The Contextual Cueing Effect Disappears During Joint Search in Preschool Children

Abstract

During preschool years, children's interacting with others increases. One of the involved developmental skills is task co-representation, through which children 5 years and older represent a partner's task in a similar way to their own task. In adults, task co-representation makes participants attend to and form memories of objects relevant to both their own and their partner's tasks; however, it is unclear whether children can also form such memories. In Experiment 1, we examined the memory facilitation of joint search using a contextual cueing effect paradigm. Children were presented search displays repeatedly with the same or random layouts and searched and responded to the target either alone (the single group, *N* = 32, *M* = 73.6 months old, aged 61-80 months) or with their parent (the joint group, *N* = 32, *M* = 74.3 months old, aged 64-81 months). Results showed that the search with the same layouts was faster than that with the random layouts for the single group, indicating that children form associative memories of target and distractors relevant to their own task. For the joint group, this effect was not statistically different from that of the single group, with exploratory analysis suggesting it was disrupted. In Experiment 2, children performed the search with a peer (*N* = 32, *M* = 72.7 months old, aged 67-79 months) and the effect was also not found. Our findings suggest that the self's and partner's tasks are represented but may not be incorporated into associative memory in 5- and 6-year-old children.

Keywords

joint action; contextual cueing effect; co-representation; preschool children

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Children present a high motivation for social interactions (Tomasello & Carpenter, 2005; Tomasello, 2019). From an early age, they engage in joint action, which is any form of social interaction whereby two or more individuals coordinate actions (Sebanz et al., 2006), such as throwing a ball back and forth (Hay, 1976) or coordinating actions for collaborative games (Warneken et al., 2006). During preschool years, 3- to 5-year-old children's time for joint action increases (Butler & Walton, 2013; Parten, 1932) and their social skills develop (Meyer et al., 2016). The development of joint action is considered to involve the development of skills to represent some aspects of the self and of a partner (Meyer & Hunnius, 2020), including tasks (Milward et al., 2014) or mental states (Białek et al., 2022). Previous studies have investigated specifically how children represent a partner during joint action (Saby et al., 2014), and have revealed that children appear to represent the partner's task in a similar way to their own (Milward et al., 2014; Milward et al., 2017; Saby et al., 2014). Such representation is called task co-representation (see Knoblich et al., 2011; Sebanz et al., 2006; Sebanz & Knoblich, 2021 for reviews).

Developmental psychology literature shows behavioral evidence that task co-representation may occur from around 5 years of age (Milward et al., 2014; Milward et al., 2017; Saby et al., 2014). Specifically, the joint Simon effect (e.g., Sebanz et al., 2003) has been found to occur among 5-year-olds (Saby et al., 2014). In the joint Simon paradigm, one of two stimuli appears on either the left or right side of a screen. A participant is instructed to respond to one stimulus and ignore the other. When a partner responds to the other stimuli, although the participant's task is the same—and therefore, their performance should not change—their performance changed and was similar to the case in which they responded to both stimuli on their own. This suggests that participants may represent their own and a

[1] Abbreviations: reaction time (RT), analysis of variance (ANOVA)

partner's actions according to a particular target. Saby et al. (2014) suggested that 5- and 6-year-olds would represent their own and a partner's tasks when they act together. Similarly, in the studies by Milward et al. (2014, 2017), one of two stimuli appeared on the center of a screen, and 5- and 6-year-olds responded to one stimulus and ignored the other. Their performance worsened when a partner responded to the other stimulus rather than the same stimulus, suggesting that the children represented both their own and the partner's tasks. Such task co-representation presumably facilitates children's performance of coordinating with a partner by improving their prediction of the partner's action (e.g., Milward et al., 2017).

It is important to investigate how joint action shapes not only children's representation but also their later behavior. As joint action affects children's memory (e.g., directly observing a partner's manual or verbal actions enhances memory encoding of a novel word or object; Lytle et al., 2018; Sommerville & Hammond, 2007; Tessler & Nelson, 1994), and memory is a fundamental process that shapes later behavior (e.g., memory of a novel word or object may be used in future communication), the present study has focused on memory. Recently, studies with adults suggest that task co-representation leads participants to remember stimuli relevant to the partner's task (Elekes et al., 2016; Elekes & Sebanz, 2020; Eskenazi et al., 2013; Wagner et al., 2017). For example, Eskenazi et al. (2013) presented two participants with a sequence of words that were chosen from three categories (i.e., fruits/vegetables, animals, household items) one at a time on a PC monitor. Two participants were allocated to different categories and asked to respond with a button when a word from the allocated category appeared. Then, they were given a surprise recall test. The results showed that not only the words of their own category but also the words of their partner's category were recalled better than those of nobody's allocated category. These results suggest that when two participants act together, a participant is likely to attend to and remember objects related to their own as well as their partner's tasks more than objects related to nobody. Such memory enhancement in a partner's response trial is assumed to be underpinned by task co-representation (Elekes et al. 2016; Elekes & Sebanz, 2020; Eskenazi et al., 2013; Wagner et al. 2017). According to Elekes et al. (2016) and Elekes and Sebanz (2020), task co-representation, where participants represent a partner's task in a similar way to their own, leads participants to focus on stimuli relevant to their own and the partner's tasks similarly, resulting in memory enhancement of these stimuli.

While these studies involve memory of an object that is presented in isolation, previous studies with adults suggest that task co-representation also affects the memory of multiple objects (Sakata et al., 2021; Zang et al., 2022). In these studies, researchers employed a contextual cueing paradigm, in which the associative memory between target location and distractor configuration was implicitly and/or explicitly acquired (Chun & Jiang, 1998). In an empirical study with adult participants, unbeknown to a participant, the same layouts of a target and distractors are repeatedly presented (i.e., the repeated trials) with randomly generated layouts (i.e., the control trials) in a mixed order. Whether participants notice the repetition or not, their reaction time (RT) for a target gradually shortens in the repeated trials more than in the random trials (called *the contextual cueing effect*, Chun & Jiang, 1998). Associative memory between a specific target position and a specific configuration of distractors rapidly guides participants' attention toward the target (Chun & Jiang, 1998). Similar to Eskenazi et al. (2013), Sakata et al. (2021) asked pairs of participants to take turns acting—friend pairs (i.e., the joint group) jointly searched for the same target and pressed a button according to the target orientation (i.e., one responded to the target orienting to left, and the other responded to the target orienting to right). Different participants (i.e., the single group) individually searched and responded to the target orienting to one side but did not respond to the target orienting to the other side. Even though the individuals' task was identical across the groups (a Go/No-Go task), the results showed that the contextual cueing effect emerged earlier in the joint group than in the single group. The effect's emergence timing in the joint group was similar to the case of another experiment in which participants individually searched and responded to targets orienting to both left and right sides (i.e., the same as the original paradigm in Chun & Jiang, 1998). These results can be interpreted such that associative memory may have been formed not only in participants' own response trial but also in their partner's response trial, which consequently facilitated the emergence of the contextual cueing effect. Task co-representation made participants allocate attention to stimuli relevant to their own and the partner's tasks and facilitated associative memory in joint search.

