Metacognitive Illusion in Category Learning: Contributions of Processing Fluency and Beliefs

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ABSTRACT

Interleaving with other categories of stimuli has been shown to enhance category learning. However, learners, tend to believe that blocking enhances learning, even after their own performance had showed the opposite. The present study explored the contributions of processing fluency (Experiment 1) and beliefs (Experiment 2) to the illusion that blocking enhances category learning. We found that: (a) learners' performance benefited from interleaving, but their metacognitive judgments were not in conformity with it, (b) the perceived tendency of metacognitive illusion was reduced by inserting an unrelated cartoon image in the blocked presentation condition to decrease fluency, and (c) learners came to the experimental task with a pre-existing belief that the instruction of blocking by topic was superior to intermixing topics. This belief disappeared when learners were offered the theoretical explanation of why interleaving exemplars is more effective. In conclusion, this study revealed that processing fluency and held beliefs were two factors that cause this metacognitive illusion.

KEYWORDS

category learning
fluency
belief
metacognitive illusion

INTRODUCTION

Metacognition is the cognition of cognition, including the ability to monitor and control it. Monitoring refers to the evaluation of cognition (e.g., *metacognitive judgment*) and control refers to the selection and execution of cognition. It is generally believed that metacognitive judgment directly influences the choice of learning strategies, thus affecting performance. Learners endeavor to manage their learning in optimal ways, based on their own judgment, but if their judgment is wrong, they cannot achieve the expected learning effect through the selected method. This phenomenon is called *metacognitive illusion*, or an instance in which a learners' metacognitive monitoring is inaccurate and does not match their actual performance. For example, although learners benefit from interleaving with other categories of examples, their judgment is to the contrary—they rather tend to believe that blocking enhances learning (Birnbaum, Kornell, Bjork, & Bjork, 2013; Bjork, Dunlosky, & Kornell, 2013; Kornell & Bjork, 2008; Kornell, Castel, Eich, & Bjork, 2010; Tauber, Dunlosky, Rawson, Wahlheim, & Jacoby, 2013; Wahlheim, Dunlosky, & Jacoby, 2011; Yan, Bjork, & Bjork, 2016).

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Although it is clear that learners prefer to study under the blocked condition relative to the interleaved condition (e.g., learners rated higher metacognitive judgments for blocking than for interleaving), little is known about what factors affect the metacognitive judgment of these two schedules. The accuracy of metacognitive judgment affects learners' academic performance (Cao & Nietfeld, 2005; Hartwig & Dunlosky, 2017; McCabe, 2011; Nietfeld, Cao, & Osborne, 2005); thus, it is imperative to investigate what factors cause metacognitive illusions that lead learners to prefer suboptimal conditions of learning. Therefore, the primary goal of this research was to investigate what factors contribute to the illusion that blocking enhances category learning.

According to the dual processing systems theory (Koriat, 2000; Koriat & Bjork, 2006), there are two processing mechanisms for metacognitive monitoring: *experience based* and *theory based*. Experience-based metacognitive judgments are based on learners' subjective experiences and refer to processing fluency, or a sense of ease when processing information, which learners assume will lead to good retrieval during the test. This feeling might occur under one of two conditions: when the absolute magnitude of fluency increases or when the fluency becomes surprisingly strong compared to the individual's expectation (Whittlesea & Leboe, 2003). Theory-based metacognitive judgments rely both upon rules and theories extracted from memory (e.g., prior theories) and upon explicit inferences about these rules. Thus, we assumed that processing fluency and prior beliefs would influence metacognitive judgment.

A series of studies showed that beliefs influence metacognitive judgment (Jia et al., 2016; Mantonakis, Galiffi, Aysan, & Beckett, 2013; Undorf & Erdfelder, 2015; Witherby & Tauber, 2017). For instance, Witherby and Tauber (2017) asked participants to read a hypothetical experiment (Experiment 1) in which learners studied a list of concrete (e.g., *table*) and abstract words (e.g., *loyalty*), and to make judgments of learning (JOLs; e.g., to estimate how many words of each category could the learners in the experiment remember correctly). The participants' mean prediction was higher for concrete words (60%) than that for abstract words (42%). To further investigate the contributions of beliefs, Witherby and Tauber had participants study concrete and abstract words themselves and make pre-study JOLs for each word on a scale from 0-100% (Experiments 2 and 3). Again, participants made higher pre-study JOLs for concrete words than for abstract words. Other studies have found similar results (Jia et al., 2016; Mantonakis et al., 2013; Undorf & Erdfelder, 2015). However, an individual's prior belief may be incorrect due to the existence of cognitive bias. In this case, metacognitive illusion may occur (McCabe, 2011).

