

Positive Emotion Enhances the Adaptability of Contextual Cue Learning

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Abstract

Contextual cue learning lacks adaptability, which manifests in two aspects: first, difficulty in binding a new target location onto previously acquired scene representations (Re-learning), indicating that the updating of scene representations is obstructed; second, after acquiring a set of scene representations, difficulty in learning another entirely new set of scenes (New-learning). Research suggests that the ability to bind a new target location onto old scene representations may be related to attentional scope size, whereas learning new scenes requires resetting the learning function. Positive emotion can effectively broaden attentional scope and ameliorate rigidity in existing cognitive patterns; therefore, positive emotion priming may potentially enhance adaptability in contextual cue learning. The present study utilized emotional images with neutral and positive valence to prime corresponding emotions, investigating contextual cue learning when binding new target locations to old scenes and when learning entirely new scenes, to verify whether positive emotion can improve adaptability in contextual cue learning. The experiments revealed that positive emotion could not facilitate contextual cue learning for binding new target locations onto old scenes (Re-learning), but could facilitate learning of entirely new scenes (New-learning). These results indicate that positive emotion can enhance participants' scene learning ability and thereby promote learning of new scenes, yet cannot reduce automatic retrieval of old representations triggered by representational similarity, and consequently cannot improve the updating process of old representations.

Full Text

Positive Emotions Enhance Adaptability in Contextual-Cueing Learning

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Abstract

Contextual-cueing learning exhibits a notable lack of adaptability, manifesting in two distinct ways: first, difficulty in binding a new target location onto previously acquired scene representations (Re-learning), which reflects impaired updating of scene representations; and second, difficulty in learning an entirely new set of scenes after acquiring one set (New-learning). Research suggests that the ability to bind a new target location to old scenes may be related to attentional scope, whereas learning new scenes requires resetting the learning function. Positive emotions can effectively broaden attentional scope and reduce fixation on existing cognitive patterns, suggesting that positive affective priming may enhance the adaptability of contextual-cueing learning. This study used affective pictures with neutral and positive valence to induce corresponding emotional states, examining contextual-cueing learning when binding new target locations to old scenes and when learning entirely new scenes, to test whether positive emotion can improve adaptability in contextual-cueing learning. The results revealed that positive emotion did not facilitate contextual-cueing learning for binding new targets to old scenes (Re-learning), but did promote learning of new scenes (New-learning). These findings demonstrate that positive emotion can enhance scene learning ability and thereby facilitate learning of new scenes, yet cannot reduce automatic retrieval of old representations caused by representational similarity, and consequently cannot improve the updating process of old representations.

Keywords: contextual cueing, positive emotion, affective priming, visual search

Introduction

Contextual cueing refers to spatial layouts that can guide attention (Chun & Jiang, 1998). Building on previous research of real-world phenomena, Chun and Jiang hypothesized that visual contextual cues could improve visual search efficiency by guiding attentional allocation, and conducted a series of laboratory experiments to verify this hypothesis. In their experiments, visual scenes were divided into two categories: repeated scenes and novel scenes. Repeated scenes were defined as those where target and distractor positions remained fixed across trials, whereas novel scenes featured randomly changing target and distractor positions across trials. The results showed that search reaction times for repeated scenes were shorter than those for novel scenes, a phenomenon termed the contextual-cueing effect.

The contextual-cueing effect demonstrates that during search, participants

learned the contextual cues in repeated scenes and utilized these cues to improve search efficiency (Chun & Jiang, 1998). This effect has been replicated extensively in subsequent research (Chun & Jiang, 1999, 2003; Olson & Chun, 2001, 2002).

