 = .52$ as it reduced in accordance with the epoch. However, there were a non-significant main effect of the configuration and a non-significant interaction, $F(1, 24) = 2.70$, $p = .114$, $\eta_p^2 = .10$; $F(4, 96) = 0.32$, $p = .867$, $\eta_p^2 = .01$, indicating that the contextual cueing effect was not due to speed-accuracy trade-off.

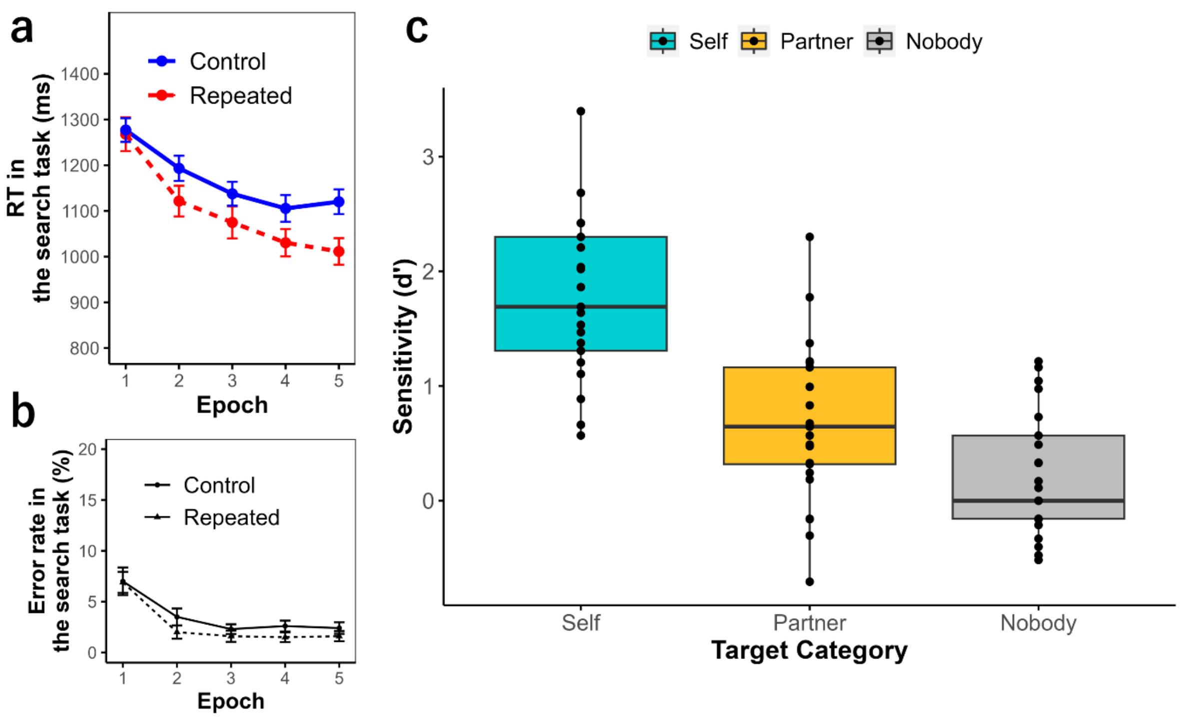

Fig. 3 (a) The reaction times (RTs) and (b) error rates in the learning phase in Experiment 1. (c) The performance in the subsequent memory test. The RTs are depicted in color and the error rates are depicted in gray scale. The repeated trials are shown as solid lines, and the control trials as dashed lines

2.2.2. The memory test

Memory performance is depicted in Fig 3b. For our critical test, we conducted a one-way ANOVA to compare recognition memory performance of the objects, which were assigned as target objects to the participants themselves, the partner, or nobody. As there was a significant main effect, $F(2, 48) = 41.07$, $p < .001$, $\eta_p^2 = .63$, multiple comparisons were carried out using Holm's Sequentially Rejective Bonferroni Procedure. As compared to the objects assigned to nobody, better performance was observed for objects assigned to the participants themselves, $t(24) = 9.12$, $p < .001$, as well as those assigned to the partner, $t(24) = 2.28$, $p = .032$. Objects of the participants themselves were also better recognized than those of the partner, $t(24) = 6.61$, $p < .001$.

We also compared memory performance of the participants' own target to the performance of the distractor objects. This was done for manipulation check such that participants' own targets were at least remembered better than the distractors. While all the old objects from the three target categories were presented 25 times during the search task, the old objects of the distractors from the control trials were presented less frequently (the least is once). Therefore, we predicted that participants' own targets were remembered better than distractors. We performed this analysis separately from the analysis above, because direct comparison between the three target categories and distractors was not controlled for both presentation frequency and category variety. The old objects of distractors were chosen from various categories. Category variety can affect memory performance, as performance is worse for many exemplars from the same category than for those from various categories (Konkle et al., 2012). When a *t*-test was applied, the distractors were expectedly less recognized, $t(24) = 8.46$, $p < .001$.

2.2.4. Exploratory Analysis

We investigated whether the participants who searched more quickly were likely to remember the partner's target better because they had time to attend to the partner's target after finding their own target. The RTs in the search task were not significantly correlated with the memory performance for the partner's target ($r = -.22$, $p = .28$).

2.3. Discussion

We found that the participants' own targets were remembered better than the partner's and nobody's targets. Furthermore, and most importantly, the partner's targets were also remembered better than the nobody's targets. This suggests that the participants paid attention to the partner's target and accumulated it in memory. Although they did not clearly attend to the partner's target at the same moment as the partner, they knew that the partner attended to it most among the search array. The participants' memory reflected the partner's attentional prioritization. Exploratory analysis suggested that enhanced memory for the partner's target cannot be explained by the search time.

