The Effect of Individuals' Beliefs About Processing Fluency on the Font Size Effect Postprint

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Abstract

This study examines the influence of individuals' beliefs about processing fluency on Judgment of Learning (JOL) and explores the mechanism underlying the font size effect. Through two experiments, the study investigated how beliefs such as "font size affects processing fluency" (Experiment 1) and "processing fluency affects memory performance" (Experiment 2) influence the font size effect. The results revealed that: 1) When individuals believed that large fonts were more fluent (Experiment 1) or that greater fluency led to better memory (Experiment 2), their JOL values for large-font items were significantly higher than for small-font items; 2) When individuals believed that small fonts were more fluent (Experiment 1) or that fluency was unrelated to memory (Experiment 2), there was no significant difference in JOL values between large-font and small-font items, and the font size effect disappeared. These findings indicate that individuals' beliefs about processing fluency constitute an important cause of the font size effect and serve as a crucial cue when making learning judgments.

Full Text

The Influence of Learner' s Beliefs About Processing Fluency on the Font-Size Effect

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Abstract

This study investigated how individuals' beliefs about processing fluency influence judgments of learning (JOL) and examined the cognitive mechanism underlying the font-size effect. Two experiments were conducted to assess the impact of beliefs about "font size affecting processing fluency" (Experiment

1) and "processing fluency affecting memory performance" (Experiment 2) on the font-size effect. The results revealed that: (1) When participants believed that large fonts were more fluent (Experiment 1) or that greater fluency led to better memory (Experiment 2), their JOLs were significantly higher for large-font items than for small-font items; (2) When participants believed that small fonts were more fluent (Experiment 1) or that fluency was unrelated to memory (Experiment 2), no significant differences emerged in JOLs between large- and small-font items, and the font-size effect disappeared. These findings demonstrate that beliefs about processing fluency constitute an important source of the font-size effect and serve as a critical cue for making learning judgments.

Keywords: font-size effect; judgments of learning; beliefs about processing fluency
Classification Code: B842

Learners' predictions about their future test performance on recently studied materials substantially influence the effectiveness of their self-regulated learning (Dunlosky & Rawson, 2012; Kornell & Metcalfe, 2006; Thiede, Anderson, & Therriault, 2003). These predictions, known as judgments of learning (JOL), represent one of the most extensively studied forms of metacognitive monitoring (Dunlosky & Metcalfe, 2009; Mueller, Tauber & Dunlosky, 2013). For nearly four decades, researchers have debated the mechanisms underlying JOL formation, with two primary hypotheses emerging: the processing fluency hypothesis and the beliefs hypothesis. Recent research on the font-size effect—in which JOLs are higher for words presented in larger versus smaller fonts—has provided crucial evidence for both accounts. While some studies suggest that the font-size effect stems from processing fluency (Kornell, Rhodes, Castel, & Tauber, 2011; Rhodes & Castel, 2008), others indicate that it arises from beliefs about memory (Hu et al., 2015; Mueller, Dunlosky, Tauber, & Rhodes, 2014). Mueller and Dunlosky (2017) recently proposed that the font-size effect emerges from beliefs about processing fluency rather than from fluency itself, offering preliminary evidence to support the beliefs hypothesis. Building on this work, the present study provides more direct evidence for how beliefs about processing fluency influence the font-size effect, thereby shedding further light on the cognitive mechanisms of metacognitive judgments.

Koriat' s (2000, 2007) dual-process model offers an influential theoretical framework for understanding metacognitive monitoring. This model posits that metacognitive monitoring comprises two systems: theory-based monitoring and experience-based monitoring. Theory-based monitoring involves making judgments based on explicit theories or beliefs about memory, representing a conscious, deliberate process. In contrast, experience-based monitoring relies on subjective experiences such as processing fluency, operating at an unconscious level. Extensive empirical research has supported this model (Jia et al., 2016; Li et al., 2016; Mueller, Dunlosky, & Tauber, 2016; Mueller et al., 2013; Susser & Mulligan, 2015), with studies on the font-size effect providing particularly compelling evidence (Hu et al., 2015; Kornell et al., 2011; Mueller et al., 2014;

Rhodes & Castel, 2008).

Rhodes and Castel (2008) first documented the font-size effect, demonstrating that font size influences JOLs. In their study, participants learned 36 words, half presented in large font (48 pt) and half in small font (18 pt). Each word appeared for 5 seconds, after which participants made JOLs by predicting the likelihood (0–100%) of recalling the word on a subsequent test, followed by a free recall task. The results showed that JOLs were higher for large-font items than for small-font items, yet font size did not affect actual recall performance. This font-size effect has been consistently replicated in subsequent research (Kornell et al., 2011; Miele, Finn, & Molden, 2011; Mueller et al., 2014).

