Brief Communication

The effect of choice on intentional and incidental memory

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Recent studies have revealed that memory performance is better when participants have the opportunity to make a choice regarding the experimental task (choice condition) than when they do not have such a choice (fixed condition). These studies, however, used intentional memory tasks, leaving open the question whether the choice effect also applies to incidental memory. In the current study, we first repeated the choice effect on the 24-h delayed intentional memory performance (experiment 1). Next, using an incidental paradigm in which participants were asked to judge the category of the items instead of intentionally memorizing them, we observed the choice effect on judgment during encoding and memory performance in a 24-h delayed surprise test (experiment 2). Participants judged more accurately and quickly and had better recognition memory for items in the choice condition than for items in the fixed condition. These results are discussed in terms of the role of choice in both intentional and incidental memory.

Human beings and animals have inherent motivation to exert control over the environment or determine their own actions (Catania 1975; Catania and Sagvolden 1980; Leotti and Delgado 2011; Boot et al. 2013; Fujiwara et al. 2013; Ang and Pizzagalli 2019). This sense of control has been considered a basic psychological need and biological necessity (Leotti et al. 2010; Weinstein et al. 2018; Tang et al. 2020). Numerous studies have found that when participants are provided opportunities to make choices/decisions, their motivation and performance are improved (i.e., choice-induced performance enhancement or the choice effect) (Patall et al. 2008; Wulf and Adams 2014; Lewthwaite et al. 2015; Meng and Ma 2015; Murayama et al. 2015; Halperin et al. 2017).

The choice effect has been consistently observed in the memory field when participants are actively trying to encode memoranda (Watanabe and Soraci 2004; Voss et al. 2011a,b; Gureckis and Markant 2012; Markant et al. 2014; Markant and Gureckis 2014). For example, in a set of studies using an intentional memory task, Voss et al. (2011a,b) created two experimental conditions: the choice condition or active blocks in which participants determined the timing and sequence of the studied items and the no-choice condition or passive blocks in which participants learned items whose timing and sequence was determined by the previous participant. The results showed that participants learned better in the choice condition than in the no-choice condition. Two subsequent studies by Murty and colleagues (Murty et al. 2015; DuBrow et al. 2019) further found the choice effect on an intentional memory task even when the choice was not related to the content of the memory task (i.e., inconsequential choice). Specifically, two objects were covered by two occluder screens (two different Japanese characters with matched preference based on a pretest), and participants were asked to remove one of the two occluder screens to remember the objects underneath. In the fixed (forced-choice) condition, they were required to remove the one on the side of a highlighted text, whereas in the choice (free-choice) condition, they decided which one to remove. Results showed that both immediate and 1-d delayed memory tests showed better performance in the choice condition than the fixed condition.

As specified above, these previous studies used intentional memory tasks. With such tasks, participants may be more motivated in the choice condition to intentionally use memory strategies (e.g., verbal rehearsal and mental-imagery strategies) as compared with the fixed condition (Greene 1987; Humphreys et al. 2010; Slotnick et al. 2012). Would the choice effect still exist if the participants could not intentionally use such memory strategies? One such paradigm involves incidental memory. Two studies have tested the choice effect on incidental memory (Hirano and Ukita 2003; Rotem-Turchinski et al. 2019). (It is worth noting that the incidental memory paradigm has also been used to study a related effect—the chosen-item effect—in two studies [Coverdale and Nairne 2019; Coverdale et al. 2019]. In these studies, participants were presented pairs of items and asked to choose one in each pair [i.e., choosing the more useful or less useful items, with materials being counterbalanced across participants to control for the effect of potential differences in materials]. After a 1- or 2-min distractor task, participants were given a surprise memory test. Results showed that the chosen items were better recalled than the nonchosen alternatives in the subsequent surprise test. The chosen-item effect, however, is independent of the choice effect because it was studied only under the free-choice condition [i.e., no forced-choice