In children, while previous studies show evidence that 5- and 6-year-olds form task co-representation, it is not clear whether children form memory of stimuli relevant to their own and a partner's task. When children form task co-representation, where they represent a partner's task in a similar way to their own, they may pay strong attention to stimuli relevant to the partner's task similarly to those relevant to their own task and form memory of both stimuli. Since multiple objects are often present simultaneously in life, searches are prevalent from an early age (Amso & Kirkham, 2021). Therefore, the primary aim of the current study was to investigate whether joint search facilitated the forming of implicit associative memory in 5- and 6-year-old preschool children. The contextual cueing effect has been observed in wide range of ages, such as infants (Bertels et al., 2017; Tummeltshammer & Amso, 2018; see Jiang et al., 2019 for a review) as well as in children aged 5 to 9 years (e.g., Dixon et al., 2015; Merrill et al., 2013; Yang & Merrill, 2014; Yang & Merrill, 2015a; Yang & Merrill, 2018). One concern is that the experiment procedures were slightly different from those employed in studies with adults (i.e., removing random layouts). It is not clear whether 5- and 6-year-old children can extract the spatial regularity of the repeated trials from the mixture of the repeated and control trials. A previous study recruiting 6- to 8-year-olds, 10- to 12-year-olds, and young adults suggested that there is a developmental difference in the ability to extract the regularity within the mixture and show the contextual cueing effect (Yang & Merrill, 2015b). A study using the electroencephalogram with adults (Vaskevich et al., 2021) provided neurological evidence for cognitive load when the random trials were mixed with the repeated trials. Therefore, our secondary aim was to assess the contextual cueing effect of 5- and 6-year-old children when they perform alone and add evidence that they attain developmental skills for extracting the regularity within the mixture and showing the contextual cueing effect.

In this experiment, children performed the visual search task either alone (i.e., the single group) or with their parents (i.e., the joint group). As for the joint group, children may experience joint search more frequently with a close partner rather than a stranger in daily lives. Moreover, Shafaei et al. (2020) showed that the joint Simon effect in adolescents and adults, assumed to reflect task co-representation, was larger when a partner was subjectively closer. Thus, we recruited children’s close others as their partners. During the task, the same search layouts were repeatedly shown (i.e., the repeated trials) with random layouts (i.e., the control trials) in an intermixed order. The target was oriented either on the left or right side. In Experiment 1, the children responded to the target oriented to one side in both the single and joint groups. In the joint group, we recruited their parents as their partners. The parents sat next to the children and responded to the target oriented to the other side. We expected that children would attend to the configuration more strongly when acting along with their parents than when acting individually, resulting in the acceleration of memory accumulation of the spatial regularity. Thus, we predicted that the joint group would show the contextual cueing effect earlier and/or in greater size than the single group. To generalize the findings of Experiment 1, we recruited children’s peer partners in accordance with Sakata et al. (2021) in Experiment 2.

Experiment 1

Methods

The hypotheses, primary analyses, sample size, and rationale of the study were pre-registered. Pre-registrations are available online ([the link is removed for double-blind review]). Non-registered analyses are labeled as exploratory below. The procedure of the study was approved by the Ethics Committee of XXXX University, No. XXX [removed for double-blind review].

Participants

Children were recruited through the child-participant database owned by the laboratory team in the university. They were assigned to either the single group or joint group, alternated based on order of participation. We had a preregistered target sample size of 32 for each group. For the sample size rationale, the expected effect size of the contextual cueing effect was "large" because the previous studies for testing the contextual cueing effect of children showed the large effect size (Dixon et al., 2010; Merrill et al., 2013; Yang & Merril, 2014; Yang & Merril, 2015a; Yang & Merril, 2015b; Yang & Merrill, 2018). To detect the interaction between the groups, we determined a sample of 32 for each group, which is the same size as Sakata et al.'s (2021) sample. Following the registered plan for data exclusion, children with high error rates were excluded (above 15 %; the rate was set to meet with the adults' data in Sakata et al. 2021). Children were added until the determined sample size was reached. Based on this procedure, we recruited 37 children in the single group (*M* = 72.5 months old, *SD* = 4.8, ranged from 60 to 80 months old, 17 females), and 38 children in the joint group (*M* = 74.0 months old, *SD* = 4.4, ranged from 64 to 81 months old, 18 females). Since five children in the single group and six children in the joint group were excluded, the final sample for analysis included 32 children in the single group (*M* = 73.6 months old, *SD* = 3.7, ranged from 61 to 80 months old, 17 females) and 32 children in the joint group (*M* = 74.3 months old, *SD* = 4.4, ranged from 64 to 81 months old, 18 females). One parent of each child in the joint group also participated as partners (26 females; information of their age is missing).

All of the children's parents reported that the children had normal or corrected-to-normal visual acuity. Parents in the joint group also had normal or corrected-to-normal visual acuity. Parents were provided with the study purpose, methodology, risks, right to withdraw, duration of the experiment, and handling of individual information. Written informed consent was obtained by parents of all children. The voluntary nature of participation was communicated to them prior to testing. They were paid JPY 2000 for their participation.