Investigations into the mechanism underlying the font-size effect have provided support for the dual-process model. On one hand, research by Kornell et al. (2011) and Rhodes and Castel (2008) suggests that the effect arises from processing fluency. For instance, Rhodes and Castel (2008) asked participants to make ease-of-reading judgments for large- and small-font items, finding that participants rated large-font words as easier to read, indicating that large-font items were perceived as more fluently processed. To further test this hypothesis, the researchers reduced the processing fluency of all learning materials by presenting words in alternating case (e.g., aLtErNaTiOn). Under these conditions, the font-size effect disappeared, suggesting that processing fluency plays a crucial role in how font size influences JOLs.

On the other hand, Mueller et al. (2014) demonstrated that beliefs—such as the notion that large fonts are more important than small fonts—cause the font-size effect, independent of processing fluency. In their Experiments 1 and 2, font size affected JOLs but not processing fluency (as measured by lexical decision reaction times and self-paced study time), suggesting that the effect was unrelated to fluency. In Experiment 3, participants read a description of a font-size experiment and then estimated how many large- versus small-font items hypothetical participants would recall. Experiment 4 required participants to make pre-study JOLs before learning, which would be influenced by beliefs rather than fluency. Both experiments revealed a font-size effect, indicating that font size influences JOLs through beliefs.

These findings suggest that both processing fluency and beliefs may contribute to JOLs. As Dunlosky et al. (2015) noted, processing fluency and beliefs are sometimes closely linked and may interact to jointly influence JOLs. For example, people might base their JOLs on beliefs about processing fluency (Finn & Tauber, 2015). Similarly, Mueller and Dunlosky (2017) argued that the font-size effect likely stems from beliefs about processing fluency. Specifically, participants believe that large-font items are easier to process than small-font items and that more fluently processed items are better remembered. To test this hypothesis, Mueller and Dunlosky manipulated beliefs about font color (blue/green) through instructions. They chose color because it does not affect processing fluency and people generally believe it is irrelevant to fluency. If participants could be led to believe that color affects fluency and their JOLs reflected this belief—showing higher JOLs for the color they believed was more fluent (e.g., blue) than the other color (e.g., green)—this would demonstrate that beliefs about fluency influence JOLs. In Experiment 4, the experimental group read instructions stating that "blue font is processed more fluently than green font," while the control group received no such instructions. All participants studied words in different colors, made JOLs, and completed a recall test. The results showed that the experimental group gave significantly higher JOLs for blue-font items than for green-font items, whereas the control group showed no difference between blue and green fonts. These findings suggest that beliefs about processing fluency influence JOLs.

However, although Mueller and Dunlosky' s (2017) results demonstrate that beliefs about processing fluency affect JOLs, their study did not directly examine the font-size effect. Therefore, it remains unclear whether the font-size effect is indeed based on beliefs about processing fluency. Furthermore, as Mueller and Dunlosky acknowledged, participants hold not only the belief that "large-font items are easier to process" but also that "more fluently processed items are better remembered." In essence, beliefs about processing fluency involved in the font-size effect include both "how learning material characteristics affect processing fluency" and "how processing fluency affects memory performance." Yet Mueller and Dunlosky' s research only examined the former. Given that beliefs about "processing fluency affecting memory performance" constitute an important component of fluency-related beliefs, the present study argues that it is necessary to further investigate how this particular belief influences JOLs.

In summary, the present study aims to: (1) examine how beliefs about processing fluency influence the font-size effect; and (2) separately investigate the effects of beliefs about "font size affecting processing fluency" and "processing fluency affecting memory performance" on JOLs. To achieve these goals, we conducted two experiments. Experiment 1 manipulated beliefs about "font size affecting processing fluency" through instructions to examine the role of this belief in the font-size effect. Experiment 2 manipulated beliefs about "processing fluency affecting memory performance" through instructions to examine its role in the font-size effect. Exploring these questions will help us understand more specifically and comprehensively how beliefs about processing fluency influence JOLs and their role in the font-size effect, thereby providing new evidence for the cognitive mechanisms underlying metacognitive judgments.

Experiment 1

Experiment 1 investigated how beliefs about "font size affecting processing fluency" influence the font-size effect. We manipulated beliefs through instructions: one group was led to believe that large fonts are more fluently processed than small fonts (hereafter, the Large-Font-More-Fluent group), another group was led to believe that small fonts are more fluently processed than large fonts (the Small-Font-More-Fluent group), and a control group received no instructions. If the previously observed font-size effect is based on beliefs about processing fluency rather than fluency itself, then the Large-Font-More-Fluent group and the control group should exhibit the font-size effect. Moreover, because the instructions emphasize the belief that "large fonts are more fluent than small fonts," this belief may have a stronger influence on JOLs than in the absence of instructions. Therefore, the font-size effect may be larger in the Large-Font-More-Fluent group than in the control group. Conversely, the Small-Font-More-Fluent group received instructions emphasizing that "small fonts are more fluent than large fonts." If participants base their JOLs primarily on their beliefs about processing fluency rather than on fluency itself, then participants in this group should give higher JOLs for small-font items than for large-font items, showing an effect opposite to the typical font-size effect.