Contextual-cueing learning lacks adaptability, which manifests in two specific ways. First, after acquiring a set of contextual cues, changing the target locations in these learned scenes makes it difficult to learn the new target-related contextual cues (Re-learning). Second, after acquiring one set of contextual cues, learning another entirely new set becomes difficult (New-learning). The difficulty in Re-learning was discovered by Manginelli and Pollmann (2009). In their study, participants first learned a set of contextual cues. Subsequently, while maintaining the same distractor backgrounds, the target location was changed to a previously empty location. The results showed that even when these repeated scenes were presented far more times than during initial learning, no contextual-cueing effect emerged, indicating that learning of contextual cues related to the new target location was blocked. Another study found that after 30 repetitions of repeated scenes during the learning phase, participants required three consecutive days of intensive practice (80 repetitions) to establish new scene-target associations on old scenes, showing only a marginally significant contextual-cueing effect. Achieving the same effect magnitude as the old target location required seven consecutive days of practice (Zellin et al., 2014). While New-learning also demonstrates learning difficulties (Mednick et al., 2009), the repeated scenes in New-learning conditions are entirely new and completely different from old scene memory representations stored in the brain, unlike the highly similar Re-learning scenes. Zellin et al. (2013) found that for repeated scenes presented from the beginning of the task, participants showed a marginally significant contextual-cueing effect after only 2 repetitions. However, after 15 repetitions of repeated scenes during the learning phase, when presented with a new set of repeated scenes, participants required at least 20 repetitions to produce a marginally significant contextual-cueing effect.

Various methods can improve the adaptability of contextual-cueing learning. Research indicates that intensive practice, sleep, and quiet rest can facilitate learning of new scenes (New-learning) because sleep and quiet rest can reset cognitive control functions to varying degrees, allowing the learning function to restart (Mednick et al., 2009; Zellin et al., 2013). However, these methods cannot improve Re-learning difficulties (Zellin et al., 2013; Zellin et al., 2014). One study found that increasing the salience of the new target enabled participants to successfully learn updated contextual cues in Re-learning conditions. By increasing target brightness to attract attention, the study found that after changing the target location in learned scenes, a contextual-cueing effect could be produced after only 25 repetitions. The researchers argued that the highly salient target effectively attracted attention, broke existing attentional patterns and fostered new ones, while increasing attentional processing of the new target, ultimately facilitating updating of old scene memory representations and enabling formation of new memory representations linking the new target

location with the background (Conci & Zellin, 2021). Another study directly compared contextual-cueing learning under Re-learning conditions during global versus local attention, finding that Re-learning became easier when participants engaged in global attention, but remained difficult during local attention. This suggests that establishing a more global background representation is an important condition for updating old contextual-cueing representations (Zinchenko et al., 2020). Overall, current research indicates that after acquiring a set of contextual-cueing representations, New-learning requires transitioning cognitive control to a more passive state, whereas Re-learning requires increased attentional processing of the new target or global attention to scenes.

Positive emotion exerts complex and widespread influences on cognitive processing (Ashby & Isen, 1999; Goschke & Bolte, 2014). Positive emotion refers to emotions with positive valence, associated with satisfied needs and pleasant subjective experiences (Guo & Wang, 2007). Bolte and Goschke proposed that positive emotion increases dopamine release, which acts on the prefrontal cortex and striatum to reduce cognitive stability and increase cognitive flexibility, ultimately decreasing the protective degree of cognitive control over current processing. They specifically noted that task-irrelevant positive emotion shifts cognitive control from maintaining existing processing and active control to flexible updating and passive control (Bolte & Goschke, 2010; Dreisbach & Goschke, 2004; Goschke & Bolte, 2014). The changes in cognitive control mode induced by positive emotion are similar to those produced by sleep and rest, suggesting that positive emotion may promote restarting of learning functions and thereby improve contextual-cueing learning ability, particularly New-learning. Other studies have found that positive emotional states broaden observers' attentional scope (Bolte & Goschke, 2010; Fredrickson & Branigan, 2005) and can increase processing of local targets according to task demands (Baumann & Kuhl, 2005). Therefore, positive emotion may also facilitate contextual-cueing learning under Re-learning conditions.