Apparatus and Stimuli

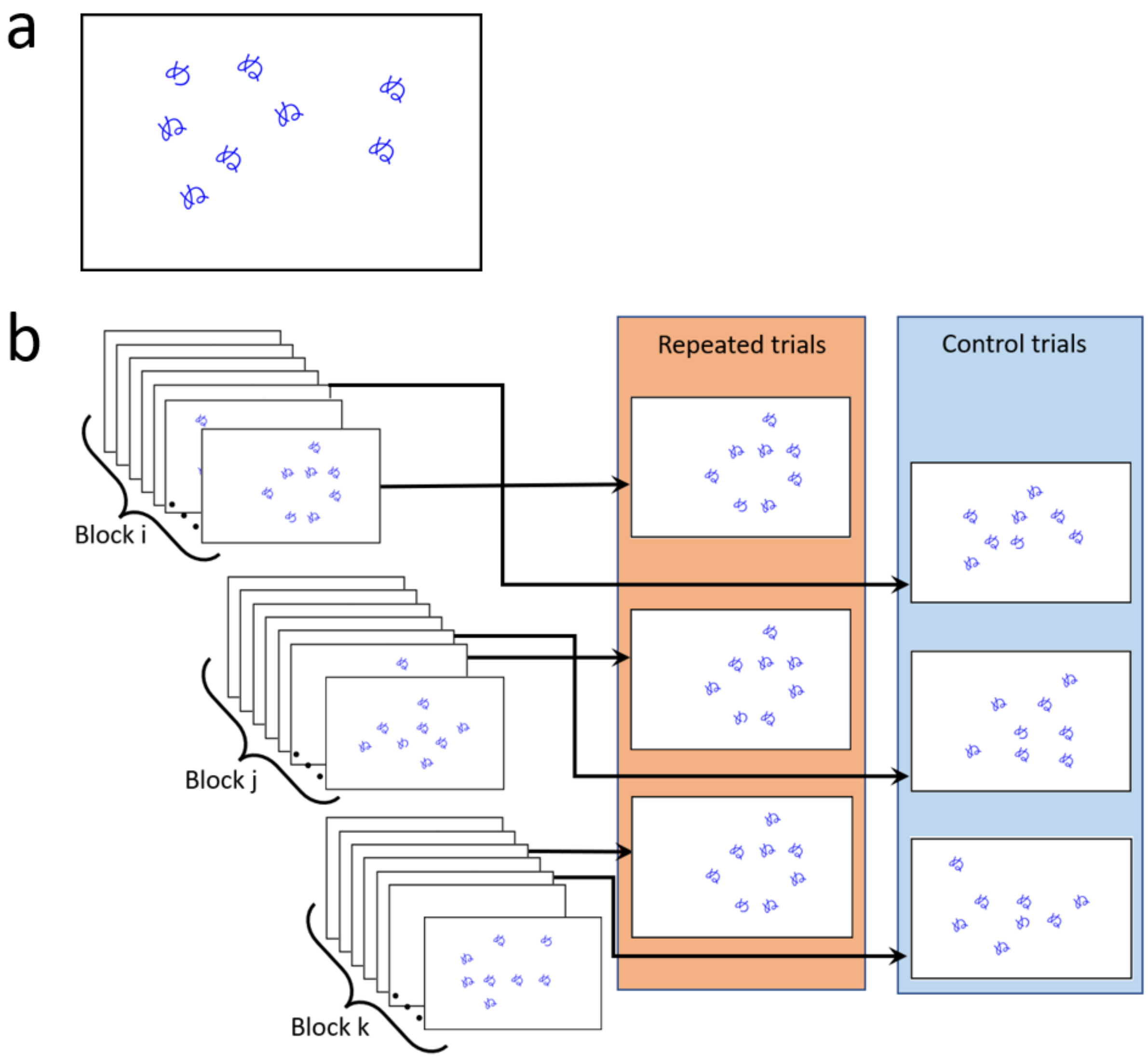
The experiments were operated with MATLAB (www.mathworks.com), using the Psych toolbox extension (Brainard, 1997; Kleiner et al., 2007; Pelli, 1997). The stimuli were presented on an LCD monitor (SHARP, LC-40DX2). Two keyboards to record responses were placed on a table 110 cm away from the monitor, and two chairs were placed in front of the table. The distance between the centers of the chairs was 60 cm. The child's chair height was adjusted such that their eye levels were aligned with the center of the monitor. The distance between the center of the monitor and the participants' eyes was about 114 cm.

We made stimuli children-friendly to lessen the burden in the recognition process, as the recognition process of the target and distractor is involved with working memory and long-term memory (Desimone & Duncan, 1995; Duncan & Humphreys, 1989; Wolfe, 2021). While letters of the English alphabet were used as a target and distractors in Sakata et al. (2021), Japanese Hiragana め (pronounced /mɛ/) and ぬ (pronounced /nu/) were used as the target and distractor in this study. They were subtending approximately 2° width × 2° height of visual angle. These Hiragana characters have been shown to be readable by almost all Japanese 5-year-olds (Ota et al., 2018). One target and seven distractors were presented on an invisible 6 × 4 grid (42° width × 28° height, with a jitter between 0° and 0.24° within each cell to reduce collinearity). All the stimuli were blue (50 cd/m^2) in color against a white (140 cd/m^2) background. The color luminance was measured with a light meter (KONICA MINOLTA JAPAN, INC. Luminance Color Meters CS-100A).

Twelve out of twenty-four locations were chosen as the target locations in the beginning of the experiment to equally present the target on the left and right sides of the search display. These locations were used once per block throughout the experiment. Each block contained six repeated trials and six control trials. In the repeated trials, a specific target location was always associated with a specific configuration of distractors. Thus, both the target location and distractor configurations were repeated across blocks. In the control trials, the distractor locations were randomly determined in each trial, and therefore, only the target locations were repeated across blocks (Figure 1). Presentation order of the repeated and control trials was randomized every block. Both in the repeated and control trials, the target was oriented toward the left in three trials and the right for the other three trials, which were randomly selected in each block. Thus, for each child in each block, there were six go trials and six no-go trials. Moreover, a specific target location paired with a specific distractor configuration in the repeated trials could be experienced as go trials in some blocks and no-go trials in other blocks. Similarly, a specific target location in the control trials could be experienced as go trials in some blocks and no-go trials in other blocks. The number of go and no-go trials for each target location was not made strictly equal, although the expected value was equal. Distractors were randomly oriented toward the left or right.

Figure 1

The Contextual Cueing Effect Paradigm



Note. (a) A search display contained one target (め) and seven distractors (ぬ). (b) The configurations within a block were all different, while half of them were shown once every block (i.e., the repeated trials). The other half were randomly generated every block, but only the target position was repeated (i.e., the control trials). The figure shows an example display of one configuration of the repeated trials and one target position of the control trials.

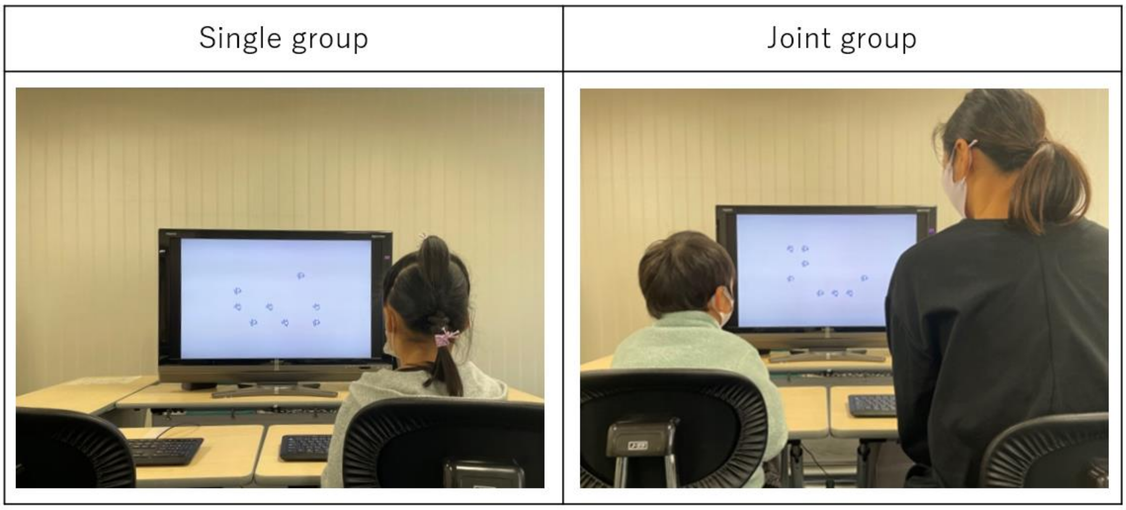
Procedure

Before starting the search task in the experiment setting, each child sat in front of a small note PC showing a Power Point display and were given step-by-step instructions. Their parents sat behind the child in both the single and joint groups, but this step-by-step instruction was directed to the children. At first, the child was shown め and ぬ and asked to say them aloud. After checking the sounds of these characters, they were shown two example search displays one by one. They were instructed to search for a target and point to it with their finger. Then, they were shown six other search displays and told to press the button when the target was oriented toward their assigned orientation. Half of them were told to press a button when the target was oriented toward the left. The other half were told to press the button when the target was oriented toward the right. The button was marked with a ladybug sticker. They were also instructed to say “do not press” when the target was oriented to the opposite of their assigned orientation. When the child pressed the button or verbally reported that they should not press the button, the experimenter gave feedback (e.g., “Yes, it should be pressed!” “Yes, it should not be pressed. You are right!”). After the child could respond correctly to all the displays, the rule instruction phase was over, and they moved to sit in front of the large monitor. The instruction phase took approximately five minutes.