Whereas the conclusions on the impact of beliefs on metacognitive judgments are consistent, whether or not metacognitive judgment occurs due to processing fluency remains controversial. The fluency heuristic is one of the most commonly used in both remembering and nonremembering tasks (Whittlesea & Leboe, 2000). Some studies found that fluency does not affect metacognitive judgment (Jia et al., 2016; Mueller, Tauber, & Dunlosky, 2013; Witherby & Tauber, 2017). In these studies, to evaluate the fluency effect, response time was recorded during lexical decision (Witherby & Tauber, 2017, Experiment 4), self-spaced study (Jia et al., 2016, Experiment 2a; Witherby & Tauber, 2017, Experiment 5), mental imagery (Witherby & Tauber, 2017, Experiment 7) and different conceptual fluency conditions (Mueller et al., 2013, Experiment 3). Moreover, the number of trials to acquisition was measured (Witherby & Tauber, 2017, Experiment 6). In some cases, fluency was additionally disrupted by presenting words in a difficult font style (Jia et al., 2016, Experiment 2b) or in an alternating format (e.g., *aLtErNaTe*, Mueller et al., 2013, Experiment 2). Results showed that processing fluency contributed minimally to JOLs. However, most studies have also shown that learners preferred high to low fluency and judged their performance better in high fluency conditions (Carpenter, Mickes, Rahman, & Fernandez, 2016; Hertzog, Dunlosky, Robinson, & Kidder, 2003; Mantonakis et al., 2013; Undorf & Erdfelder, 2015). For instance, Carpenter et al. (2016) had participants watch a videotaped lecture that was delivered by the same instructor in either a fluent or disfluent manner. Then, the participants predicted their performance on an upcoming test. The results revealed that participants gave predictions of higher scores for the fluent instructor than that for the disfluent one. It is worth noting that in some studies, fluency did not influence individual academic performance (Carpenter et al., 2016; Rhodes & Castel, 2008, 2009). Metacognitive illusion may thus occur if learners make their metacognitive judgments based on processing fluency.

Considerable evidence also supports the assertion that fluency and beliefs influence metacognitive judgment in many learning paradigms (e.g., word frequency, lexical specificity). In contrast, there is less evidence regarding the effect of fluency and beliefs on category learning. For instance, examining metacognitive judgments on natural concepts learning, Wahlheim, Finn, and Jacoby (2012) presented their participants with bird families in high repetition and high variability conditions, and found that the studied stimuli benefited from repetition while novel stimuli benefited from variability. However, the results of metacognitive judgments revealed that learners were not aware of the benefits of variability. The authors stated that these results were due to fluency and beliefs, but they did not examine them experimentally. Yan et al. (2016) recently explored this issue. They asked participants to learn the style of paintings of 12 artists in interleaved and blocked conditions, and make category learning judgments (CLJ) on the probability of classifying new paintings correctly in the final test. The CLJs were used as an indicator of fluency both during the study phase (Experiment 1a) and afterwards (Experiment 1b). In Experiment 2, the participants were directly informed on which condition their performance was better and were asked to attribute the advantage so that the researchers could infer each participant's respective belief.

Although the results showed that both fluency and belief influenced metacognitive judgment (Yan et al., 2016), the authors' conclusions could be elaborated upon. First, in Experiment 1, Yan et al. used the CLJ value to infer that fluency influenced metacognitive judgment. But surprisingly, the results of Experiment 1b showed that the CLJ values in the interleaved presentation condition were higher. The authors doubted this result reflected that learners were aware of the interleaving effect, thus, they asked them to recall the schedule in which an artist had been presented. However, the results did not support their guesses—if this was difficult for the learners, they judged the artist must have been studied under the interleaved condition. In other words, the learners did not think they would benefit from interleaving. Considering that Yan et al. did not give a clear explanation why CLJ values in the interleaved condition were higher than in the blocked condition" it can be assumed that this result suggested interleaving was more fluent. According to Yan et al, CLJ reflected fluency. However, this was contrary to their conclusions that blocking exemplars of the same category creates a sense of fluency. Therefore, using CLJ as an indicator of fluency might have confounded the results.

Second, Yan et al. (2016) did not investigate the effect of prior beliefs in their research. Instead, in line with previous studies (McCabe, 2011; Tauber et al., 2013), they assumed participants held a prior belief that blocking exemplars of the same category rather than interleaving exemplars of different categories would enhance performance. They also explained the results in reference to this assumption. Both when learners could not match their actual performance with the initial schedule and when the learners discounted their classification performance under the interleaved condition, Yan et al, attributed these results to the influence of prior beliefs. Although the results indicated that participants held this belief, Yan et al. could not separate a pre-existing belief that participants held before they came to the experiment from the belief that was formed by the influence of fluency, because they did not investigate the prior belief in advance.

In summary, it is necessary to further explore the impact of fluency and beliefs on the metacognitive illusion in category learning. To this end, we have designed two experiments. In Experiment 1, we directly manipulated fluency by inserting an unrelated cartoon image in the blocked presentation condition and explored whether metacognitive judgments were different under different levels of fluency. In Experiment 2, in order to measure the existence of prior belief and the influence of prior belief on the metacognitive judgment, we asked participants to make a judgment before the experiment. Based on the dual processing systems theory (Koriat, 2000; Koriat & Bjork, 2006) and the results of previous studies (Carpenter et al., 2016; Hertzog et al., 2003; Jia et al., 2016; Mantonakis et al., 2013; Undorf & Erdfelder, 2015; Witherby & Tauber, 2017), we hypothesized that both fluency and belief would influence metacognitive judgment.

EXPERIMENT 1

We assume that learners feel a sense of ease when studying in the blocked condition rather than in the interleaved condition, which makes them mistakenly believe that blocking, rather than interleaving, enhances learning. This is the reason for the emergence of metacognitive illusions. To explore the effect of fluency on metacognitive judgment, we manipulated fluency in the blocked condition by inserting a cartoon drawing, while maintaining the original fluency in the interleaved condition. We then measured whether the learners' judgment on the effectiveness of the two study schedules would change when the fluency in the blocked condition changed. We expected that in the *fluent* group, participants would consider blocking to be more effective and in the *nonfluent* group, that they would believe the two study schedules had equal effectiveness, or even that they benefit more from interleaving than blocking.