This study explored whether positive emotion can improve adaptability in contextual-cueing learning. The experiment was divided into two phases: a learning phase where participants completed a classic contextual-cueing paradigm to form memory representations of contextual cues, and a switch phase where participants were presented with Re-learning (old background-new target) and New-learning (new background-new target) conditions. Simultaneously, this phase included both neutral and positive emotion state conditions, with the neutral emotion condition serving as a baseline. By comparing contextual-cueing learning between these conditions, we examined the influence of positive emotion states on adaptability in contextual-cueing learning. We hypothesized that if positive emotion states can improve adaptability in contextual-cueing learning, then during the switch phase, participants would establish contextual-cueing effects more quickly in the positive emotion condition compared to the neutral emotion condition.

2.1 Participants

Cohen (2013) defined a large effect size in t-tests as Cohen's $d = 0.80$. Using G*Power 3.19 software, we calculated that with Cohen's $d = 0.80$, $\alpha = 0.05$, and $N = 18$, statistical power $1 - \beta = 0.95$. Therefore, we recruited 18 participants (3 males, 15 females) with a mean age of 23.4 years ($SD = 2.2$). All participants had normal or corrected-to-normal vision and were right-handed. Participants received compensation after completing the experiment and provided informed consent prior to participation. The study was approved by the Liaoning Normal University Ethics Committee.

2.2 Materials and Apparatus

We used affective pictures with emotional valence for emotion priming. Because these pictures were task-irrelevant, they would not form emotional memory representations themselves, allowing us to isolate the effect of emotional priming on proactive interference in implicit memory while excluding interference from the emotional materials' own memory representations. The emotion priming pictures were selected from the Chinese Affective Picture System (CAPS). We selected 160 emotional pictures from CAPS, including 80 positive-valence and 80 neutral-valence pictures, each with a pixel size of 1024×768 . Positive pictures included cute babies, animals, and beautiful landscapes, while neutral pictures depicted objects such as cups and tables.

For the visual search task, we adopted a classic contextual-cueing adaptability paradigm similar to Manginelli and Pollmann (2009). Each visual search scene consisted of 12 stimuli: 11 letter Ls at various rotation angles (0° , 90° , 180° , 270°) and one letter T rotated 90° left or right. All stimuli were black ($RGB=0,0,0$) presented on a gray background ($RGB=128,128,128$). Participants viewed the display from a distance of 55 cm. The letters T and L subtended $1.3^\circ \times 1.3^\circ$ of visual angle, and the entire scene subtended $37.2^\circ \times 28.3^\circ$ of visual angle. Each stimulus was randomly jittered by 0.8° of visual angle to prevent collinearity.

Scene layouts were randomly generated by computer. The scene space was divided into a rectangular area comprising 8×6 meta-squares (48 total). Using the screen center as the origin, each of the four quadrants in the coordinate system contained 12 meta-squares. Each scene contained 12 stimuli: 1 target and 11 distractors, evenly distributed across the four quadrants. During scene generation, target locations were determined first. Among the 48 meta-squares, we selected 4 positions in each quadrant (16 total) as target locations for the learning phase. Using the same method, we selected another 16 positions from the remaining locations as target locations for the positive emotion priming condition, with the remaining 16 serving as target locations for the neutral emotion priming condition.

Stimuli were presented on a 19-inch LCD monitor with a resolution of 1024×768 and a refresh rate of 60 Hz. The experimental program and

behavioral responses were implemented and recorded using E-Prime software.

2.3 Experimental Design and Procedure

The formal experiment consisted of two phases: a learning phase and a switch phase. The learning phase was completed first, followed immediately by the switch phase without any notification.

The first phase was the learning phase, designed to enable participants to acquire a set of contextual cues and form a stable contextual-cueing effect. This phase included 16 target locations. We selected 8 target positions across the 4 quadrants as target locations for repeated scenes and randomly generated 8 scenes at the beginning of the experiment. These 8 scenes maintained fixed target and distractor positions throughout the entire experiment, constituting the repeated scenes. The remaining 8 target positions served as target locations for novel scenes. Although target positions were fixed for novel scenes, the distractor positions were newly generated for each trial, preventing participants from using the distractor background to guide attention. Eight repeated scenes and 8 novel scenes formed one block of 16 trials, with the 16 scenes presented in random order within each block. Five blocks constituted one epoch. The initial learning phase comprised 3 epochs (15 blocks total), meaning each repeated scene was presented 15 times during the learning phase.