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condition] in these two studies. Theoretically, the chosen-item effect might occur in both free-choice and forced-choice conditions.) In the study by Hirano and Ukita (2003), participants were presented a word pair (e.g., block-cement) and a category item (e.g., building). In the free-choice condition, participants were asked to choose which word was more associatively related to the category item whereas in the forced-choice condition, the word was randomly assigned by the experimenter. A subsequent surprise memory test showed better memory performance in the free-choice condition than in the forced-choice condition. More recently, Rotem-Turchinski et al. (2019) investigated whether choice making affected the incidental memory of narrative events. Participants were asked to view movie clips as two segments (prechoice and postchoice). Between the two segments, participants were either allowed to choose between two options of the content of an event or forced to choose the option given by the computer. Results of a subsequent surprise memory test showed that compared with the forced-choice condition, the free-choice condition resulted in better memory of not only the choice-related content but also the details of the pre and postchoice stages. In these two studies, participants' choices were based on their understanding or preference of the words' associations (Hirano and Ukita 2003) or their preferences of content of the movie clips (Rotem-Turchinski et al. 2019). In other words, participants made the choices based on some aspects of the content of the items. Therefore, although these results could be explained by the choice effect, the studies could not rule out a potential confounding role of the content of the items (i.e., better memory for preferred content).

In the current study, we adopted the inconsequential choice paradigm used by Murty and colleagues (Murty et al. 2015; DuBrow et al. 2019) to test whether the simple act of choice (unrelated to the content of the memoranda) can enhance subsequent memory. In addition to the control of the content of the memoranda and the encoding/learning time as implemented by Murty and colleagues, we further controlled any potential influence of differences between the two occluder screens (two Japanese characters) by using the same symbol (a question mark in a circle) on both occluder screens. Two experiments were conducted. The first experiment aimed to replicate the choice effect on intentional memory with the modified inconsequential choice paradigm and the second experiment aimed to extend it to incidental memory. In experiment 1, participants were asked to memorize the items (hence, intentional memory) and were then given a 24-h delayed memory test. In experiment 2, participants were asked to judge the category of the images during the encoding phase and were then given a surprise test 24 h later (hence, incidental memory).

A total of 96 participants were recruited for the two experiments in this study. Four participants did not complete the experimental procedure. In addition, the data from eight participants were not successfully saved due to network issues. The final sample included 84 participants: 42 for experiment 1 (22 males; mean age = 22.7 yr, SD = 2.85 yr) and 42 for experiment 2 (21 males; mean age = 21.7 yr, SD = 2.11 yr). All participants had normal or corrected-to-normal vision and reported no history of neurological problems. The study was approved by the Institutional Review Board of the Institute of Psychology, Chinese Academy of Sciences. All participants provided informed consent before taking part in the experiment. Due to the COVID-19 pandemic, the experiments were conducted online instead of in the laboratory. PsychoPy3 (hosted on Pavlovia.org) was used to administer the experiment. Participants were required to complete the experiment in a quiet room without distractions (Fig. 1).

During the choice memory encoding in experiment 1, each trial started with the presentation of a cue for 1 sec that indicated the trial type (i.e., "选择 [choice]" or "非选择 [fixed]" condition).

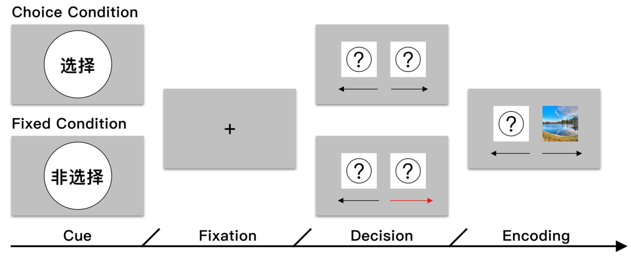

Figure 1. Schematic depiction of the encoding phase for the two experiments ("选择" means "choice" and "非选择" means "fixed"). Participants removed one of the occluder screens to memorize the item (experiment 1) or judge the category of the item (experiment 2). In the choice condition, they could make their own choices to remove either the *left* or *right* occluder, whereas in the fixed condition, they were forced to remove the one on the side with a red arrow.