Method

PARTICIPANTS

A total of 60 undergraduate students from Guangzhou University participated for course credit. They were randomly assigned to the fluent or the nonfluent condition. Six of the participants (three in each group) did not follow instructions during the experiment and were excluded from analyses. The final sample included 54 participants, 27 in the fluent condition (16 female, 11 male; M_{age} = 20.56 years; *SD* = 1.99) and 27 in the nonfluent condition (17 female, 10 male; M_{age} = 19.89 years; *SD* = 0.79).

MATERIALS

The materials, selected from Kornell and Bjork (2008), were 120 paintings, 10 paintings by each of the following 12 artists: Georges Braque, Henri-Edmond Cross, Judy Hawkins, Philip Juras, Ryan Lewis, Marilyn Mylrea, Bruno Pessani, Ron Schlorff, Georges Seurat, Ciprian Stratulat, George Wexler, and Yiemei.

DESIGN

We manipulated the study schedule (blocked vs. interleaved) and condition (fluent vs. nonfluent) in a 2 × 2 mixed design. The study schedule was manipulated within subjects, and the condition was manipulated between subjects.

PROCEDURE

Each participant completed the experiment on a personal computer. During the study phase, 72 paintings, six by each of the 12 artists, were presented for 3 s, with the artist's name displayed below the painting. After each painting, there was a 1 s blank screen. Six artists were assigned to the blocked condition and another six to the interleaved condition, which were randomized per participant. Participants underwent a total of 12 blocks, each block containing six trials, with the ordering of paintings randomly determined for each participant. In each block, either six paintings of a given artist were consecutively presented (blocked presentation, B) or one painting from each of six different artists was presented mixed (interleaved presentation, I), as shown in Figure 1. Following Yan et al. (2016), the order of the blocks was BIIBBIIBBIIB. The difference was that in the nonfluent group, each painting in the blocked condition was followed by a cartoon drawing (see Figure 2) for 1 s to decrease fluency[1], whereas, in the fluent group, there was no cartoon drawing. Before the experiment, the participants would be reminded that the cartoon image had nothing to do with the experiment and it should be ignored.

After the study phase, participants were asked to solve 50 simple math questions as a time-filler task, followed by a test to identify previously unseen paintings by the same artists whose paintings were presented in the study phase. In the test phase, there were four blocks.

Each block contained one painting by each of the 12 artists, presented in random order. One painting at a time was presented in the center of the screen, while the 12 artists' names were displayed below. The participants were asked to choose the name corresponding to the artist who created the painting currently being presented. The response time was not limited. Also, feedback was provided once the participant responded. If the response was correct, the word correct appeared on the screen; otherwise, the word incorrect and the correct artist's name appeared on the screen.

At the end of the experiment, the participants were provided an explanation of the blocked and interleaved study schedules and were asked to evaluate their effect on a 7-point scale: a rating of 1 indicated that blocking was better, a neutral rating of 4 indicated that both blocking and interleaving resulted in equivalent performance, and a rating of 7 indicated that interleaving was better

Results

CLASSIFICATION PERFORMANCE

A 2 × 2 (study schedule × condition) repeated-measures analysis of variance (ANOVA) revealed that the main effect of study schedule was significant, $F(1, 52) = 18.37$, $p < .01$, $\eta_p^2 = 0.26$. Interleaving paintings resulted in better performance ($M = 0.48$, $SD = 0.16$) than blocking ($M = 0.41$, $SD = 0.17$). The main effect of condition was not significant, $F(1, 52) = 0.10$, $p = .75$, $\eta_p^2 = 0$, indicating that fluency did not affect the performance. No study schedule × condition interaction was observed, all *F*s < 1. The results of these analyses are presented in Figure 3.

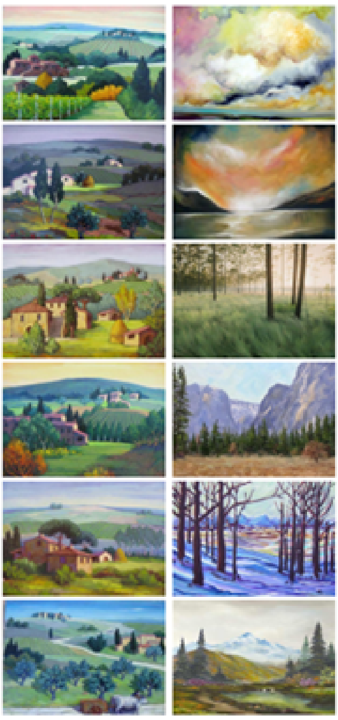

FIGURE 1.

The six paintings on the left column were all by the same artist (blocked), and the six paintings on the right column were all by six different artists (interleaved)..