The second phase was the switch phase, designed to investigate whether contextual-cueing learning under New-learning and Re-learning conditions was influenced by positive emotion priming. New-learning repeated scenes were completely different from those in the learning phase, including both distractor backgrounds and target positions. In Re-learning repeated scenes, the distractor backgrounds remained identical to those in the learning phase, while only the target location changed. Importantly, new target locations in this condition were always in the quadrant diagonal to the old target location (Zellin et al., 2013) (see Figure 1 [Figure 1: see original paper]).

As mentioned previously, both the positive and neutral emotion priming conditions included 16 target locations each. These 16 target locations in each condition were divided into two sets: 8 for the New-learning condition and 8 for the Re-learning condition. Within each set, 4 served as target locations for repeated scenes and 4 for novel scenes. For example, in the positive emotion priming-New-learning condition, there were 4 repeated scene targets and 4 novel scene targets. The generation method for repeated and novel scenes was identical to that used in the learning phase.

During the switch phase, New-learning and Re-learning conditions were presented in random order within each block. Specifically, each block contained 4 New-learning scenes, 4 Re-learning scenes, and 8 novel scenes. As before, 5 blocks constituted one epoch.

The critical experimental factor in the switch phase was the emotional valence

of the priming condition. Each emotional valence condition comprised 7 epochs. All epochs of the same emotional valence were presented consecutively as a complete block before proceeding to the other valence condition. Specifically, after completing all 7 epochs of positive emotion priming, the neutral emotion condition was presented. This approach was adopted to maintain consistency of emotional state. To eliminate order effects, the presentation order of positive and neutral emotion conditions was counterbalanced across participants.

Overall, the initial learning phase consisted of 3 epochs (15 blocks), while the switch phase included 7 epochs of positive emotion priming (35 blocks) and 7 epochs of neutral emotion priming (35 blocks). The entire experiment comprised 1,360 trials. The experimental procedure is illustrated in Figure 2 [Figure 2: see original paper].

Figure 1. Scene layouts for the initial learning phase and the two learning conditions in the switch phase

Additionally, this study did not include a scene recognition task, as is typical in classic contextual-cueing research, for two reasons. First, scene recognition tasks are used to determine whether contextual-cueing memory is implicit, but the present findings do not concern the implicit or explicit nature of contextual-cueing memory. Second, research has shown that regardless of whether participants are aware of scene regularities or can explicitly retrieve these scenes, the representations are stored in the same memory system, are utilized during search, and produce consistent contextual-cueing effects (Kroell et al., 2019).

Figure 2. Experimental flowchart. During the switch phase, New-learning scenes, Re-learning scenes, and novel scenes were presented in a mixed random order, while the presentation order of positive and neutral emotion conditions was counterbalanced across participants.

Before the experiment began, all 18 participants rated the valence of the emotion pictures. They rated both neutral and positive pictures on a 1-to-9 scale, where “1” corresponded to “very unpleasant” and “9” to “very pleasant.” The purpose of this rating was to ensure significant differences in emotional valence between the two picture sets.

Following the emotion rating task, participants completed a visual search practice task consisting of 20 trials with randomly generated scenes to familiarize themselves with the task.

The formal experiment then began. In the learning phase, each trial started with a 500 ms central fixation point, followed by the visual search scene. The scene disappeared automatically after participants responded or after 5 s if no response was made. Participants were instructed to search for the letter T among Ls and determine its orientation, pressing the “J” key for a T rotated 90° left and the “F” key for a T rotated 90° right, responding as quickly and accurately as possible. Trials with no response within 5 s were considered non-response trials and were followed by the next trial. In the switch phase, a 2 s emotion picture

was inserted between the fixation point and the visual search scene to induce the corresponding emotion; all other procedures remained identical to the learning phase. A rest screen was presented after each block, allowing participants to rest as needed.