3. Experiment 2a

Experiment 1 suggested that the partner's target drew more attention than other distractors and was accumulated in the participant's memory. Experiments 2a and 2b examined whether a partner's target was further associatively learned with the configuration of distractors. If the position of the partner's target was associatively learned with the configuration of the distractors, similarly to the participants' target, the partner's target would be found faster in the repeated than in the control trials when the participants were asked to search for it. Therefore, the experiment was divided into learning and transfer phases. In the transfer phase following the learning phase, one individual from a participant pair searched for what the partner had searched for in the learning phase, while the other individual searched for what nobody had searched for in the learning phase.

3.1. Materials and methods

We preregistered our hypotheses, primary analyses, and sample size. The preregistrations are available online (https://osf.io/bkwgq).

3.1.1. Participants

We recruited forty-two stranger pairs of university students (i.e., 84 participants). They were allocated to either the partner-target group (*M* = 20.07 years old, *SD* = 2.02, females = 22) or the nobody-target group (*M* = 20.12 years old, *SD* = 1.89, females = 22). G*Power was used to determine the sample size. The estimated effect size was f = 0.324 (η_p^2 = .095) based on the effect size in Experiment S1 (conducted before Experiment 2a; see Supplementary Information C). The power was set to 0.8. The number of groups (the partner-target vs. the nobody-target) and measurements (repeated vs. control) was two. Correlation among measurements and nonsphericity correction were set to 0.5 and 1 at default, respectively. We entered these numbers, choosing the repeated-measures ANOVA with within-between factors. It gave a sample of 27 for each group. The ideal number involved multiples of six due to counterbalancing the target categories and the sitting position of the groups. Therefore, we determined the sample size to be 30 for each group. Following Conci et al. (2011) and Conci & Müller (2012), participants who did not show the contextual cueing effect at the last epoch of the learning phase were excluded (see details in the Analysis section). Therefore, we continued to recruit participants until 30 in each group showed the contextual cueing effect at the 5th epoch. When the data collection of the 42 pairs was concluded, twelve participants were excluded from each group. The data from 30 participants in the partner-target group (*M* = 19.87 years old, *SD* = 1.61, females = 17) and 30 in the nobody-target group (*M* = 20.00 years old, *SD* = 1.80, females = 15) were used in the analysis.

3.1.2. Apparatus and stimuli

Apparatus and stimuli were identical to Experiment 1, with some exceptions. As the surprise memory test was not conducted, only 16 target objects chosen from the MIT data set were used. The additional 16 target objects collected from the BOSS dataset and the Internet using a Google image search were not used.

3.1.2. Procedure

The procedure of Experiment 2a was identical to that of Experiment 1, with following exceptions. While a two-minute rest was provided between the learning phase and the surprise memory recognition test in Experiment 1, the learning phase was immediately followed by the transfer phase in Experiment 2a. After the learning phase, the pairs called the experimenter, and the transfer phase was immediately initiated. The program showed which category each participant should search for in the transfer phase, as the partner-target group and the nobody-target group were determined based on their sitting position, which was counterbalanced across pairs. The partner-target group searched for the partner's past category, while the nobody-target group searched for a category allocated to nobody in the learning phase. The transfer phase had 160 trials divided into 10 blocks. In the repeated trials, the identities and locations of the targets and distractors were maintained from the learning phase. In the control trials, those of the targets were the same as the learning phase.

After completing the search task, participants were shown eight search arrays from the repeated and control trials, and asked to press a button (1–7) to indicate their familiarity.

3.1.2. Analysis

As pre-registered, we excluded participants who did not show the contextual cueing effect (i.e., shorter RT in the repeated trials than in the control) at the 5th epoch. We compared the means of the repeated and control trials of each participant at the 5th epoch. Using such a criterion was also carried out by Conci et al. (2011) and Conci and Müller (2012), although they compared the average of all the epochs of the learning phase. These studies used such a criterion because they investigated whether the contextual cueing effect was observed in both the pre-transfer target and the post-transfer target. Similar to Conci et al. (2011) and Conci and Müller (2012), the present study also asked whether participants exhibited the contextual cueing effect for the partner's target. Moreover, it may not be likely that participants form associative memory of the context with the partner's target but not with their own target. In Experiment S1, individual data showed that the difference between the RT for the repeated and control trials fluctuated across the epochs. Some of the participants initially exhibited a shorter RT for the control condition (i.e., the opposite direction to the contextual cueing), gradually decreased in that tendency, and finally displayed a contextual cueing effect at the last epoch. Therefore, we considered that the last epoch reflected the extent of participants' contextual learning in the learning phase more clearly.

3.2. Results

One preregistered analysis with a mixed effect modeling was moved to exploratory analysis, because entered variables of random and fixed effects described in the preregistration were inappropriate, and the model was replaced with multiple regression.

After exclusion, the 30 participants from each group were analyzed. As it has been cautioned that comparing at one epoch may not reflect the overall contextual cueing effect (Sisk et al., 2019), we also checked the correlation between the contextual cueing effect at the last epoch of the learning phase and that of the average across all the epochs, which showed a high correlation (r = .87). Fig 4 shows the RTs and error rates for each condition.