After a fixation cross for 1.5/2 sec, two occluder screens of question marks in circles were displayed on the left and right sides. Participants were instructed to remove one of the occluder screens within 5 sec and then *memorize* the image underneath. In the choice condition, participants could make their own choice to remove either the left or right occluder, whereas in the fixed condition, participants were forced to remove the predetermined occluder on the side with a red arrow. After the removal of the occluder, an image was presented for 2 sec for participants to remember. Participants were informed that there would be a 24-h delayed recognition test. To prevent carryover effects (Anderson et al. 2006), participants performed two flanker tasks in which they judged the direction of the middle arrow of a set of three arrows for 4.8 sec (2.4 sec for each flanker task) after encoding. An intertrial interval (ITI) of blank screen was presented for 1.3/1.5/1.7 sec at the end of each trial. There were 60 trials for each condition, 30 indoor images and 30 outdoor images, counterbalanced across participants. Critically, the memorandum of each trial was predetermined and matched between the two conditions in the current inconsequential paradigm. That is, although participants were either allowed or not allowed to make a choice, their action would not determine what items were shown in either condition. After an approximately 24-h delay, participants returned for a recognition test in which the 120 previously presented images and 120 new images were presented. Participants were instructed first to judge whether the images were "old" or "new" within 20 sec and then to rate their confidence within 20 sec (1–2 sec ITI).

A paired *t*-test was conducted to test the difference between the choice and fixed conditions in memory performance (accuracy) on the recognition test (the percentage of "old" responses for the "old" images) for experiment 1. Experiment 1 replicated the choice effect on intentional memory (see Fig. 2), consistent with previous studies (Murty et al. 2015; DuBrow et al. 2019), mean difference = 0.048, SD for the mean difference = 0.078, $t_{(41)} = 3.984$, $P < 0.001$, $d = 0.61$.

In experiment 2, participants were asked to *judge* the category of the images (indoor vs. outdoor objects) instead of memorizing them and were not informed about the 24-h delayed recognition test. During the category judgment task, each image was presented for 2 sec. After each response, a feedback was shown for 1.2 sec, followed by a 0.8-sec ITI. Approximately 24 h later, the participants were asked to complete a surprise test that was the same as that of experiment 1. All participants reported they did not foresee a test beforehand.

Experiment 2 also showed a significant choice effect on memory performance (see Fig. 2), mean difference = 0.029, SD for the mean difference = 0.089, $t_{(41)} = 2.109$, $P = 0.041$, $d = 0.33$. (Due to

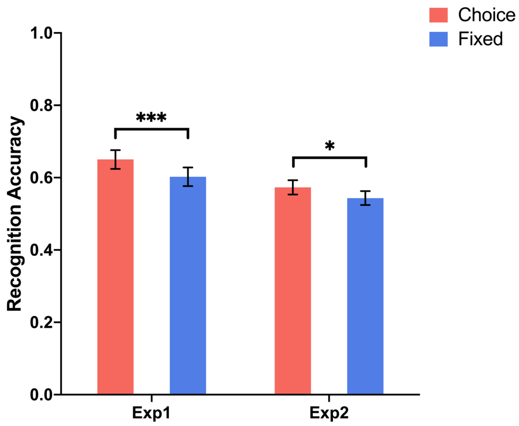

Figure 2. Choice enhanced both intentional (experiment 1) and incidental memory (experiment 2).

potential differences between the two experiments (i.e., participants were not randomized between the two experiments, and category judgment was used in experiment 2 but not in experiment 1), we did not directly compare the choice effect between the two experiments to assess its relative size for intentional vs. incidental memory. Instead, we focused on demonstrating the choice effect on incidental memory.) We also examined the difference between the choice and fixed conditions in judgment performance (response time [RT] and accuracy) in the encoding phase. The results showed a significant choice effect on both RT (see Fig. 3A) and accuracy (see Fig. 3B); that is, participants performed faster and more accurately in the choice condition than in the fixed condition: for RT, mean difference = −0.073, SD for the mean difference = 0.055, $t_{(41)} = -8.692$, $P < 0.0001$, $d = -1.34$; for accuracy, mean difference = 0.022, SD for the mean difference = 0.035, $t_{(41)} = 4.109$, $P < 0.001$, $d = 0.63$.