2.5 Data Analysis

Data were analyzed using SPSS 20.0 software. For the emotion rating task, paired-sample t-tests were conducted on participants' ratings to determine the discriminability between positive and neutral emotions. For reaction time data, preprocessing first excluded trials with no response within 5 s and trials with reaction times exceeding 3 standard deviations above or below the individual mean.

Preprocessed data were then subjected to repeated measures ANOVA. For the learning phase, a 2 (scene type: repeated vs. novel) \times 3 (epoch: 1-3) repeated measures ANOVA was performed on reaction times to confirm that participants had learned the scenes.

For the switch phase, contextual-cueing effect values served as the dependent variable in a 2 (emotional valence: positive vs. neutral) \times 2 (learning condition: New-learning vs. Re-learning) \times 2 (learning phase: early vs. late) repeated measures ANOVA. The contextual-cueing effect (CC) was defined as the difference between mean reaction times for novel scenes and repeated scenes:

$$\text{Contextual Cueing Effect (CC)} = \text{RT}(\text{novel scenes}) - \text{RT}(\text{repeated scenes})$$

CC reflects participants' learning of distractor backgrounds. When participants have formed memory representations of contextual cues and use them to improve search efficiency, CC will be greater than 0. If participants cannot learn or utilize contextual cues, CC will equal 0. Moreover, larger CC values indicate better learning and utilization of contextual cues.

Each emotional valence condition in the switch phase comprised 7 epochs. The early phase was defined as the first two epochs of the switch phase, and the late phase as the final two epochs. This arrangement increased the number of trials per condition, yielding more stable results. If contextual-cueing learning occurred, CC would be greater than 0 in the late phase. Whether CC exceeded 0 in the early phase reflected the speed of learning. These analyses identified factors influencing CC. One-sample t-tests compared CC values against 0 for each condition to determine whether participants had acquired new contextual cues.

3.1 Emotion Picture Rating Results

In the emotion picture rating task, positive pictures received a mean valence rating of 5.82 (SD = 0.65), while neutral pictures received a mean rating of 5.03

(SD = 1.12). A paired-sample t-test revealed a significant difference in valence between positive and neutral pictures ($t(17) = -4.79$, $p < 0.001$), indicating good discriminability between the two picture sets and confirming the appropriateness of our picture selection.

3.2 Visual Search Task Results

The mean accuracy rate was 98.78% (SD = 0.02), indicating that all participants understood the task well and could perform it successfully. After excluding non-response trials and trials with reaction times exceeding 3 standard deviations from the overall mean, the mean number of remaining trials per participant was 1,317 (SD = 26).

Learning Phase

In the learning phase, a 2 (scene type: repeated vs. novel) \times 3 (time course: epochs 1-3) repeated measures ANOVA was conducted on reaction times to examine how scene type and time course influenced participants' reaction times. Mauchly's test of sphericity indicated that the variance-covariance matrix of the dependent variable was equal for the interaction term scene type \times time course and for the time course factor ($p > 0.05$). The repeated measures ANOVA revealed a significant main effect of scene type ($F(1,17) = 46.76$, $p < 0.001$, $\eta^2 = 0.73$), a significant main effect of time course ($F(2,34) = 22.87$, $p < 0.001$, $\eta^2 = 0.57$), and a significant interaction between scene type and time course ($F(2,34) = 4.00$, $p = 0.028$, $\eta^2 = 0.19$).

Given the significant interaction, simple effects analyses were conducted. For time course, in epoch 1, reaction times for novel scenes (M = 1406 ms, SD = 205 ms) were significantly slower than for repeated scenes (M = 1313 ms, SD = 238 ms) ($F(1,17) = 9.13$, $p = 0.008$, $\eta^2 = 0.35$). In epoch 2, the difference between novel scenes (M = 1297 ms, SD = 189 ms) and repeated scenes (M = 1156 ms, SD = 191 ms) was also significant ($F(1,17) = 34.49$, $p < 0.001$, $\eta^2 = 0.67$). In epoch 3, the difference between novel scenes (M = 1276 ms, SD = 235 ms) and repeated scenes (M = 1095 ms, SD = 164 ms) remained significant ($F(1,17) = 47.21$, $p < 0.001$, $\eta^2 = 0.74$) (see Figure 3 [Figure 3: see original paper]).