3.2.1. The learning phase

We conducted a three-way ANOVA to analyze RTs in the learning phase. The independent variables were group (partner-target group vs. nobody-target group), configuration (repeated vs. control trials), and epoch (from 1^{st} to 5^{th} epoch), and the dependent variable was RT. The contextual cueing effect was observed across the groups as there was a significant main effect of the configuration showing shorter RT in the repeated trials than the control trials $F(1, 58) = 94.76$, $p < .001$, $\eta_p^2 = .62$ and a significant two-way interaction between the configuration and epoch, $F(4, 232) = 9.87$, $p < .001$, $\eta_p^2 = .15$. Multiple comparisons showed a significant difference between the trials in all epochs, but the first epoch showed the smallest effect size $F(1, 58) = 16.82$, $p < .001$, $\eta_p^2 = .22$. The main effect of the epoch was significant due to shorter RT with an increase in the epoch, $F(4, 232) = 136.54$, $p < .001$, $\eta_p^2 = .70$, while that of the group was not, $F(1, 58) = 0.02$, $p = .892$, $\eta_p^2 = .00$. The two-way interactions were not significant between the group and configuration, or between the group and epoch, $F(1, 58) = 1.13$, $p = .293$, $\eta_p^2 = .02$, $F(4, 232) = 1.20$, $p = .096$, $\eta_p^2 = .03$, respectively. The three-way interaction was not significant, $F(4, 232) = 2.01$, p

= .094, η_p^2 = .03.

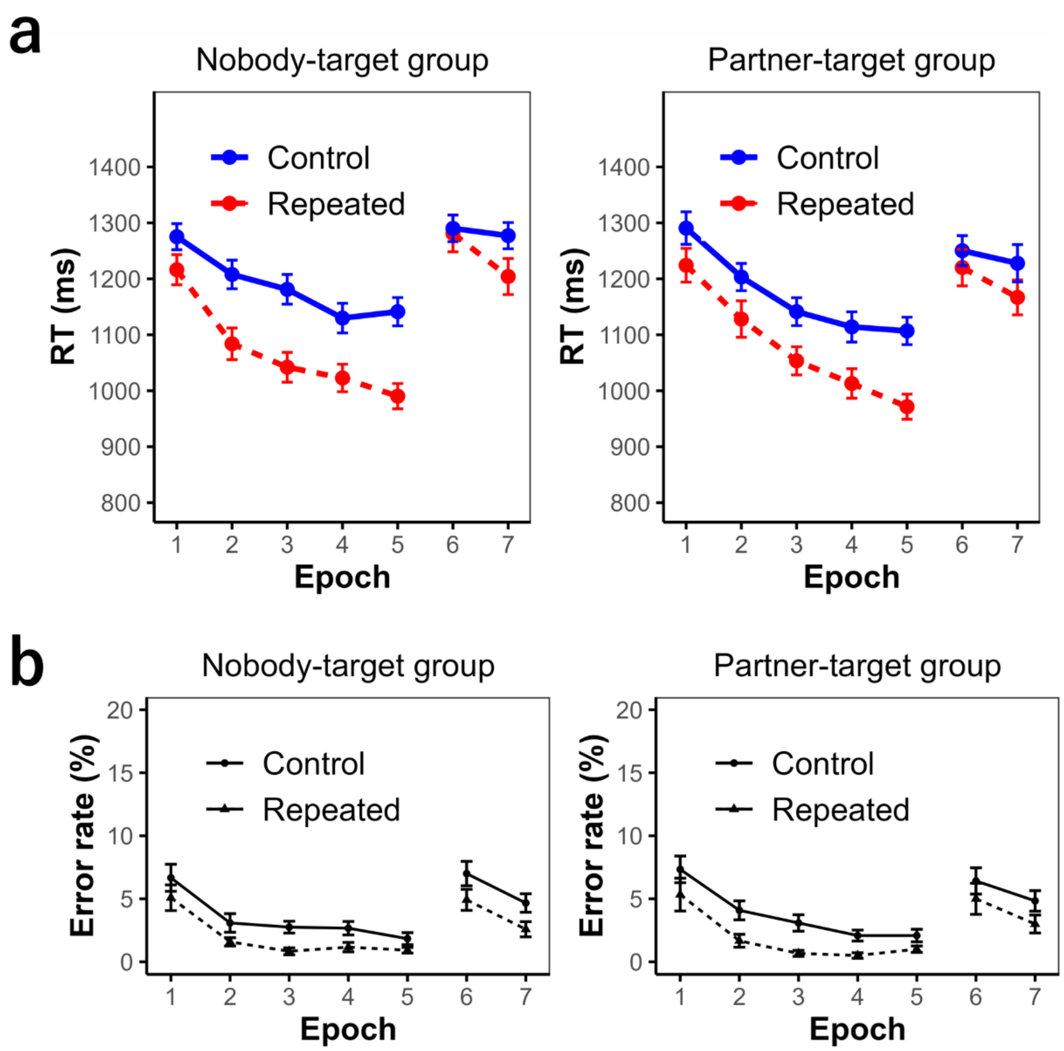

Fig. 4 The reaction times (RTs) and error rates in Experiment 2a. The RTs are depicted in color (a) and the error rates are depicted in gray scale (b). The repeated trials are shown as the solid lines, and the control trials as dashed lines

3.2.2. The transfer phase

To investigate our main question, we conducted a two-way (group x configuration) ANOVA for the first epoch of the transfer phase (i.e., the 6th epoch). We entered the group and configuration as independent variables and RT as dependent variable. The main effects of the group and configuration were not significant, $F(1, 58) = 1.93$, $p = .170$, $\eta_p^2 = .03$; $F(1, 58)$

= 0.95, p = .334, η_p^2 = .02. The two-way interaction was also not significant, $F(1, 58) = 0.28$, p = .601, η_p^2 = .01. We also conducted a Bayesian ANOVA with default prior scales (JASP Team, 2023; Morey & Rouder, 2015; Rouder et al., 2012), entering the group as a between-participant factor, and the configuration as a within-participant factor. The best model based on Bayes factors was the null model. The null model was preferred than the model including the main effects and the model including the main effects and the interaction by BF_{01} of 4.97 and 16.49 respectively. The findings did not favor the model with the interaction.