METACOGNITIVE JUDGMENTS

We conducted an independent sample *t*-test to compare the mean rating of two groups. The results showed that the difference in metacognitive judgment values between the two groups was nonsignificant: $t(52) = 1.63$, $p = .11$. This seems to indicate that metacognitive judgment did not change due to changes in fluency. Although the difference was nonsignificant, the metacognitive judgment value of the nonfluent group was lower than that of the fluent group. Thus, to further analyze the impact of fluency on metacognitive judgment, one-sample *t*-tests were carried out to compare the mean rating to the unprejudiced response of 4 (McCabe, 2011). For the participants in the fluent group, the mean rating ($M = 2.52$, $SD = 1.60$) was significantly lower than the neutral 4, $t(26) = 4.81$, $p < .001$, $d = 1.89$; however, the difference between the mean rating ($M = 3.22$, $SD = 2.08$) and the rating of 4 in the nonfluent group was marginally significant, $t(26) = 1.94$, $p = .06$, $d = 0.38$, indicating that in the fluent group, participants tended to believe blocking was more effective. Participants in the nonfluent group also believed they had more benefit from studying under the blocked condition, but the degree was not as high as that of the fluent group, and even they judged the effect of the two study schedules to roughly be the same. In summary, the results of metacognitive judgments showed that reducing fluency can reduce the propensity for metacognitive illusion.

Discussion

In Experiment 1, participants profited from interleaving rather than blocking, however, their metacognitive judgment did not match this effect, indicating that participants held metacognitive illusions. This is consistent with existing studies (Birnbaum et al., 2013; Kang & Pashler, 2012; Kornell & Bjork,2008; Kornell et al., 2010).

For the participants in the nonfluent group, the difference between the metacognitive judgment values and the rating of 4 was marginally significant, whereas the mean rating in the fluent group was significantly lower than the neutral 4, indicating that fluency affects metacognitive judgment. This is also in line with some previous studies (Carpenter et al., 2016; Hertzog et al., 2003; Mantonakis et al., 2013; Undorf & Erdfelder, 2015).

In the nonfluent group, even though the fluency in the blocked presentation was reduced by inserting an unrelated cartoon drawing, participants still judged that blocking was more effective than interleaving or that both schedules were equally effective. This suggests that, in addition to fluency, there are other factors that influence metacognitive judgment. According to the hypothesis of metacogni-

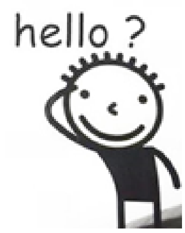

FIGURE 2.

The cartoon drawing shown in the blocked condition in the *nonfluent* group.

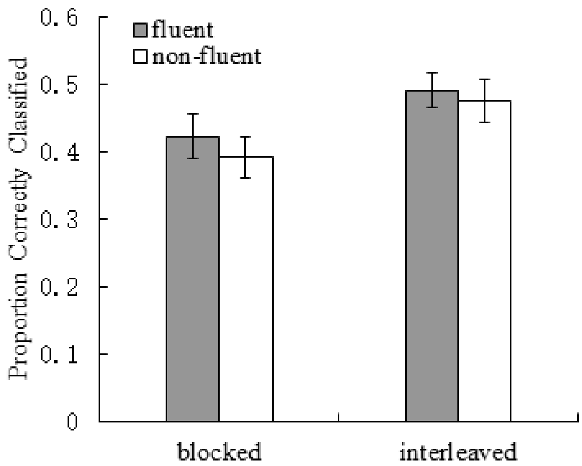

FIGURE 3.

Classification results for blocked and interleaved artist presentation in the fluent and nonfluent groups. Error bars indicate the SEM.

tive monitoring from the dual processing systems theory (Koriat, 2000; Koriat & Bjork, 2006) and previous studies (Jia et al., 2016; Mantonakis et al., 2013; Undorf & Erdfelder, 2015; Witherby & Tauber, 2017), the inferred belief should be one of those factors. We explored this possibility in Experiment 2.

EXPERIMENT 2

Based on the results of Experiment 1, we hypothesized that belief is one of the factors influencing metacognitive judgment. We tested whether learners hold the belief that blocking is a more effective study schedule, which leads to metacognitive illusion. Furthermore, we checked whether this belief would change to a new belief and eliminate the metacognitive illusion after the participants received a theoretical explanation of the interleaving effect. We expected participants to hold a prior belief that blocking instruction by topic is superior to interleaving topics and for the belief to disappear after learners receive the theoretical explanation why interleaving exemplars is better.

At present, there are two approaches to explore the influence of beliefs: ask learners to make the metacognitive judgment at the beginning of the whole experiment or ask at the beginning of each trial. We used the former one for two reasons. First, making a metacognitive judgment in each trial may interfere with learners and have an impact on the results. Second, making a metacognitive judgment at the beginning of the first trial can avoid fluency effects, however, the fluency experience in the first trial will affect the metacognitive judgment made at the beginning of the second trial.

Method

PARTICIPANTS

For Experiment 2, a total of 60 undergraduate students from Guangzhou University participated for course credit. None of them participated in Experiment 1. They were randomly assigned to the *no information* or the *information* condition. Three of them (one from the no information group, two from the information group) did not follow instructions during the experiment and the accuracy of six other participants (two in the no information group and four in the information group) was less than 9%. These nine students were excluded from the analyses. The final sample included 51 participants, 27 in the no information condition (15 female, 12 male; M_{age} = 20.15 years; SD = 2.22) and 24 in the information condition (16 female, 8 male; M_{age} = 19.46 years; SD = 0.96).

MATERIALS

Other than the number of paintings, the materials were the same as in Experiment 1. There were 12 paintings in the test phase in Experiment 2, one by each of the 12 artists.