Each child sat in the left or right chair, corresponding to their assigned orientation in the rule instruction phase (Figure 2). The parents in the joint group were told to sit next to the child and press a key when the target was oriented toward either the right or left, such that the parents’ assigned orientation was opposite to their child’s assigned orientation. The parents in the single group sat at the back of the experiment room. Ladybug stickers were put on number 1 of the numerical keypad of the left keyboard and number 3 of the right keyboard. The participants were required to search for the target and press the key as quickly and accurately as possible when the target was oriented toward their assigned orientation and not to press the key when it was oriented toward the opposite. They engaged in practice blocks followed by experiment blocks. The arrays in the practice blocks were different from those in the experiment blocks, as the program of the practice blocks randomly chose each target location and generated distractor configurations similarly to the program of the experiment blocks.

Figure 2

Experiment Setups in Experiment 1



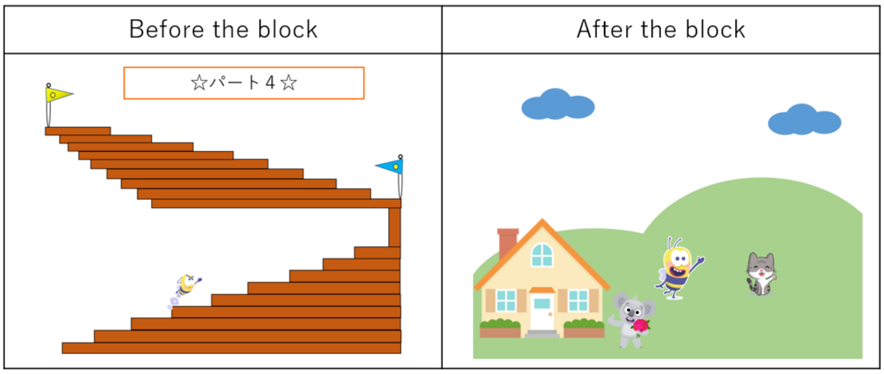
Note. The sitting position of each child was counterbalanced.

Every trial started with a fixation cross in the center of the screen for 1,000 ms. It was followed by the search display. The child searched for the target and pressed the button if the target was oriented toward their assigned orientation. The presentation duration of a search display was 3,500 ms, except that it was 6,000 ms in only the first block of practice trials (see below for the number of blocks). Irrespective of their response, after 3,500 ms, the blank display was shown for 1,000 ms with feedback. When the child (and the parent in the joint group) successfully made a response for their go trial or inhibited a response for their no-go trial, a smiley face appeared with a high pitch tone. When the child (and/or the parent in the joint group) made an error (i.e., improper key press or no key press), a frowning face appeared with a low pitch tone. Feedback was not discriminated for the child and parent in the joint group. Therefore, error feedback was also provided when the child made a correct response and the parent made an incorrect response, but such a case was rarely observed. We recorded all responses before the 3,500 ms time out (the presentation duration of a search display).

There were 24 practice trials divided into two blocks and 216 experimental trials divided into 18 blocks with small rest times in between. Immediately before the joint group carried out the practice phase, the experimenter said, "You will press a button when め is oriented toward left, and your parent will press a button when it is oriented toward right. For cases in which you respond correctly but your parent makes an error, you will see an error feedback. So, do your best and try not to make a mistake yourself. Ok, now we begin the practice phase." Through this instruction, the parents in the joint group were told what they should do. The experimenter also told them not to talk to each other and always face directly toward the monitor during the blocks. To maintain the child's motivation, a character of a bee was displayed on stairs before each block, and it went up one step for each block (Figure 3). After every block, different animal characters were shown. The child received enthusiastic praise and applause between the blocks from the experimenter.

Figure 3

Images Presented Before and After Each Block



Note. This figure depicts images before and after the 4th block as an example.

Analysis

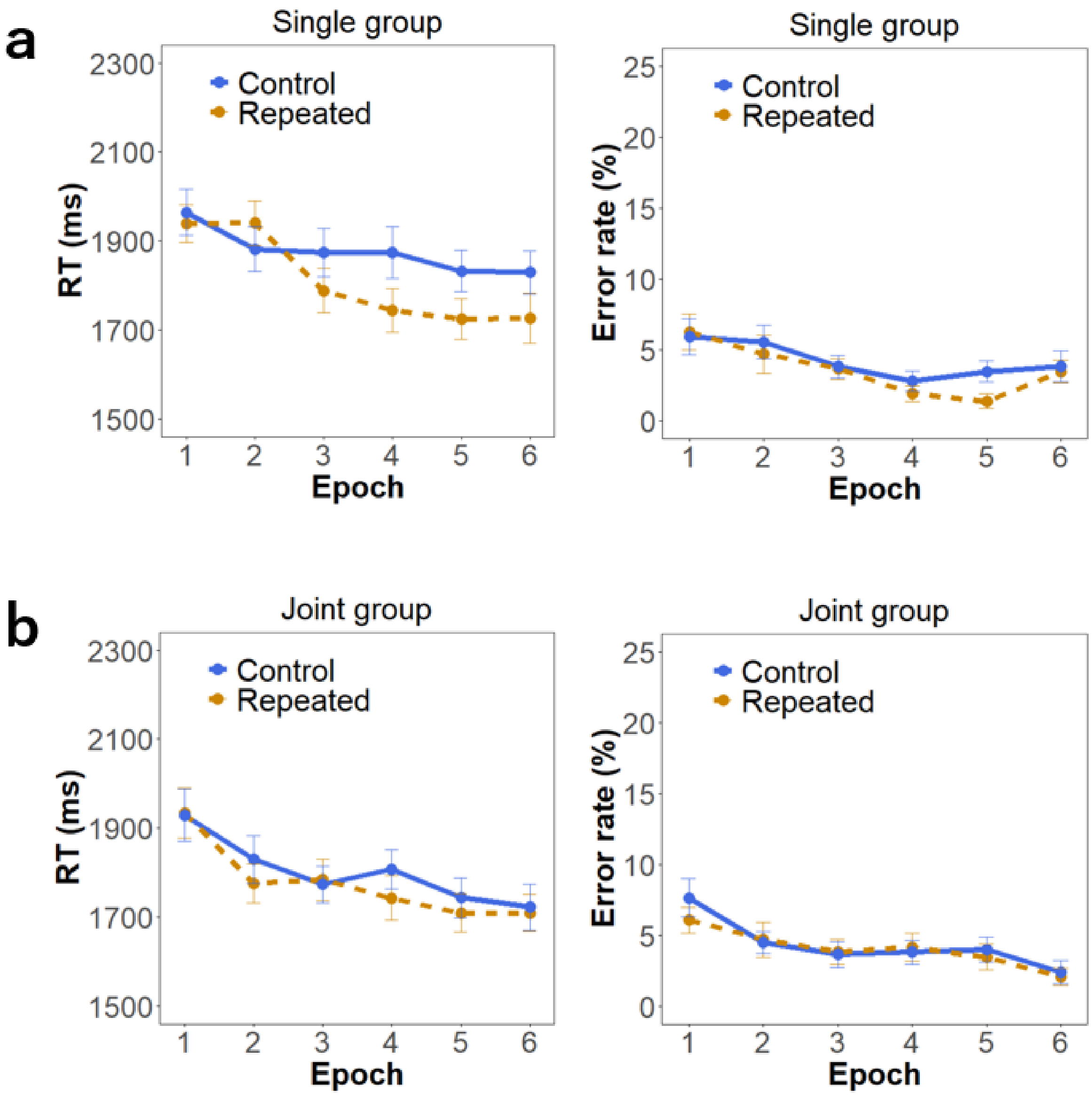
As per our preregistration, the trials in which the RT was shorter than 200 ms were excluded. The blocks were collapsed into six epochs for analysis. Specifically, we divided the 18 blocks into six epochs (each comprising three blocks) and calculated the average of the RTs of each participant's go trials in each epoch. R software (R Core Team, 2020) was used for all the analyses. To analyze RTs, we included go trials wherein the child responded correctly and applied a three-way analysis of variance (ANOVA). The independent variables were group (single vs. joint group), configuration (repeated vs. control trials), and epoch (1–6). For error rates, we counted omission and commission errors and conducted a three-way ANOVA with the same independent variables.