3.2.3. Check speed-accuracy trade-offs

For accuracy, we carried out the same analyses as for RT. In the learning phase, the main effect of the configuration was significant as error rate was lower in the repeated than the control trials, $F(1, 58) = 30.93$, $p < .001$, η_p^2 = .35. The main effect of epoch was significant as error rate decreased with an increase in the epoch, $F(4, 232) = 35.01$, $p < .001$, η_p^2 = .38. Any other main effects and interactions were not significant, $Fs < .87$, $ps > .483$, $\eta_p^2 < .02$. In the 6th epoch, the main effect of the configuration was significant with lower error rate in the repeated than the control trials, $F(1, 58) = 4.99$, p = .029, η_p^2 = .08 while the main effect of group and the interaction were not, $F(1, 58) = 0.04$, p = .840, η_p^2 = .00; $F(1, 58) = 0.18$, p = .672, η_p^2 = .00. These results did not substantially produce speed-accuracy trade-offs.

3.2.4. Exploratory Analyses

The transfer phase, including the 6th and 7th epochs, was analyzed. The main effects of the configuration and epoch were significant, $F(1, 58) = 5.63$, p = .210, η_p^2 = .09; $F(1, 58) = 27.13$, $p < .001$, η_p^2 = .32. The two-way interactions between the group and configuration, and between the group and epoch were not significant, $F(1, 58) = 0.02$, p = .900, η_p^2 = .00; $F(1, 58) = 0.20$, p = .657, η_p^2 = .00. There was a significant interaction between configuration and epoch, $F(1, 58) = 12.65$, $p < .001$, η_p^2 = .18, such that the repeated trials took significantly a shorter RT than the control trials at the 7th epoch, F (1, 58) = 12.86, $p < 0.001$, $\eta_p^2 = .18$, but not at the 6th epoch, F (1, 58) = 0.95, $p = .334$, $\eta_p^2 = .02$. This interaction was not modulated by the group, as the three-way interaction was not significant, F (1, 58) = 1.55, $p = .219$, $\eta_p^2 = .03$.[3] Computing Bayes factors, we found that the best model included the main effects of the configuration and epoch and the configuration x epoch interaction. The second model included the main effects of the configuration, epoch, and group and the configuration x epoch interaction and gave BF_{01} of 1.22, comparing with the best model. The third model additionally included the group x configuration interaction to the second model and showed BF_{01} of 3.70. The full model with the three-way interaction showed BF_{01} of 16.96. These findings suggest that the contextual cueing effect was not different across the groups. When the error rates were analyzed, significant main effects of the configuration and epoch were found, F(1, 58) = 12.87, $p < .001$, $\eta_p^2 = .18$; F(1, 58) = 19.30, $p < .001$, $\eta_p^2 = .25$. There were no significant effects regarding the group or the interactions, $Fs < 0.33$, $ps > .566$, $\eta_p^2 < .01$.

Next, we assessed whether the contextual cueing effect at the 6th epoch was associated with target-distance between the learning and transfer phases. According to Makovski and Jiang (2010) and Yang and Merrill (2015), RT gets longer when a target is relocated to a distant rather than an adjacent location to the original location. Similarly, in the transfer phase in the current study, the new target located away from the initial target may show less contextual cueing effect. Therefore, the distance between the targets of the learning and the transfer phases in each trial was calculated for each participant. Followingly, the average distances of the repeated trials and the control trials were respectively calculated for each

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[3] We also performed the same analyses without exclusion in Experiments 2a and 2b, but there was no substantial change in the significant patterns.

participant. Then, the difference between the averages of the repeated and control trials was used as an index of target-distance. We carried out a multiple regression with the group and target-distance as independent variables. The dependent variable was the RT difference between the repeated and control trials in the 6th epoch. The RT difference between the repeated and control trials at the 6th epoch was not significantly related with the target-distance, $b = 0.012$, $p = .580$, group, $b = - 0.014$, $p = .732$, or their interaction, $b = 0.014$, $p = .653$.

Other exploratory analyses regarding the familiarity test are shown in Supplementary Information A–B.

3.3. Discussion

Neither the partner-target group nor the nobody-target group showed the contextual cueing effect at the first epoch of the transfer phase. Exploratory analysis found that both groups showed it at the 7th epoch, but the sizes were comparable across the groups. Experiments 2a suggested that the partner-target group did not associatively learn the position of the partner's target with the context during the learning phase.

While associative memory with the context was unlikely to be formed, one concern was that the results might stem from insufficient power. Therefore, Experiment 2b was conducted with a larger sample size. Additionally, to expect a larger effect size of the contextual cueing effect of the partner-target group in the transfer phase, the number of blocks in the learning phase was increased.

4. Experiment 2b

In Experiment 2a, the sample size was determined based on the effect size of our prior study with a small sample size (18 per group). However, it may not be an appropriate justification because the effect size obtained with a small sample may not be reliable (Brysbaert, 2019). Lakens (2022) proposes that the strongest justification was based on the smallest effect size that was considered interesting. Lakens (2022) also suggested referring to previous studies which targeted the same effect. The present study's critical analysis was a two-way ANOVA with one repeated-measure factor (repeated trials vs. control trials) and one between-subject factor (partner-target group vs. nobody-target group). This study's prediction was a significant interactive effect suggesting that the difference of the trials would be larger in the partner-target group than the nobody-target group. Regarding the interactive effect, the smallest effect size that is interesting and informative was considered the middle size (i.e., Cohen's d = 0.4, f = 0.20). Additionally, the present study referred to two types of previous studies. The first was the studies of the memory of a partner's action target (i.e., the joint memory effect, Eskenazi et al., 2013; Elekes et al., 2016; Elekes & Sebanz, 2020) since this study's predicted interaction was grounded on the joint memory effect. Some of the previous studies conducted a within-subject one-way ANOVA and showed that the joint memory effect had a large effect size. Moreover, one of them conducted a two-way ANOVA and revealed that the joint memory effect was significant in one condition but not in the control condition. This interactive effect had a larger effect size than the middle. These studies employed approximately 30 participants per group. The second was previous studies examining similar effects (i.e., the social inhibition of return). Some of these studies conducted a two-way ANOVA and employed approximately 35 participants per group (e.g., Gobel & Giesbrecht, 2020; Tufft & Gobel, 2021). Considering these two types of studies, it was assumed that an effect size for the present study's hypothesis could be examined with 40 participants per group. Since this study's main analyses were conducted after excluding participants who did not exhibit the contextual cueing effect in the learning phase, this sample was aimed at 40 individuals per group. In our previous study, the sample size before exclusion was 1.4 times the sample size after exclusion. Therefore, the sample before exclusion was determined to be 56 participants per group.