DESIGN

For the no information condition, the procedure was the same as the fluent group in Experiment 1, but with the following changes. First, the participants needed to make two metacognitive judgments, one before the experiment and one at the end. Before making the first metacognitive judgment, they were required to read the description of the Kornell and Bjork (2008) study. They were then asked to evaluate the effect of two study schedules on the 7-point scale used in Experiment 1 and write down on paper the reason for their judgment. Second, there was only one block in the test phase, which contained 12 new paintings, one by each of the 12 artists, presented in random order. It was similar in structure to the interleaving block, so if it contained multiple blocks in the test, the participants would experience the advantage of interleaving, reducing the difference in the benefit of two study schedules. The single test block in Experiment 2 was similar to Experiments 3, 5, and 6 of Yan et al. (2016).

For the information condition, the procedure was exactly the same as the no information condition. The only difference was that in the information condition, participants were provided with the theoretical explanation about the advantage of interleaving after the test, whereas the participants in the no information condition were not.

Results

CLASSIFICATION PERFORMANCE

The result of the paired-samples t-test showed that interleaving examples resulted in significantly higher accuracy (M = 0.52, SD = 0.17) than did blocking (M = 0.45, SD = 0.22), $t(50) = 2.56$, $p < .05$, $d = 0.72$. The results of these analyses are presented in Figure 4.

FIRST METACOGNITIVE JUDGMENT

The results of an independent samples t-test revealed that the difference between the first metacognitive judgments made by the two groups was nonsignificant, $t(49) = 0.17$, $p = .87$, $d = 0.00$, indicating that participants in the no information group (M = 3.39, SD = 2.18) and participants in the information group (M = 3.33, SD = 2.46) ini-

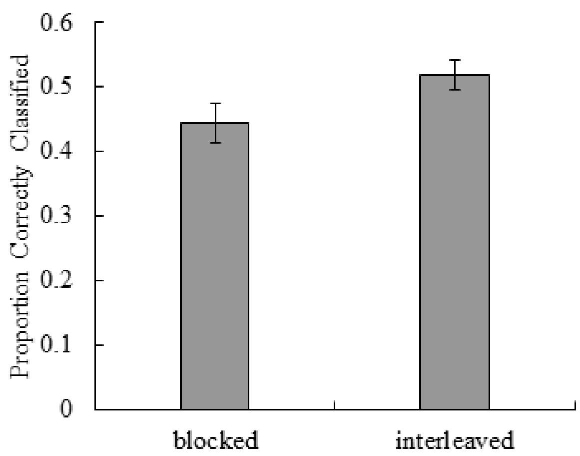

FIGURE 4.

Classification results for blocked and interleaved artist presentation. Error bars indicate the *SEM*.

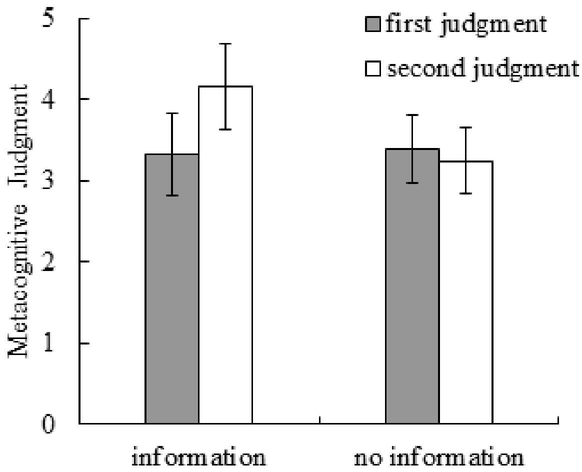

FIGURE 5.

Averaged metacognitive judgments made before (first) and at the end of the experiment (second). Error bars indicate the *SEM*.

tially held the same belief. Thus, if the difference between the second metacognitive judgments made by the two groups was significant, it would due to the new information, not because of their initial belief differences.

A one-sample *t*-test was conducted to compare the mean rating of schedule effectiveness to the neutral response of 4 (McCabe, 2011). We found that the mean rating (M = 3.31, SD = 2.44) was marginally significantly lower than 4, $t(50) = 2.01$, $p = .05$, $d = 0.57$, indicating that the participants held a prior belief that blocking paintings was superior to interleaving. These results are presented in Figure 5.

ATTRIBUTION OF METACOGNITIVE ILLUSION

Table 1 summarizes the number and percentage of participants in different conditions. The results revealed a divergence between the participants' actual performance and their metacognitive judgments. In many cases, their metacognitive judgments did not match their actual results. This most frequently occurred when the performance was the same in two study schedules or was better in the interleaved condition; in these cases, the participants judged that blocking was better. A total of 25 participants judged blocking was more effective even though this did not match their actual performance. We additionally analyzed the reasons they wrote down to justify their judgements. Two psychology graduate students were trained to classify the reasons these participants wrote down (see Figure 6). In case of disputes, the two raters reached an agreement through negotiation. The internal consistency and reliability of the raters was 0.81, $p < .01$.

TABLE 1.

Frequencies and Percentages of Participants Making the First Metacognitive Judgment of Study Schedule Efficacy and Their Actual Performance

Actual performance	Metacognitive judgment: Blocked was more effective	Equal efficacy	Interleaved was more effective
Blocked > interleaved	3 (25.0%)	5 (41.7%)	4 (33.3%)
Equal	10 (66.7%)	1 (6.7%)	4 (26.7%)
Interleaved > blocked	15 (62.5%)	3 (12.5%)	6 (25.0%)
All	28 (54.9%)	9 (17.6%)	14 (27.5%)

Note. The frequency count and percentage are given for the first metacognitive judgment. The ratings of 1-3 mean that participants thought blocking was more effective; 4 means that participants thought the two study schedules had equal effectiveness; and 5-7 meant that participants thought interleaving was more effective.