Results

Figure 4 shows the RTs and error rates in Experiment 1. A three-way repeated measures ANOVA revealed significant main effects of configuration, repeated = 1793 ms, control = 1838 ms; $F(1, 62) = 4.26$, $p = .043$, $\eta_p^2 = .06$, and epoch, Epoch 1= 1942 ms, Epoch 6 = 1747 ms; $F(5, 310) = 17.74$, $p < .001$, $\eta_p^2 = .22$. This indicates that the contextual cueing effect was found across the groups. There was no significant main effect of group, single = 1843 ms, joint = 1788 ms; $F(1, 62) = 1.19$, $p = .280$, $\eta_p^2 = .02$, as the overall RT was not different between the single and joint groups. Importantly, the interaction between group and configuration was not significant, $F(1, 62) = 0.85$, $p = .361$, $\eta_p^2 = .01$. Thus, the statistics did not support that the contextual cueing effect was different between the groups, though the size of the contextual cueing effect (i.e., the difference between the repeated and control trials) appears to be different between the groups in Figure 4. The interactions between group and epoch and between configuration and epoch were not significant either, $F(5, 310) = 0.75$, $p = .589$, $\eta_p^2 = .01$, and $F(5, 310) = 1.39$, $p = .228$, $\eta_p^2 = .02$, respectively. The three-way interaction was not significant, $F(5, 310) = 1.54$, $p = .178$, $\eta_p^2 = .02$.

Figure 4

Reaction Times and Error Rates in Experiment 1



Note. (a) Reaction times and error rates in the single group. (b) Reaction times and error rates in the joint group. The control trial is depicted by the solid line. The repeated trial is depicted by the dashed line. Error bars indicate the standard error for each condition.

The children's error rates including omissions and false alarms ranged between 0.9 % and 11.6 % (*M* = 4.0 %, *SD* = 2.5). There was a significant main effect of epoch, Epoch 1=

6.5 %, Epoch 6 = 3.0 %; $F(5, 310) = 7.96$, $p < .001$, $\eta_p^2 = .11$, which is presumably due to the practice effect. Other main effects and interactions were not significant ($F < 3.16$, $p > .080$, $\eta_p^2 < .05$).

Exploratory Analysis

The lack of interaction between configuration and epoch indicated that the statistics did not support the contextual cueing effect being different between the single and joint groups, and that both groups showed the contextual cueing effect. Even though it is not ideal to break down without a statistically significant interactive effect, for the exploratory investigation of the effect size of each group, we carried out ANOVAs separately for each group, entering configuration and epoch. The single group showed a significant main effect of configuration, repeated = 1810 ms, control = 1875 ms; $F(1, 31) = 4.40$, $p = .044$, $\eta_p^2 = .12$, and a significant interaction between configuration and epoch, $F(5, 155) = 3.22$, $p < .001$, $\eta_p^2 = .09$, thus showing the contextual cueing effect. However, in the joint group, the main effect of configuration and the interaction did not reach significance, repeated = 1776 ms, control = 1801 ms; $F(1, 31) = 0.66$, $p = .422$, $\eta_p^2 = .02$, and $F(5, 155) = 0.38$, $p = .864$, $\eta_p^2 = .01$, respectively, which implies the absence of the contextual cueing effect.