4.1. Materials and methods

We preregistered our hypotheses, primary analyses, and sample size. The preregistrations are available online (https://osf.io/y5weh).

4.1.1. Participants

As planned, fifty-six stranger pairs of university students (i.e., 112 participants) were recruited. As in Experiment 2a, one from each pair was allocated to the partner-target group (*M* = 20.70 years old, *SD* = 1.88, females = 27), and the other to the nobody-target group (*M* = 20.91 years old, *SD* = 2.23, females = 27). For analyses, we excluded those who did not show the contextual cueing effect at the last epoch of the learning phase. The nobody-target group had 11 participants to be excluded while the partner-target group had 9 participants. As a result, we analyzed the data of 47 participants in the partner-target group (*M* = 20.60 years old, *SD* = 1.89, females = 24) and 45 in the nobody-target group (*M* = 20.89 years old, *SD* = 2.33, females = 22).

4.1.2. Apparatus and Stimuli

The apparatus and stimuli were the same as Experiment 2a.

4.1.3. Procedure

The procedure of the learning phase in Experiment 2b was identical to that of Experiment 2a; however, it had three exceptions. First, the number of blocks in the learning phase was increased to 40. Therefore, Experiment 2b had eight epochs of the learning phase and two epochs of the transfer phase. Second, a two-minute rest was taken between the learning and transfer phases, similar to Experiment 1. Lastly, a familiarity test was not carried out at the end of the experiment since it was not informative to this study's hypothesis (see Supplementary Information A).

4.2. Results

As in Experiment 2a, we checked the correlation between the contextual cueing effect at the last epoch and that of the average across all the epochs of the learning phase, using the sample before exclusion. It showed a high correlation (r = .83). Since the number of excluded participants was different between the groups, ANOVA was conducted with applying type III sums of squares[4]. Fig 5 shows the RTs and error rates for each condition.

4.2.1. The learning phase

To analyze RTs in the learning phase, we conducted a three-way ANOVA, with entering group (partner-target group vs. nobody-target group), configuration (repeated vs. control trials), and epoch (from 1st to 8th epoch) as independent variables. We found a significant main effect of the group, $F(1, 90) = 8.57$, $p = .004$, $\eta_p^2 = .09$, as the nobody-target group showed shorter RTs than the partner-target group. We also found a significant main effect of the configuration, with shorter RT in the repeated trials than the control trials, $F(1, 90) = 132.32$, $p < .001$, $\eta_p^2 = .60$. The main effect of the epoch was significant due to shorter RT with an increase in the epoch, $F(7, 630) = 238.30$, $p < .001$, $\eta_p^2 = .73$. There was a significant two-way interaction between the configuration and epoch, $F(7, 630) = 9.59$, $p < .001$, $\eta_p^2 = .10$. Multiple comparisons revealed that all epochs had significant differences of the configuration, with the first epoch showing the smallest effect $F(1, 90) = 14.51$, $p < .001$, $\eta_p^2 = .14$, and the last epoch showing the largest $F(1, 90) = 195.27$, $p < .001$, $\eta_p^2 = .68$. The two-way interactions were not significant between the group and configuration or between the group and epoch, $F(1, 90) = 0.00$, $p = .953$, $\eta_p^2 = .00$, $F(7, 630) = 1.88$, $p = .071$, $\eta_p^2 = .02$, respectively. The three-way interaction was not significant, $F(7, 630) = 0.89$, $p = .513$, $\eta_p^2 = .01$. These results indicate that the contextual cueing effect was observed, but not differed between the groups.

[4] We also conducted the following analyses with taking out the last two participants data from the partner-target group to make the size of the groups equal, but the significance patterns were not substantially different.