SECOND METACOGNITIVE JUDGMENT

The result of an independent-samples *t*-test revealed that the difference between the second metacognitive judgments made by the two groups was nonsignificant, $t(49) = 1.38$, $p = .17$. This indicates that although participants in the information group were provided with

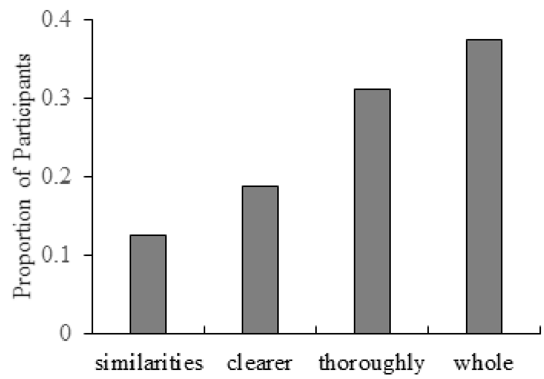

FIGURE 6.

The participants' attributions for why they thought blocking was better. *Similarities* represented answers such as "good for finding the similarities within each concept", *clearer*—"less confusing", *thoroughly*—"to facilitate learning each category thoroughly", and *whole*—"to grasp the characteristics of each category as a whole."

the theoretical explanation of the interleaving effect, their judgments remained the same as those participants' in the no information group. Although the difference was not statistically significant, the mean rating of the no information group (M = 3.15, SD = 2.14) was lower than that of the information group (M = 4.17, SD = 2.60). To further determine whether participants established a new belief after being provided with the theoretical explanation of interleaving, one-sample t-tests were conducted to compare the participants' effectiveness ratings in the two groups to the neutral rating of 4.

The results revealed that the second metacognitive judgment in the no information group was significantly lower than 4, $t(26) = 2.07$, $p < .05$, $d = 0.81$, indicating that the participants in the no information condition still believed that blocked presentation was more effective, whereas there was no significant difference between the metacognitive judgments of participants in the information group and the neutral response of 4, $t(23) = 0.31$, $p = .76$, $d = 0.07$, indicating that the belief of the participants in the information group changed to the belief that blocking was as good as interleaving after being provided the theoretical explanation for why interleaving examples was actually more effective than blocking.

Table 2 summarizes the number and percentage of the participants' second metacognitive judgments in different conditions. When the participants were not provided any information after the test, 63% of them thought that blocking was more effective while 25.9% that interleaving was more effective. However, in the information condition, where learners were provided with a theoretical explanation for the interleaving effect, 51% considered blocking more effective while 43.1% responded that interleaving was better. Following the approach used by Yan et al. (2016), all the "equal" responses (e.g., effectiveness ratings of 4) were excluded from the analyses and a χ^2 test of independence was conducted. If the learners could establish a new belief to correct the metacognitive illusion after new information was provided, then the judgment made in the information group would be different from that made in the no information group. The results revealed that the metacognitive judgment was independent of actual effectiveness in the no information condition, $\chi^2(1)= 0.07$, $p = .79$. However, in the information condition, the metacognitive judgment was dependent on the learners' actual performance, $\chi^2(1)= 3.35$, $p = .06$. These results suggest that learners were not aware of the interleaving effect in the no information condition, but were in the information condition.

Discussion

The results were consistent with those of Experiment 1. In Experiment 2, they showed that compared to blocking stimuli of a given category, interleaving stimuli across different categories enhanced the classification performance, but the participants' metacognitive judgment revealed that they thought the blocked presentation was more effective, indicating that the participants held a metacognitive illusion.

By allowing the participants to make metacognitive judgments before the experiment, the influence of prior beliefs was examined. Since the participants did not yet begin the experiment and would not be affected by fluency, the metacognitive judgment made before the experiment was mainly the product of prior belief. The results revealed that the participants' metacognitive judgments were marginally lower than the neutral effectiveness judgement of 4, indicating that they held a prior belief that blocking was more beneficial for learning. This result is consistent with previous studies (Jia et al., 2016; Mantonakis et al., 2013; Undorf & Erdfelder, 2015; Witherby & Tauber, 2017).

We were interested in those participants who benefited from leaning in the interleaved condition but still held the belief that blocking enhanced classification performance on novel stimuli to a greater degree than did interleaving. We found that the main reason given was that they thought consecutively presenting stimuli of a given category could help them grasp the characteristics of each category as a whole,

TABLE 2.
Frequencies and Percentages of Participants Making the Second Metacognitive Judgment of Study Schedule Efficacy and Their Actual Performance