To further test whether one aspect of encoding (RT) was related to subsequent memory performance, trials in each condition were median-split into "slow" and "fast" trials for each individual participant (i.e., ∼30 [not exactly 30 because we analyzed the trials of correct judgment] low-RT or "fast" trials and 30 high-RT or "slow" trials in each condition). This analysis was similar to that used in a previous study using the intentional memory paradigm (e.g., an analysis of the memory accuracy for each item as a function of duration for which it was viewed during encoding) (Voss et al. 2011b). A 2 (judgment RT: fast vs. slow) × 2 (condition: choice vs. fixed) ANOVA was performed. Memory performance was the dependent variable. As shown in Figure 4A, the results showed a nonsignificant main effect of judgment RT ($F_{(1,41)} = 0.115$, $P = 0.736$, $\eta^2 = 0.003$), a significant main effect of condition ($F_{(1,41)} = 4.434$, $P = 0.041$, $\eta^2 = 0.098$), and a significant interaction effect between judgment RT and condition ($F_{(1,41)} = 5.745$, $P = 0.021$, $\eta^2 = 0.123$). Simple effect analysis revealed that for the "fast" trials, participants encoded items better in the choice condition than in the fixed condition ($P = 0.004$), whereas for the "slow" trials, no difference was found between the two conditions ($P = 0.759$).

Considering that the average RT differed between the two conditions (as reported earlier), an additional analysis was conducted by using the same absolute RT cutoff for both conditions (i.e., the median RT of both conditions) instead of the median split within condition. Although this approach led to an uneven distribution of "fast" and "slow" trials for each condition, there were enough trials for each type (no fewer than 15 trials; the average numbers [and the range] of 33 [28–41] "fast" trials and 26 [18–32] "slow" trials under the choice condition and 25 [18–32] "fast" trials and 33 [27–41] "slow" trials under the fixed condition) to allow us to obtain reasonably reliable estimates of memory performance by type of trials by condition. As shown in Figure 4B, similar to the analysis using within-condition median split, results by using the same absolute RT cutoff showed a nonsignificant main effect of judgment RT ($F_{(1,41)} = 0.337$, $P = 0.565$, $\eta^2 = 0.008$), a significant main effect of condition ($F_{(1,41)} = 4.360$, $P = 0.043$, $\eta^2 = 0.096$), and a significant interaction effect between judgment RT and condition ($F_{(1,41)} = 5.779$, $P = 0.021$, $\eta^2 = 0.124$). In sum, these results suggest that the choice effect was driven by "fast" trials.

In the current study, we first replicated the previously reported choice effect on the intentional, 1-d delayed memory (Murty et al. 2015; DuBrow et al. 2019). Decades of research have revealed beneficial effects of active learning (e.g., self-directed learning in which participants decide what and when to learn) (Takahashi 1991; Voss et al. 2011a,b; Markant et al. 2014; Markant and Gureckis 2014; Ruggeri et al. 2019). Two plausible mechanisms for the mnemonic benefit of active learning are metamemory judgment (e.g., participants made appropriate decisions based on the items' content and their own knowledge, state, and learning habits) (Takahashi 1991, 1992; Watanabe and Soraci 2004) and the perceived control (Murty et al. 2015; DuBrow et al. 2019). Because the choice was inconsequential in the current study and there were no differences in the learning content, the learning time, and even the occluder between the choice and fixed conditions, our results seemed to rule out the role of metamemory judgment and suggest that pure choice increases perceived control, which enhances memory in the context of active learning.

More importantly, the current study provided direct evidence for the choice effect on incidental memory. Although two previous studies reported the choice effect on incidental memory (Hirano and Ukita 2003; Rotem-Turchinski et al. 2019), they did not control the content of the items, and hence their results were subject to alternative interpretations such as differences in the familiarity, preference, and significance of the memoranda. By using the modified inconsequential choice paradigm, our study produced the "pure" choice effect. It has been suggested that humans have an innate desire for autonomy or sense of control and choice making

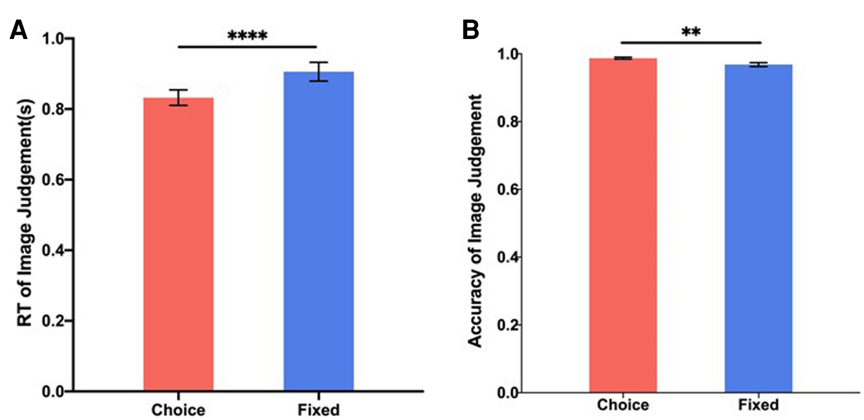

Figure 3. Choice sped up the judgment RT (*A*) and enhanced judgment accuracy (*B*) during encoding (experiment 2).