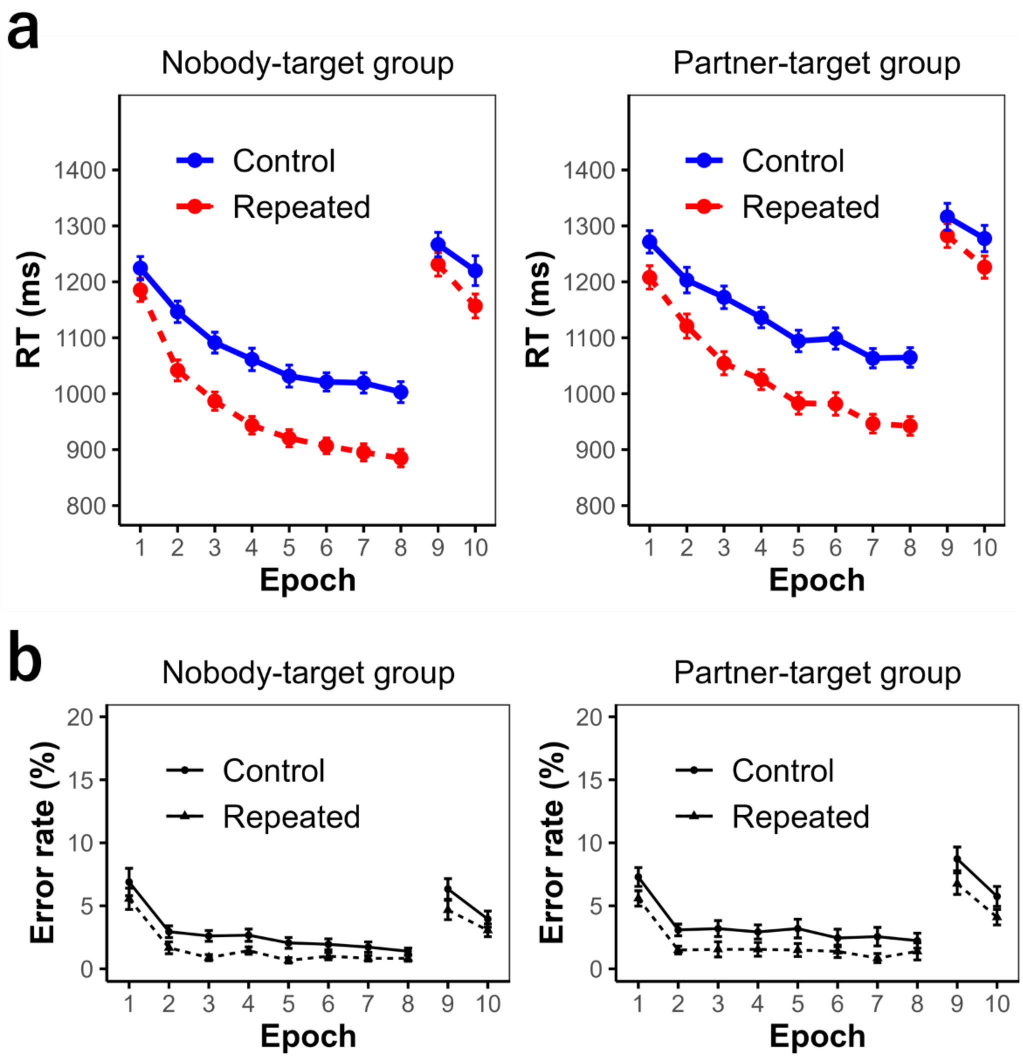

Fig. 5 The reaction times (RTs) and error rates in Experiment 2b. The RTs are depicted in color (a) and the error rates are depicted in gray scale (b). The repeated trials are shown as the solid lines, and the control trials as dashed lines

4.2.2. The transfer phase

Critically, a two-way (group x configuration) ANOVA was conducted for the first epoch of the transfer phase (i.e., the 9th epoch), with the group and configuration as independent variables and RT as dependent variable. The main effect of the group was not significant, $F(1, 90) = 3.56$, $p = .062$, $\eta_p^2 = .04$, while the main effect of the configuration was significant, $F(1, 90) = 4.47$, $p = .037$, $\eta_p^2 = .05$. The repeated trials took shorter RTs than the control trials, indicating the contextual cueing effect. However, the two-way interaction was not significant, $F(1, 90) = 0.00$, $p = .955$, $\eta_p^2 = .00$. We computed Bayes factors and found that the best model included the main effects of the configuration and group. This model was preferred than the model with the interaction by BF_{01} of 4.19.

4.2.3. Check speed-accuracy trade-offs

To check speed-accuracy trade-offs, we conducted the same analyses for error rates as for RT. In the learning phase, the main effect of the group was not significant, $F(1, 90) = 0.82$, $p = .368$, $\eta_p^2 = .01$. The main effect of the configuration was significant with lower error rates in the repeated than the control trials, $F(1, 90) = 48.46$, $p < .001$, $\eta_p^2 = .35$. The main effect of epoch was significant as error rate decreased with an increase in the epoch, $F(7, 630) = 42.34$, $p < .001$, $\eta_p^2 = .32$. Any interactions were not significant, $Fs < .59$, $ps > .444$, $\eta_p^2 < .01$.

For the transfer phase, in the 9th epoch, we found a significant main effect of the group, $F(1, 90) = 4.70$, $p = .033$, $\eta_p^2 = .05$. The nobody-target group showed lower error rates than the partner-target group. The main effect of the configuration was also significant with lower error rates in the repeated than the control trials, $F(1, 90) = 8.82$, $p = .004$, $\eta_p^2 = .09$. The interaction was not significant, $F(1, 90) = 0.06$, $p = .806$, $\eta_p^2 = .00$.

These results indicated that the direction of the differences found in the RT was not opposite to that in the error rates, and therefore did not show speed-accuracy trade-offs.

4.2.4. Exploratory Analyses

The transfer phase, including the 9th and 10th epochs, was analyzed. The main effect of the group was significant, $F(1, 90) = 4.59$, $p = .035$, $\eta_p^2 = .05$. The nobody-target group was faster than the partner-target group. The main effects of the configuration and epoch were also significant with shorter RTs in the repeated than the control trials, and in the 9th than the

10th epoch, $F(1, 90) = 9.63$, $p = .003$, $\eta_p^2 = .10$; $F(1, 90) = 55.05$, $p < .001$, $\eta_p^2 = .38$. However, there were no significant interactions, *Fs* < 3.30, *ps* > .073, $\eta_p^2 < .04$. We also computed Bayes factors and found that the best model included the main effects of the group, configuration, and epoch. The best model was preferred than the model additionally including the group x configuration interaction by BF_{01} of 3.54. The full model with the three-way interaction showed BF_{01} of 93.40. Thus, these results did not suggest difference in the contextual cueing effect between the groups. The error rates yielded significant main effects of the group, configuration and epoch, $F(1, 90) = 4.79$, $p = .031$, $\eta_p^2 = .05$; $F(1, 90) = 13.19$, $p < .001$, $\eta_p^2 = .13$; $F(1, 90) = 50.60$, $p < .001$, $\eta_p^2 = .36$. There were no significant interactions, *Fs* < 1.46, *ps* > .230, $\eta_p^2 < .02$.