Condition	Metacognitive judgment			
	Actual performance	Blocked was more effective	Equal efficacy	Interleaved was more effective
No information	Blocked > interleaved	5(83.3%)	0	1(13.7%)
	Equal	5(50.0%)	1(10.0%)	4(40.0%)
	Interleaved > blocked	7(63.6%)	218.2%	2(18.2%)
	All	17(63.6%)	3(11.1%)	7(25.9%)
Information	Blocked > interleaved	4(66.7%)	0	2(33.3%)
	Equal	2(40.0%)	0	3(50.0%)
	Interleaved > blocked	3(23.1%)	0	10(76.9%)
	All	9(37.5%)	0	15(62.5%)
Combined	Blocked > interleaved	9 (75.0%)	0	3 (25.0%)
	Equal	7 (46.7%)	1 (6.7%)	7 (46.7%)
	Interleaved > blocked	10 (41.7%)	2 (8.3%)	12 (50.0%)
	All	26 (51.0%)	3 (5.9%)	22 (43.1%)

Note. The frequency count and percentage in Table 2 is given for the second metacognitive judgment. The ratings of 1-3 mean the participants thought that blocking was more effective; 4 means the participants thought that the two study schedules had equal efficacy, and 5-7 means the participants thought interleaving is more effective.

and that blocking was helpful o understand each category in depth. This may be related to the individuals' educational history (Yan et al., 2016). Individuals typically get accustomed to learning a portion of information (e.g., a textbook chapter) and then learning the next one, which is similar to blocked learning. Therefore, they hold the belief that blocking is more effective.

GENERAL DISCUSSION

This study explored the influence of fluency and belief on metacognitive judgment through two experiments. In Experiment 1, we inserted an unrelated cartoon drawing into a blocked study schedule condition to increase the time interval between displaying examples of the same category, thus reducing the participants' processing fluency. By comparing the results under two fluency conditions, we investigated whether the metacognitive judgment would change to examine the effect of fluency. The results showed that after fluency was reduced, the participants' metacognitive judgments changed, and the metacognitive illusion tended to become dispelled, thus indicating that fluency affects metacognitive illusion. In Experiment 2, we explored the influence of the participants' prior beliefs by allowing them to make metacognitive judgments before the experiment. The results revealed that most of the participants strongly held the belief that blocking is more effective than interleaving when they began the experiment. When the participants were provided with a theoretical explanation on the advantage of interleaved presentation, their metacognitive judgments changed along with it, thus indicating that beliefs also influence metacognitive illusion. Taken together, the results support the hypothesis of metacognitive monitoring from the dual processing systems theory (Koriat, 2000; Koriat & Bjork, 2006) and extend the theory to category learning.

Participants' Metacognitive Illusion

The results of the two experiments consistently revealed that the participants' performance was better when they were presented with stimuli in an interleaved condition than in a blocked condition; in contrast to performance, their overall metacognitive judgments tended toward the belief that blocking was more effective. These results were consistent with previous studies (Birnbaum et al., 2013; Bjork et al., 2013; Kornell & Bjork, 2008; Tauber et al., 2013; Yan et al., 2016), showing that participants lacked metacognitive awareness.

Why did the participants prefer the blocked presentation? Previous studies (Birnbaum et al., 2013; Kornell & Bjork, 2008; Tauber et al., 2013; Yan et al., 2016) did not discuss this issue. However, we can refer to some studies in which the impact of fluency and belief on metacognitive judgments was explored (Mantonakis et al., 2013; Undorf & Erdfelder, 2015). In addition, the dual processing systems theory's explanation of metacognitive monitoring provides a theoretical explanation for this phenomenon. First, this preference could owe to fluency (Benjamin, Bjork, & Schwartz, 1998). Presenting the items of the same category consecutively (blocked presentation) makes processing the latter stimulus seem easier, leading to higher fluency, whereas interleaving different categories decreases the fluency of processing the latter stimulus. In other words, the sense of ease confuses the participants and convinces them that they are attaining mastery quicker in a blocked condition. Second, it could be related to the learner's own learning experiences (Yan et al., 2016). Their educational histories are similar to the blocked study schedule. For example, teachers tend to teach students topic by topic, and textbook authors tend to organize books into different chapters according to different topics. These experiences allow learners to form the belief that blocking is a more effective way to study.

Impact of Fluency on Metacognitive Judgment

Yan et al. (2016) explored the influencing factors of metacognitive judgment in the category learning field. They allowed participants to make CLJs during (Experiment 1a) and after the study phase (Experiment 1b). The value of the CLJs was used as an indicator of fluency. They calculated the relationship between the CLJs and metacognitive judgments, which revealed that fluency caused the cognitive illusion. However, it had not been answered yet whether it was appropriate to use CLJs as an indicator of fluency. After all, CLJs for interleaved presentation of the artists were higher in the Yan et al. (2016) study, but blocking the examples of the same category rather than interleaving examples across different categories should create a feeling of ease. Second, CLJs are metacognitive judgments. Theoretically, the value of a CLJ is related to the value of a metacognitive judgment. It seems inappropriate to draw the inference that fluency influences a metacognitive judgment because of the relationship between CLJs and metacognitive judgment.

In a departure from Yan et al. (2016), this study manipulated fluency directly by inserting an unrelated cartoon drawing into the presentation blocks. Comparing metacognitive judgment values of participants under different fluency conditions, we found that fluency affected metacognitive judgments. The general idea that a blocked condition leads to greater fluency than in an interleaved condition is common, and it leads to a metacognitive illusion. Therefore, this study decreased the fluency in the blocked condition but maintained it in the interleaved condition in order to explore whether the participants' metacognitive judgments would change when the fluency in the two study schedules changed. To the best of our knowledge, this was the first time that fluency was manipulated by inserting an unrelated stimulus.