These results indicate that contextual-cueing learning occurred very rapidly, with a significant contextual-cueing effect evident in the first epoch. The findings confirm that participants successfully acquired contextual cues during this phase.

Figure 3. Mean reaction times for novel and repeated scenes in each epoch of the initial learning phase (* indicates $p < 0.05$)

Switch Phase

Descriptive statistics for each experimental condition in this phase are presented in Table 1 .

Table 1. Descriptive statistics for contextual-cueing effects (CC) in the switch phase across conditions

A 2 (emotional valence: positive vs. neutral) \times 2 (learning condition: New-learning vs. Re-learning) \times 2 (learning phase: early vs. late) repeated measures ANOVA was conducted on these CC data to determine the effects of emotional valence, learning condition, and learning phase on CC.

Mauchly's test of sphericity indicated that the assumption of sphericity was met for the interaction terms learning type \times time phase, emotional valence \times time phase, emotional valence \times learning type \times time phase, and for the time phase factor ($p > 0.05$). The repeated measures ANOVA revealed that the main effect of emotional valence was marginally significant ($F(1,17) = 4.31$, $p = 0.053$, $\eta^2 = 0.20$), the main effect of learning type was significant ($F(1,17) = 4.57$, $p = 0.047$, $\eta^2 = 0.21$), and the main effect of learning phase was significant ($F(1,17) = 5.01$, $p = 0.039$, $\eta^2 = 0.23$). Regarding interactions, the three-way interaction of emotional valence \times learning type \times learning phase was not significant ($F(1,17) = 0.08$, $p = 0.783$, $\eta^2 = 0.01$). Additionally, the emotional valence \times learning phase interaction was not significant ($F(1,17) = 1.86$, $p = 0.191$, $\eta^2 = 0.10$), and the learning type \times learning phase interaction was marginally significant ($F(1,17) = 4.35$, $p = 0.053$, $\eta^2 = 0.20$). However, the emotional valence \times learning type interaction was significant ($F(1,17) = 4.55$, $p = 0.048$, $\eta^2 = 0.21$).

Simple effects tests were conducted, with results shown in Table 2. The results indicated that in the Re-learning condition, CC values did not differ between neutral and positive emotion priming conditions in either the early or late learning phases. In the New-learning condition, although no CC difference between emotional valence conditions emerged in the early phase, a difference appeared in the late phase.

Table 2. Simple effects test results for neutral and positive emotion conditions in the switch phase

To further determine whether participants acquired new contextual cues in each condition, one-sample t-tests compared CC values against 0. The results showed that in the positive emotion New-learning condition, CC was significantly greater than 0 in both early and late learning phases ($p < 0.05$). In the neutral emotion New-learning condition, CC was significantly greater than 0 in the late phase ($t(17) = 2.55$, $p = 0.021$). However, the neutral emotion New-learning condition in the early phase and all Re-learning conditions showed no CC significantly greater than 0 ($p > 0.05$) (see Figure 4 [Figure 4: see original paper]).

Figure 4. Contextual-cueing effects across conditions in the switch phase (* indicates that CC in that condition differed significantly from 0 based on one-sample t-test ($p < 0.05$); error bars represent standard error of the mean)

The significant emotional valence \times learning type interaction, combined with simple effects tests showing that CC in the New-learning condition was sig-

nificantly higher in the positive emotion condition than in the neutral emotion condition during the late phase, and one-sample t-test results showing CC greater than 0 in the early phase of positive emotion New-learning, demonstrate that positive emotion priming facilitates contextual-cueing learning in the New-learning condition.

Meanwhile, simple effects tests found no CC changes related to emotional valence in the Re-learning condition, and independent-sample t-tests revealed no CC significantly greater than 0 in any Re-learning condition. Therefore, positive emotion does not influence contextual-cueing learning in Re-learning.

Although independent-sample t-tests on CC showed that in the neutral emotion condition, New-learning in the late phase produced CC significantly greater than 0, the three-way interaction in the repeated measures ANOVA was not significant, nor were the emotional valence \times learning phase or learning type \times learning phase interactions. Consequently, the above-0 CC in this condition cannot be definitively interpreted as evidence of learning.