Next, a multiple regression was carried out with the group and target-distance as independent variables. The RT difference between the repeated and control trials at the 9th epoch was significantly related with the target-distance, $b = 0.042$, $p = .031$, and not with the group, $b = - 0.006$, $p = .865$. Therefore, at the 9th epoch, the shorter relocation distance of the targets of the repeated trials compared to the control trials, the larger the contextual cueing effect. The interaction was not significant, $b = -0.053$, $p = .058$, although the relationship with the target-distance was evident in the partner-target group ($r = .32$, $p = .028$) but not in the nobody-target group ($r = .08$, $p = .587$).

4.3. Discussion

Experiment 2b examined whether the participants would pay attention to the partner's target more than other distractors and form a memory, which facilitated the subsequent search. It was predicted that the partner-target group would exhibit a greater contextual cueing effect than the nobody-target group in the transfer phase. Results showed better performance in the nobody-target group (i.e., shorter RTs, lower error rates) than the partner-target group across the phases. However, it did not interact with the configuration conditions.

This suggested that both groups showed comparable sizes of the contextual cueing effect. Conci et al. (2011) and Conci and Müller (2012) found that the effect size was maintained from the last epoch of the learning phase to the transfer phase. The present finding was that the effect size was reduced from the last epoch of the learning phase to the transfer phase (η_p^2 = .68 to .05) and approximate to that of the first epoch of the learning phase (η_p^2 = .14). The contextual cueing effect can be observed with five to ten repetitions of the repeated trials (Toh & Lee, 2022; Chun et al., 2000). Therefore, it is inferred that associative memory producing the contextual cueing effect at the 9th epoch may have been mainly developed during the transfer phase. However, in the transfer phase, the shorter the distance of the target location movement in the repeated trials compared to the distance in the control trials, the greater the contextual cueing effect. Therefore, memory regarding the target locations acquired during the learning phase may have assisted the search process after the target changed.

5. General Discussion

This study investigated whether participant pairs would spontaneously pay more attention to the partner's target than other distractors, remember it, and utilize the memory for subsequent behavior when they performed seemingly independent tasks without a shared goal. It was hypothesized that they would show these alignments outside the turn-taking structure that should facilitate coordination toward a shared goal. Participants were asked to search for different targets repeatedly in the learning phase. Following this, the surprise memory recognition test was conducted in Experiment 1 to investigate the memory of the identities of the partner's target. The results suggested that the partner's target was attended more than other distractors and that the identity of the partner's target was remembered better. In Experiments 2a and 2b, after the learning phase, participants were asked to search for a target that either a partner or nobody had searched for in the transfer phase. As a result, no difference in the contextual cueing effect between the partner's target and the nobody's target was observed, possibly indicating the limited formation of associative memory between the partner's target and distractor configuration.

Previous studies (Elekes et al., 2016; Elekes & Sebanz, 2020; Eskenazi et al., 2013; He et al., 2011; He et al., 2014; Wagner et al., 2017) had pairs of participants turn-takingly attended to each other's target and revealed better memory of the partner's target than nobody's target. From existing studies, it was unclear whether pairs would pay attention to and remember a partner's target if they did not attend to it at the same moment. It was also unknown whether memory about a partner's target facilitates participants' subsequent behavior. To address the first gap in the literature, Experiment 1 found evidence that the participants paid attention to a partner's target and formed memory about the partner's target identity. To address the second gap in the literature, Experiments 2a and 2b suggested that associative memory between the position of the partner's target and the context was not formed to a sufficient extent to facilitate subsequent search.

The present study found that the pairs of participants formed memory of each other's most prioritized object among a cluster of objects. Many instances of joint action are implemented with limited capacity to monitor each other's attended object (Vesper et al., 2017). Therefore, the relationship between shared attention and joint action should be examined (Böckler & Sebanz, 2013; Milward & Carpenter, 2018; Siposova & Carpenter, 2019). Frith (2012) put forward that without deliberate process, a partner's action can be taken into consideration and applied to participants' attention priority map. The present findings are consistent with this account because the participants were not instructed to pay attention to the partner's target. While this account was specified with an example involving reaching action (see also Frischen et al., 2009), the present finding further shows that attention and memory prioritization occurred without reaching action but based on tasks

(Figure 6). Previous studies showed that looking time to salient objects was longer when the participants believed that another person was looking at the same monitor (Gomes & Semin, 2020; Laforest et al., 2021; Richardson et al., 2007). The present findings suggest that when people know specific information about what a partner attends to, alignments in attention and memory occur for objects that are not necessarily perceptually salient. Furthermore, the present findings suggest that alignment in attention and memory may not require two persons to attend to one object exactly at the same moment.