In the past, the fluency was disrupted by presenting words in a difficult font style (Jia et al., 2016) or in an alternating font size (Mueller et al., 2013). However, considering that the materials used in the blocked condition were the same as those used in the interleaved condition, the difference in fluency was not because of material. Thus, we did not follow manipulations used in prior studies. Comparing the blocking and interleaving learning, we found two main differences: (a) mixing exemplars from different categories and (b) temporal spacing. Because the former is the essence of the two practice schedules, we intended to manipulate the temporal spacing rather than interleaving. Thus, we manipulated the fluency in the blocked condition by inserting an irrelevant cartoon filler. The results revealed that compared to the fluent condition, participants spent more time learning in the nonfluent condition, indicating that inserting irrelevant stimuli diminished fluency. This suggests that this manipulation of fluency was effective.

Researchers used the very same manipulation of inserting fillers to explore whether the interleaving effect was due to the increased temporal spacing between stimuli of the same category or due to the interleaving of stimuli from different categories (Birnbaum et al, 2013; Kang & Pashler, 2012). They found that when learners studied in the interleaved condition, inserting a filler disrupted the process of category induction. However, if learners studied in the blocked condition, their performance would not be disrupted by inserting the filler. We inserted a cartoon filler only in the blocked condition; therefore, the process of category induction should not be disrupted. However, further examinations of the reliability and validity of this manipulation of fluency are still needed.

Influence of Belief on Metacognitive Judgment

Yan et al. (2016) informed their participants about their performance in each condition at the end of the experiment, allowing them to attribute it to the influence of beliefs on the metacognitive judgment. The results revealed that when the participants' performance was better in the blocked condition, they thought it owed to blocking being more effective. On the contrary, for those participants whose performance benefited from interleaving, they attributed this benefit to the belief that the materials were relatively simple rather than to the interleaving.

Thus, Yan et al. (2016) inferred that learners held the prior belief that blocking is more effective. However, in their research, attribution was performed at the end of the experiment, when learners had experienced the difference in fluency between the two study schedules. Therefore, the results cannot reflect the learners' prior beliefs accurately. In order to avoid the effect of fluency, we asked participants to make metacognitive judgments before the experiment. The results also showed that participants held a prior belief that blocked presentation is more effective. This belief was not consistent with their actual performance, so when they made the judgment based on this prior belief, a metacognitive illusion occurred.

Correct Metacognitive Illusions

Can we correct our metacognitive illusions? Yan et al. (2016) attempted to solve this question, but their results showed it is a daunting task. Even though the participants were informed that most of the learners benefit from interleaving or were provided detailed accounts of this effect, they tended to believe blocking is better, when the opposite was in fact true. In this study, we attempted to mend the participants' tendency to form metacognitive illusions by providing them with a theoretical explanation of why interleaving examples across different categories leads to better performance. The results showed that after obtaining a theoretical explanation, the participants' metacognitive judgments about the value of blocking improved greatly, and their belief changed from "blocking is more effective" to "the two study schedules are equally effective." Thus, the metacognitive illusion was not completely eliminated. We conclude that there are two reasons for this result.

First, the feedback on performance was not obvious. To improve the accuracy of metacognition, participants must be aware of the differences in performance under different conditions (Tullis, Finley, & Benjamin, 2013). In this study, participants were not informed about their performance in the two study schedules directly, and the different study schedules were not highlighted, so the participants may have confused which artist's paintings were presented in which study schedule (Yan et al., 2016). Once this situation occurred, it was easy to make a wrong judgment when given feedback. The theoretical explanation of the advantage of interleaving did not work in such cases.

Second, the information participants received could have not been enough. McCabe (2011) enrolled four groups of participants from different types of courses. Two groups consisted of students from introductory psychology courses. For the first group, they did not receive any information on memory and learning, and for the second, they heard a lecture about this topic. The third group consisted of students from 200-level cognitive psychology courses who had learned about this topic and discussed this topic in class. The fourth group was enrolled from an advanced seminar on cognition and education. Students in this group had read and discussed the related articles. McCabe compared the metacognitive judgments of these four groups of participants and found that the accuracy of the metacognitive judgment of the fourth group was significantly higher than that of the other three. McCabe believes that providing targeted instruction could improve students' metacognitive awareness; according to McCabe, the more information the students were exposed to, the stronger the effect. Therefore, future research can explore whether participants' metacognitive illusions can be corrected by providing various kinds of information, such as the respective advantages and disadvantages of the two study schedules, the actual performance, and the theoretical explanation.

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FOOTNOTES

[1] We also carried out an experiment in which participants studied the 12 artists' paintings under both fluent (F) and nonfluent (N) conditions. Paintings by six artists were presented under fluent condition; the remainder were presented under the nonfluent condition. The selection of artists and the order of presentation were randomized for each participant. The order of blocks was NFFNNFFNNFFN. All paintings presented in the blocked condition. Each painting was displayed until the participant pressed the space bar to advance to the

next painting. We collected data from 35 participants and analyzed the reaction time. The results of the paired sample t-test showed that compared to the fluent condition (M = 4464.78 ms, SD = 2812.19 ms), participants spent more time studying in the nonfluent condition (M = 5096.27 ms, SD = 3252.58 ms), $t(34) = 2.52$, $p = .01$, $\eta_p^2 = 0.63$. This suggests that our manipulation of fluency was effective.

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