4 Discussion

This study aimed to explore whether positive emotion can improve adaptability in contextual-cueing learning. Using task-irrelevant affective pictures as emotion priming materials, we established a neutral emotion condition as the baseline and a positive emotion condition as the experimental condition to examine contextual-cueing learning in Re-learning and New-learning conditions. The results showed that positive emotion only facilitated learning of entirely new scenes (New-learning) but had no effect on learning scenes composed of old backgrounds and new targets (Re-learning).

Previous studies using sleep and other methods to improve learning ability in the New-learning condition found that at least 3 to 4 epochs were required to demonstrate a significant contextual-cueing effect (Zellin et al., 2013). In contrast, with positive emotion priming, the New-learning condition showed a significant contextual-cueing effect within the first two epochs (early learning phase), indicating that positive emotion can more effectively improve adaptability in contextual-cueing learning compared to sleep and other methods.

Although positive emotion promoted learning of new scenes, it had no effect on Re-learning. If Re-learning involved processing the presented old background-new target scenes as entirely new scenes, then experimental manipulations that improve new scene learning should also facilitate relearning of old scenes. However, the present findings show that while positive emotion priming enhanced New-learning, Re-learning remained extremely difficult. This indicates that the Re-learning process does not simply treat presented scenes as entirely new; rather, the processes of relearning old scenes and learning new scenes are fundamentally different.

Previous research has found that successful Re-learning requires binding a new

target location onto existing background-target associations, forming a scene representation that contains both the old distractor background and both old and new target locations (Zellin et al., 2011)—in other words, updating old scene representations. The present results support this view and further demonstrate that such updating is extremely difficult (Geyer et al., 2021).

Zinchenko et al. (2020) found that Re-learning became easier when participants engaged in global attention, suggesting that attentional scope may be important for Re-learning. Positive emotion causes attention to become more diffuse (Dreisbach & Goschke, 2004) and broadens attentional scope (Fredrickson & Branigan, 2005), which might therefore be expected to improve adaptability in Re-learning. However, this study found no facilitative effect of positive emotion on Re-learning. This is because broadened attentional scope is not equivalent to global attention. In Zinchenko et al. (2020), the global attention condition required participants to fixate on the central point while using peripheral vision to search, allowing scenes to enter the brain in a global manner and enabling implicit cognitive processing to more easily detect differences between old and new scenes, thereby facilitating integration of old scene representations with new targets. In the present study, although attentional scope was somewhat broadened, it was insufficient to produce global attention; participants still searched in a local manner, preventing formation of global scene representations and thus failing to facilitate relearning of old scenes.

Increasing new target salience can direct attention to the new target location, enhancing processing of that location and thereby promoting Re-learning (Conci & Zellin, 2021). Additionally, previous research has shown that positive emotion can indeed facilitate processing of local targets (Baumann & Kuhl, 2005), leading to the hypothesis that positive emotion should promote the Re-learning process. However, the empirical evidence from this study does not support this hypothesis. The reason for this discrepancy is that the facilitative effect of positive emotion on local target processing is essentially a conscious adaptation to task demands—an explicit and active cognitive regulation process. In contrast, scene learning and updating in this study was an incidental, implicit process without explicit task demands; participants did not consciously deepen processing of the new target, ultimately failing to facilitate updating of old scene representations.