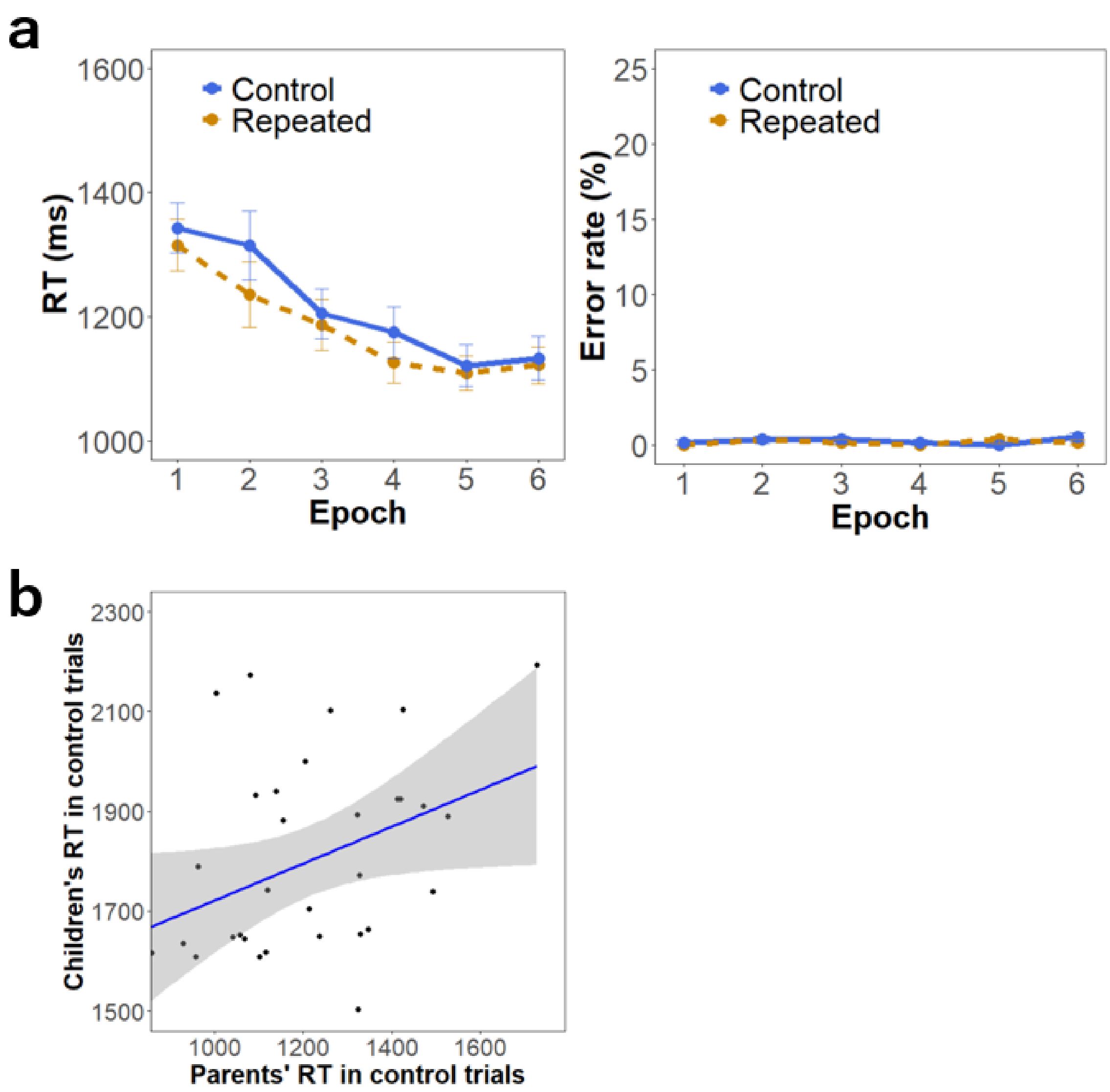
We also checked the RTs of the parents. Figure 5 shows the RTs and error rates of the parents who participated in the search task as a partner in the joint group. We applied two-way ANOVAs to analyze the RT and error rate, with configuration (repeated vs. control trials) and epoch (1–6) as independent variables. For the RT, we found significant main effects of configuration, repeated = 1182 ms, control = 1215 ms; $F(1, 31) = 4.82$, $p = .036$, $\eta_p^2 = .13$, and epoch, Epoch 1 = 1329 ms, Epoch 6 = 1127 ms; $F(5, 155) = 19.79$, $p < .001$, $\eta_p^2 = .39$, which indicates that the parents showed the contextual cueing effect. The interactions between configuration and epoch were also not significant, $F(5, 155) = 1.02$, $p = .405$, $\eta_p^2 = .03$. For the error rate, there were no significant main effects or interactions, $F <$

0.90, $p > .481$, $\eta_p^2 < .03$. Considering these results, the contextual cueing effect was found for the parents in the joint group.

To investigate whether the responses of the children in the joint group were affected by the responses of their parents who were sitting next to them and if the parents responded more quickly in general than the children, we examined the relationship between the RTs of the children and parents in control and repeated trials. RTs of the children and their parents were averaged throughout the epochs; they were significantly correlated in control trials, $r = .36$, $N = 32$, $p = .045$, but not in repeated trials, $r = .13$, $N = 32$, $p = .47$. In the control trials, the faster the parent responded, the faster the child responded.

Figure 5

Reaction Times and Error Rates of the Parents



Note. (a) Reaction times and error rate of the parents in the joint group. (b) The relationship between the reaction times of children and their parents in the control trials.

Discussion

Based on the preregistered analyses, we found a significant main effect of configuration. This effect was not modulated by group, as the interactions between configuration and group and between configuration, group, and epoch were not significant.

The results suggest that joint search did not enhance implicit associative memory. When analyzing each group in the exploratory analyses, however, a significant main effect of configuration, reflecting the contextual cueing effect, was found in the single group but not in the joint group. Considering the nature of the exploratory analysis, these results should be interpreted cautiously. Nevertheless, the exploratory findings imply that joint search may have hampered implicit associative memory. We did not hypothesize this, and it is opposite to the findings among adults in Sakata et al.'s (2021) study.

A possible reason for why this study's result was different from Sakata et al.'s (2021) may be that pairs of children and parents participated in the current experiment, while pairs of adult friends participated in Sakata et al.'s (2021) study. Child-parent relationships are largely different from friend relationships in terms of emotional dependence as well as the competency gap between a dyad. This may have resulted in the lack of the contextual cueing effect. The interpersonal entrainment refers to some perceptual information (auditory or visual cues) resulting in synchronous behavior of two individuals (Knoblich et al., 2011; Richardson et al., 2007). The RT of the children might have aligned with that of their parents through subtle visual or auditory information obtained from their parents' button pressing. Moreover, the parents' fast response put some pressure on or motivated the children to press a key quickly. Therefore, because the parents' RT was fast, the children's RT may have decreased to align with the parents' RT. The exploratory analyses provided supporting evidence that the RTs of children and their parents in the control trials were correlated in the joint group. This indicates that a child's response was fast when their parent's response was fast in the control trials. On the other hand, there was no significant correlation for the repeated trials. We considered that there should be some limit, as at some points, the children's RT cannot be shorter simply due to their ability. RT in the repeated trials may have reached this point because the contextual cueing effect shortened the RT in the repeated trials compared to the control trials. Therefore, in repeated trials, there may not be a variance that can produce a significant correlation, even though entrainment occurred for repeated trials.

In Experiment 2, we further investigated whether joint search affects the contextual cueing effect by reducing the effects of entrainment. As the parents' responses were much faster than peers' responses, children's responses may be entrained in the direction of speeding up mainly with a parent rather than with a peer. Therefore, we recruited pairs of peers in Experiment 2 to reduce the tendency to be entrained in the direction of speeding up and investigated whether the contextual cueing effect occurred. This modification is also consistent with the experiment procedure of Sakata et al. (2021), who recruited pairs of friends. Although using a barrier or headphones for children was another way to reduce such a tendency, we did not employ this manipulation because we were not certain regarding to what extent children consider such a controlled situation as "jointly acting with another person."

Experiment 2

In Experiment 1, the joint group did not exhibit an earlier emergence of or more pronounced contextual cueing effect as compared to the single group. Rather, joint search with parents disrupted the contextual cueing effect in children. In Experiment 2, we recruited peers of children to align the setting with Sakata et al. (2021) and to lessen speed pressure for the response that was caused by the children having a more competent partner (i.e., parents). We had two questions. The first question was whether joint search with a peer resulted in or attenuated the contextual cueing effect. If the joint-peer group showed a significant contextual cueing effect, we would investigate the second question—whether the formation of the contextual cueing effect was different between the joint-peer group and single group in Experiment 1.

Methods

We preregistered our hypotheses, primary analyses, and sample size (non-preregistered analyses are indicated as being exploratory). The preregistrations are available online ([link removed for double-blind review]).