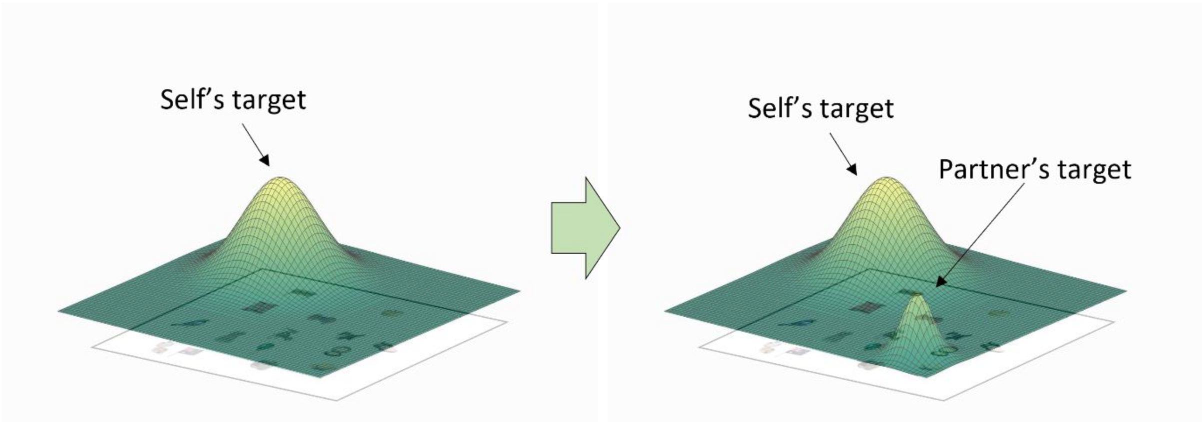

Fig. 6 The assumed model for the attention priority map. The left panel shows the map based on Brady & Chun (2007) as the attention is amplified most at the position of the participants' target. The right panel shows the map suggested by the results of the present study

While participants' current or future target is associated with context (Conci et al., 2011; Conci & Müller, 2012), the partner's target may be associated as little as the nobody's target. Previous studies have suggested that participants do not represent a partner's task in the same way as their own (e.g., Constable et al., 2018; Gambi et al., 2015; Hoedemaker & Meyer, 2019). For example, Hoedemaker and Meyer (2019) asked participants to name a sequence of three pictures alone or in taking turns with a partner. When the participants were responsible for all three pictures, they fixated on the second picture before the third picture.

When they were responsible for the first and third pictures and nobody was naming the second, they almost never fixated on the second picture. However, when the partner was naming the second picture, the participants fixated on it about 25% of the time, showing that the participants did not process the partner's naming picture with sufficient attention compared to their own naming picture. This may be because they were not motivated to attend to and complete the full processing of the partner's naming picture. Similarly, in the present study, the participants conceivably did not search for the partner's target as strongly as for their own. A weaker motivation to search for the partner's target relative to the participants' own target may have resulted in forming less associative memory. Moreover, in Conci et al. (2011) and Conci and Müller (2012), participants were told that a distractor would be a future target, and the distractor was associatively learned with the context. As the partner's target was never involved with the participants' task, it may be unlikely to be associated or may need immense learning sessions. When one configuration is associated with both primary and secondary targets, associations with the secondary target may depend on how much it is attended to during a search for the primary target.

Moreover, associative memory between the partner's target and a distractor configuration may be modulated by search motivation for the partner's target. Enhancing search motivation for the partner's target may lead to a larger contextual cueing effect for the partner's target than the nobody's target. For example, search motivation may be enhanced by instructing participants that the partner's target or the nobody's target would become a new target later in the experiment, as in Conci et al. (2011). Moreover, the relationship with a partner may also affect the search motivation for the partner's target (e.g., psychological closeness). Future studies can investigate how motivation and social effects are related.

Future studies can also assess the associative memory of the partner's target in a parallel situation similar to the current setting as well as that in a turn-taking situation.

Whereas responses of participant pairs in turn-taking, following the previous studies (e.g., Sebanz et al., 2003), searches can be considered in varied settings. Regarding this, we propose two settings. The first is that participant pairs search for the same target but respond to it in turn-taking. This can assess the associative memory of the partner's response target. In our prior work using the contextual cueing paradigm, we asked pairs of participants to search for the same target and decided which participant would respond according to the target orientation (Experiment 1 of Sakata et al., 2021). Therefore, similar to Elekes et al. (2016), Elekes and Sebanz (2020), Eskenazi et al. (2013), and Wagner et al. (2017), the one participant's response trial was the other's non-response trial, and vice versa (i.e., a turn-taking situation). In that case, motivation to search for a target is equivalent until the participants find out whether a target is actually their own response target or the partner's response target. The results showed that the contextual cueing effect emerged earlier than when the participants conducted the task alone. Associative memory of the partner's response target can be directly assessed by swapping the response targets within a pair. The second setting is that participant pairs search for different targets in parallel but are presented with only one target in each trial and thus respond through turn-taking. In this case, the distractor configuration associated with the partner's target is not identical to that associated with the participants' target. When the targets are not presented in the same display, each target may be associated with a corresponding configuration. Future studies should cautiously rule out the possibility that participants may use some strategies: for example, since participants can decide that the current display does not contain their target when finding the partner's target, they may search for both targets. Considering these two settings together can reveal the extent to which search processes should be shared between participant pairs to form associative memory of the partner's target.

The present study investigated whether participant pairs would spontaneously attend to the partner's target more than other distractors, remember it, and the memory would facilitate subsequent behavior even outside of the turn-taking structure. We observed evidence for identity memory of the partner's search target, although we did not find direct evidence for associative memory that could facilitate subsequent search behavior. The results suggest that the partner's target is accumulated in memory even when two persons are not certain that they simultaneously attend to each other's target, and interpersonal shared representation may be spontaneously created in the absence of tight temporal synchronization. This may be an underlying mechanism to spontaneously elicit appropriate behavior in cooperation or competition.

Declarations

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Competing interests

None. The authors have full control of all primary data.

Ethics Approval

All procedures were approved by the ethics committee of the Unit for Advanced Studies of the Human Mind, Kyoto University, No. 30-P-17 and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.

Consent to participate

Informed consent was obtained from all individual participants included in the study.

Data and/or Code availability

The data and analyses codes of the experiments are available on the OSF repository (https:// osf. io/ 2tf43/).

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