Positive emotion cannot accelerate contextual-cueing learning in the Re-learning condition but can facilitate it in the New-learning condition. This facilitation is achieved by restarting the learning process. Previous research has found that positive emotion can increase cognitive flexibility and reduce cognitive stability, eliminating habitual and automated cognitive processes and making cognitive processing more passive and susceptible to environmental influences (Dreisbach & Goschke, 2004; Goschke & Bolte, 2014). This implies that positive emotion can promote restarting of learning functions that have been closed or blocked. Moreover, research on contextual cueing has shown that rigid cognitive control functions negatively affect contextual-cueing learning, whereas restarting

learning functions can facilitate relearning of contextual cues. In one study, participants first searched scenes with random target locations but fixed distractor backgrounds; subsequently, using the same distractor backgrounds with fixed target locations, participants failed to acquire contextual cues in the second phase because the previous random search had become habitual and automated, blocking learning of new regularities (Jungé et al., 2007). This study highlights how habitual automated cognitive control blocks contextual-cueing learning. Quiet rest and overnight sleep can effectively facilitate learning of entirely new scenes by restarting learning functions (Mednick et al., 2009; Zellin et al., 2013). Therefore, in this study, positive emotion facilitated New-learning by making cognitive control more flexible and passive, thereby initiating new learning processes.

Positive emotion makes cognitive control flexible and passive and restarts learning functions, which might seem to suggest that Re-learning should also be facilitated in positive emotional states. However, this phenomenon was not observed in the present study. In fact, representations stored in the memory system must be retrieved before guiding behavior. The greater the similarity between new materials and old memory representations, the stronger the automatic retrieval of old memory representations (Craig et al., 2013; Delaney & Logan, 1979; Friedman & Miyake, 2004; Lustig & Hasher, 2001). In this study, the only difference between new scene materials in the Re-learning condition and previously acquired contextual-cueing memory representations was the target location. When these new scene materials entered the memory system, the old contextual-cueing memory representations were automatically retrieved, keeping them in a highly activated state (Geyer et al., 2021). This automatic retrieval reduces memory updating ability in three ways: first, repeated retrieval strengthens the memory trace of the old contextual-cueing representation itself (Karpicke, 2017); second, the increasing activation from retrieval impedes memory formation for the new target location representation (Morton & Munakata, 2002); and finally, activation of the old contextual-cueing representation directs attention to the old target location, further increasing processing of the old target location and nearby distractors (Geyer et al., 2021). When memory representations of old background-target associations are further strengthened while memory formation for new target location representations is blocked, adding a new target representation onto old background-target association memory becomes extremely difficult.

Positive emotion can eliminate automated and habitual cognitive processing, and automatic retrieval is clearly an automatic process. Therefore, it might seem that the automatic retrieval explanation is insufficient to account for Re-learning difficulties under positive emotion conditions. In fact, in previous research, automatically occurring cognitive processing refers to artificially established automated and proceduralized cognitive processes whose degree of automaticity depends on participants' level of practice. In contrast, automatic retrieval caused by representational similarity is an innate brain function, and thus positive emotion intervention cannot inhibit this genetically determined au-

automatic retrieval. Moreover, even if positive emotion does inhibit this automatic retrieval to some extent, as long as the process does not disappear completely, activation of the old contextual-cueing memory representation will inevitably increase, and the integration process between the new target location and old contextual-cueing memory representation will continue to be blocked, leaving Re-learning adaptability poor.

Morton and Munakata (2002) proposed that proactive interference occurs and impedes memory processing of new representations when the activation strength of new knowledge relevant to the current task is insufficient to overcome previous experience. Retrieval increases activation of old representations, making activation of new representations relatively insufficient. Therefore, one might easily assume that automatic retrieval of old contextual-cueing representations also causes poor adaptability in the New-learning condition, and that positive emotion facilitates New-learning by inhibiting automatic retrieval of old contextual-cueing memory representations. In reality, however, the similarity between old and new scene materials in the New-learning condition is very low, making automatic retrieval of old representations unlikely and thus limiting its role. In summary, the primary reason for improved New-learning adaptability induced by positive emotion in this study is not inhibition of automatic retrieval of old representations, but rather elimination of habitual cognitive processing and restarting of learning functions.

Overall, positive emotion in this study facilitated learning of entirely new scenes (New-learning) by eliminating habitual cognitive processing modes and promoting restarting of learning functions. However, it could not effectively prevent automatic retrieval of old scene representations caused by representational similarity, and therefore could not facilitate updating of learned contextual-cueing representations (Re-learning).

Note: Figure translations are in progress. See original paper for figures.

Source: ChinaXiv – Machine translation. Verify with original.