Participants

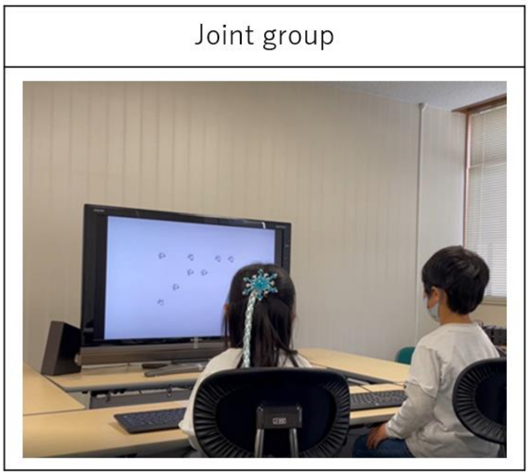
Participants were recruited from the database owned by the university and from kindergartens near the university. We asked parents to accompany their child and bring their child’s friend who went to the same kindergarten or lived in the same neighborhood along with the friend’s parent. It was ensured, by asking the parents, that the children in a pair knew each other. As in Experiment 1, we added participants until the determined sample size (32) was reached. The sample size of 32 was the same as that of the single group of Experiment 1, which showed the significant contextual cueing effect. The sample size of previous studies (Dixon et al., 2010; Merrill et al., 2013; Yang & Merril, 2014; Yang & Merril, 2015a; Yang & Merril, 2015b; Yang & Merrill, 2018) was around 20. Therefore, we determined a sample of 32 as sufficient to detect the expected effect size of the contextual cueing effect. The final sample to be analyzed included 32 children (M = 72.7 months old, SD = 3.0, ranged from 67 to 79 months old, 25 females). One pair did not complete the task and was therefore excluded from the analysis. Additionally, data from four children were excluded from the analysis because their error rate was higher than the criterion for Experiment 1. In sum, 38 children participated in the experiment (M = 72.9 months old, SD = 3.0, ranged from 67 to 79 months old, 26 females).

Apparatus and Stimuli

All the apparatus and stimuli were identical to those in Experiment 1. The only difference in the setup was that the peers sat side by side (Figure 6).

Figure 6

Experiment Setups in Experiment 2



Procedure

The procedure of Experiment 2 was almost the same as that of Experiment 1, with one exception. To explain the step-by-step instructions to each child in a pair separately, we asked one child to wait in another room with their parent until the instruction to the other child was finished. Thereafter, they switched, and we instructed the other child. Following this, before the practice phase, the experimenter had both children sit side by side in front of the monitor and said to them, “Child A (saying the child’s name) would press a button when め is oriented toward left, and Child B (saying the child’s name) would press a button when it is oriented toward right. For cases in which you respond correctly but your friend makes an error, you will see an error feedback. So, do your best and try not to make a mistake yourself. Ok, now we begin the practice phase.”

Analysis

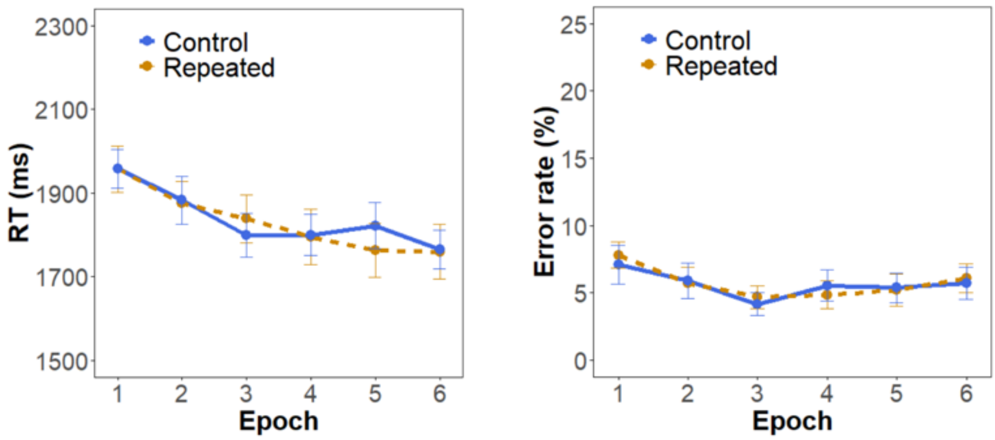
The blocks were collapsed, and R software was used as in Experiment 1. We conducted two-way repeated measures ANOVAs to analyze the RT and error rate, with configuration (repeated vs. control trials) and epoch (1–6) as the independent variables.

Results

Figure 7 shows the RTs and error rates. For the RT, the main effect of configuration was not significant, repeated = 1832 ms, control = 1838 ms; $F(1, 31) = 0.04$, $p = .853$, $\eta_p^2 = .13$, but the main effect of epoch was significant, Epoch 1 = 1957 ms, Epoch 6 = 1763 ms; $F(5, 155) = 8.04$, $p < .001$, $\eta_p^2 = .21$. The interaction between configuration and epoch was also not significant, $F(5, 155) = 1.02$, $p = .405$, $\eta_p^2 = .03$. These results indicate that the contextual cueing effect was not found in Experiment 2. The error rate of each child ranged from 0.9 % to 12. 0 %, and there were no significant effects, *Fs* < 0.90, *ps* > .481, $\eta_p^2 < .03$.

Figure 7

Reaction Times and Error Rates in Experiment 2



Note. The control trial is depicted by the solid line. The repeated trial is depicted by the dashed line. The error bars indicate the standard error for each condition.

Exploratory Analysis

As the data included both children in the pairs, we also conducted a mixed effect modeling in which RT was the dependent variable and configuration was the independent variable, with random intercepts of participant and pair. The result replicated the nonsignificant effect of configuration on RT, $b = 0.02$, $p = .738$, the significant effect of epoch, $b = -0.03$, $p < .001$, and the nonsignificant effect of the interaction, $b = 0.01$, $p = .614$.

Discussion

From the results, we did not observe the contextual cueing effect as a main effect of configuration, and the interaction between configuration and epoch was not significant. The results therefore suggest that children's engagement in joint search disrupted the contextual cueing effect even with peers. The response of the peer partners in Experiment 2 was not as fast as the response of the parent partners in Experiment 1. Although we recruited peer partners similar to the study by Sakata et al. (2021) and the speed gap within pairs was smaller than in Experiment 1, the contextual cueing effect was not observed.

General Discussion

The current study aimed to investigate whether joint search enhances implicit memory in 5- and 6-year-old preschool children. We employed the contextual cueing paradigm and examined whether the contextual cueing effect, which is underpinned by associative memory between a target position and distractors in a configuration, would be observed in an earlier epoch or to a larger degree in the joint group than in the single group. The results in Experiment 1 showed statistically comparable contextual cueing effects across the groups, though the RT patterns were different. Separate analyses for each group revealed that the contextual cueing effect was present in the single group but not in the joint group. As the RTs of children and parents in the control trials were correlated, we presumed that the RT in the control trials may be sped up by entrainment with the parent's fast response and reach the RT in repeated trials. Therefore, we conducted Experiment 2 with peer partners to investigate whether joint search would facilitate or disrupt the contextual cueing effect. Experiment 2 did not result in the contextual cueing effect.