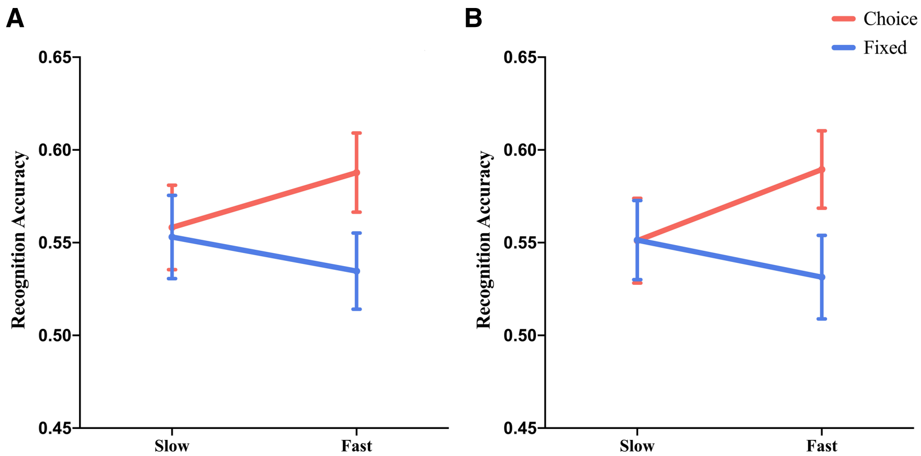

Figure 4. Choice improved memory only for items of short judgment RT during encoding. (*A*) Items in each condition were split into "slow" and "fast" ones by the median RT of this condition for each individual participant. (*B*) Items in each condition were split into "slow" and "fast" ones by the same absolute RT cutoff (median RT of both conditions) for each individual participant.

reflects that sense of control and hence is inherently rewarding (Leotti et al. 2010; Leotti and Delgado 2011; DuBrow et al. 2019). The fundamental nature of the choice effect was further supported by the evidence of the choice effect in relation to judgment accuracy and RT during the encoding task, which is consistent with previous studies using various other tasks (e.g., the stopwatch task or motor learning task) (Patall et al. 2008; Lewthwaite et al. 2015; Murayama et al. 2015). This simultaneous enhancement of both accuracy and RT indicates that choice impacts the encoding in an automatic way, without explicit strategies (i.e., speed–accuracy tradeoffs). This interpretation is further bolstered by another finding of our study; namely, choice-related memory enhancement existed only for fast trials. In other words, when the judgment of the items was more automatic (fast items), the choice effect was evident for incidental memory. We should hasten to add that this interpretation is tentative because the RT effect was based on a post hoc analysis and we did not systematically manipulate or measure item characteristics such as difficulty level (fast items might have lower levels of difficulty). Future studies should replicate this finding after controlling for relevant item characteristics.

Although our behavioral study did not address the neural mechanisms, the choice effect is likely to be subserved by the striatum, a key region for reward processing. External reward has been found to engage the striatum (Pessiglione et al. 2007; Frijda 2010; Pas et al. 2014), which is known to integrate input from motor planning regions and outputs impacting motor action (i.e., stronger activity when participants make faster responses) (Hersch et al. 1995; Forstmann et al. 2008). Taken together the behavioral and neuroimaging results, we speculate that the opportunity to make a choice triggers a reward signal (i.e., the release of dopamine), activates the reward-related areas (i.e., the striatum), leads to automatic attention and action planning, and produces faster incidental encoding and eventually better subsequent memory.

In conclusion, we found that an opportunity to make choices for a task could not only enhance the task performance but also induce a beneficial effect on the 1-d delayed incidental memory. The choice-induced enhancement for incidental memory depended on how the task performance was impacted by choices during encoding. Thus, we suggest that the choice can affect encoding in an incidental way (without strategies) that leads to long-term memory enhancement. These findings may have implications for our understanding of the underlying cognitive mechanisms of the choice effect on memory.

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