For the single group, the current study adds evidence that the contextual cueing effect can be observed for 5- and 6-year-old preschool children. In studies showing the contextual cueing effect in a sample including 5- and/or 6-year-old children, the children were trained with repeated trials and were then shown the repeated and control trials to examine RT differences between the trials (e.g., Dixon et al., 2010; Merrill et al., 2013; Yang & Merril. 2014; Yang & Merril, 2015a; Yang & Merrill, 2018). Dixon et al. (2010) conducted an experiment in which both the repeated and control trials were presented five times, and the contextual cueing effect was not reliably observed. In the literature of the contextual cueing effect in adults, Vaskevich et al. (2021) suggested that during mixed presentation with the control trials, the contextual regularity becomes less stable, and its predictive value becomes relatively low. Consistently, the contextual cueing effect is more likely to be observed when the ratio of the repeated trials is high both for children from 6 to 8 years old (Yang & Merril, 2015b) and adults (Bergmann & Schubö, 2021; Zinchenko et al., 2018). In a previous study showing the contextual cueing effect in infants (measured not by manual reaction but by time taken until looking at one salient target), random layouts were not included (Bertels et al., 2017). In another study (Tummeltshammer & Amso, 2018), the target position in repeated trials was associated with not only the configuration of distractors but also the color of distractors and targets. Therefore, search facilitation can also stem from memory of the color of search items and not only from the configuration of distractors (Kunar et al., 2014). The current study adds evidence that 5- and 6-year-old preschoolers can form associative memory between a target position and distractor position even when the random layouts are presented equally often with the repeated layouts in an intermixed order, by repeating the layouts many times.

The results of Experiments 1 and 2 suggest that joint search does not facilitate and even disrupts the contextual cueing effect in 5- and 6-year-old preschool children. Although we did not hypothesize this before conducting the current study, two reasons for the findings can be considered. First, the partner's presence may have attracted the child's attention and averted it from the monitor. Previous studies with adult participants suggest that, for the contextual cueing effect to be observed, attention should be deployed to the distractor configuration (Jiang & Leung, 2005; Jiménez & Vázquez, 2011; Vadillo et al., 2020). The children in the joint group may have allocated covert attention to their partner. If so, they should have omitted their response or taken longer to respond. However, the overall performance regarding RTs and error rates was comparable between the joint and single groups. Therefore, this does not seem to be a primary explanation.

Second, response selection may have utilized cognitive resources, leaving little for the contextual cueing effect. When participants only consider their own task, they only judge the target orientation in each trial and make a decision regarding their response. When they also consider their partner's task, they need to discriminate between these tasks and make a response decision. In a previous study, adult participants flexibly represented the tasks and switched the corresponding responses as if they operated two responses as their own in the joint situation, and they acquired information related to both responses (Sakata et al., 2021). However, the 5- and 6-year-old children in the current study may have utilized more cognitive resources to discriminate between the tasks and switch the responses accordingly. Previous studies with 5- and 6-year-old children (Milward et al., 2014; Milward et al., 2017) imply that the flexible representation of the self's and others' tasks is cognitively demanding. Therefore, it is reasonable to consider that flexible representation may be difficult for children who have low inhibitory control. To flexibly represent two tasks, inhibitory control and working memory are needed (Gerstadt et al., 1994). It is possible that the children did not show the contextual cueing effect during joint search because their working memory (Gathercole et al., 2004; Luciana & Nelson, 1998) and inhibitory control (Moriguchi, 2014) are still developing around these ages, and the response selection utilized and left little cognitive resources for forming associative memory. As the current study design cannot address which component (e.g., spatial working memory or central executive) was critical, a future study is needed to further elucidate the findings. This study suggests that joint action may not always help children aged 5 and 6 in accumulating memory of the external world.

As children spend a significant amount of time socially interacting, it is important to investigate how their memory changes through social interactions. From infancy to childhood, memory of a novel object is enhanced in some social contexts, such as when observing others' gaze direction (e.g., Wu et al., 2011), verbal referring (e.g., Tessler & Nelson, 1994), or hand action (e.g., Lytle et al., 2018; Yoon et al., 2008). It remains unclear whether children also modulate their attention deployment and memory prioritization in accordance with another's task when acting along with others. For the first step, we predicted that 5- and 6-year-olds can do so because they attain task co-representation. There was evidence to suggest that children of these ages come to represent their own and another's task rules when acting together (e.g., Milward et al., 2014). Representing both tasks may also require the theory of mind, that is, the ability to appropriately attribute different mental states to self and others (see also Milward & Sebanz, 2016), and explicit theory of mind is acquired by 5-year-olds (Wellman et al., 2001). However, the current results imply that joint active involvement of self and others may deteriorate children's memory. Therefore, there may be certain developmental skills to smoothly modulate their attention deployment and memory prioritization in accordance with another's task. Future studies should investigate what developmental skills are needed to accumulate memory of both self-related and others-related information during joint active involvement. Five- and six-year-old children *just* become able to represent self- and others-tasks. Previous studies have shown that 5- and 6-year-olds can produce a complementary action for a partner's action in some collaborative games, but not younger children (Brownell, 2011; Meyer et al., 2015; Meyer et al., 2016; Sacheli et al., 2019; Warneken et al., 2014), which suggests that they can represent self- and others-tasks; however, studies recruiting both children and adults have also reported that their actions are not as smooth (i.e., accurate and rapid) as those of adults (Meyer et al., 2016; Paulus, 2016; Sacheli et al., 2019). Moreover, more fine-grained coordination skills are still developing in 5- and 6-year-old children (Satta et al., 2017; Viana et al., 2020; Milward & Sebanz, 2018). Children at the age where they can smoothly produce a complementary action for a partner's action may have some skills that enable them to flexibly operate self- and others-tasks and accumulate related memory.

One of the limitations of the current study is that the short time presentation duration of search layouts and accuracy feedback may have put pressure on the children. The contextual cueing effect may be found in the joint group if these pressures are lessened and if they can save cognitive resources from response selection for associative memory. Another limitation is that the measurement of the current study was reaction time, and we assessed it as an index of implicit memory. In other words, the current paradigm cannot rule out a possibility that associative memory is formed but not expressed in the reaction time, because reaction time may be additionally affected by noise or motivation (including entrainment). The contextual cueing effect may be observed immediately after controlling the confounding factor (i.e., removing the parent in the middle of the experiment). Future study could examine this possibility.

Finally, although we did not use a barrier or headphones, it would be interesting to see whether such a manipulation affects children's contextual cueing effect. In the literature of adult participants, while the referential coding account (Dolk et al., 2014) suggests that visual/auditory noise is a trigger for participants to integrate self and others, Elekes et al. (2016) revealed that noise was not critical for participants to remember their own and a partner's action objects. Therefore, using a barrier or headphones could cancel noise and prevent entrainment, while perhaps the effects on memory can still be expected in children. Moreover, there may be developmental differences in the tendency to represent a partner's task only with the belief that the partner is performing a certain task in a separate room.

Conclusions

The current study aimed to investigate whether joint search enhances implicit associative memory in 5-and 6-year-old preschool children. The results in Experiments 1 and 2 revealed that joint search with a parent or peer did not facilitate but disrupted the contextual cueing effect. The current results suggest that the children were able to produce behavior adjusted to the environment in the single search, as the repeated distractors rapidly guided attention to the target, but they were not able to do so in the joint search. The results were inconsistent with what has been found in adults. Representing the self and a partner's tasks and incorporating them into implicit associative memory may be difficult in children of these ages.

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