2.1.1 Participants

We calculated the required sample size using G*Power software (Faul, Erdfelder, Lang, & Buchner, 2007). Previous research on the font-size effect reported Cohen' s ds ranging from 0.58 to 0.74. Based on this effect size range, a sample size of 22–34 participants per group was needed to achieve a statistical power of 0.9 (see Yang, Huang, & Shanks, 2018). Accordingly, Experiment 1 recruited 75 university students (9 male) with a mean age of 20.27 ± 1.69 years. All participants had normal or corrected-to-normal vision and were randomly assigned to the Large-Font-More-Fluent group ($n = 23$), the Small-Font-More-Fluent group ($n = 26$), or the control group ($n = 26$). None had previously participated in similar psychology experiments. Participants received compensation after completing the experiment.

2.1.2 Materials

The experiment was presented on a 17-inch PC monitor with a resolution of 1024$\times$768 and a white background. Memory items were presented in Song font, size 18 pt or 48 pt, at the center of the screen (as shown in Figure 1 [Figure 1: see original paper]).

The learning materials consisted of 60 common Chinese word pairs (e.g., "gift—high-rise building"). Twenty-two participants who did not take part in the formal experiment rated all word pairs on difficulty and familiarity using a 7-point scale. Difficulty referred to how easy it was to associate the cue word with the target word (1 = very difficult, 7 = very easy), while familiarity referred to how familiar the words were (1 = very unfamiliar, 7 = very familiar). Based on these ratings, we sorted all word pairs by difficulty and selected the 30 odd-numbered pairs to be presented in large font and the 30 even-numbered pairs in small font. Post-hoc tests revealed no significant differences between the two sets in difficulty ($t = 0.03$, $p > 0.05$; $M = 1.96$, $SD = 0.21$) or familiarity ($t = 0.44$, $p > 0.05$; $M = 6.23$, $SD = 0.27$). Additionally, four word pairs of comparable difficulty were created for practice.

2.1.3 Design

We employed a 2 (font size: 48 pt, 18 pt) × 3 (group: Large-Font-More-Fluent, Small-Font-More-Fluent, control) mixed design, with font size as a within-subjects factor and group as a between-subjects factor. The dependent variables were JOL values and recall accuracy.

2.1.4 Procedure

The experimental program was developed using E-Prime 2.0 software. Participants sat approximately 65 cm from the computer screen with their eyes level with the screen center. Before the formal experiment, participants completed four practice trials to familiarize themselves with the task and procedure.

During the formal experiment, participants first read the corresponding instructions. The Large-Font-More-Fluent group received instructions stating: "Because large fonts subtend a larger visual angle than small fonts, large fonts are easier to see and read. That is, the brain processes large fonts much more easily than small fonts, meaning large fonts are processed more fluently than small fonts." The Small-Font-More-Fluent group received instructions stating: "Because small fonts have fewer 'dot matrix' elements than large fonts, they can easily be controlled within the visual field, making it easier for the brain to process smaller fonts than larger fonts. That is, small fonts are processed more fluently than large fonts." The control group received no instructions.

After reading the instructions, all participants completed the following tasks:

(1) **Study Phase**: Sixty word pairs (30 in 18 pt font, 30 in 48 pt font) were presented individually in a fixed random order at the center of the screen, with the constraint that the same font size would not appear three or more times consecutively (to avoid order effects, half the participants studied the pairs in forward order and half in reverse order). Each word pair was presented for 5 seconds, during which participants were instructed to memorize it. Immediately after each pair disappeared, participants made a JOL by predicting the likelihood (0%-100%) of recalling the target word when given the cue word on a subsequent test (0% = definitely cannot recall, 100% = definitely can recall). After studying and judging all word pairs, participants completed a 3-minute distractor task (counting backward from 200 by threes).

(2) **Test Phase**: Cue words in different font sizes were presented randomly on the computer screen, and participants were asked to recall the corresponding target words by typing them using the keyboard. There was no time limit for responses.

After the experiment, the experimenter asked participants two questions: (1) "Do you remember the instructions you read before the formal experiment?" and (2) "Do you believe the instructions?"

2.2 Results and Analysis

We excluded data from one participant who did not follow instructions and five participants who did not believe the instructions. Among these, four were from the Small-Font-More-Fluent group (effective rate = 85%) and one from the Large-Font-More-Fluent group (effective rate = 96%). We analyzed the remaining 69 participants' data using SPSS 20.0. Descriptive statistics for all variables are presented in Table 1 .

2.2.1 Judgments of Learning The JOLs for different font sizes across the three groups are shown in Table 1. A 2 (font size: 48 pt, 18 pt) × 3 (group: Large-Font-More-Fluent, Small-Font-More-Fluent, control) mixed ANOVA on JOL values revealed a significant main effect of font size, $F(1, 66) = 12.04$, $p < 0.01$, $^2 = 0.15$, with higher JOLs for large-font items ($M = 43.74$, $SD = 15.65$) than for small-font items ($M = 41.54$, $SD = 15.06$). The main effect of group was not significant, $F(2, 66) = 0.62$, $p > 0.05$. Importantly, the interaction between font size and group was significant, $F(2, 66) = 5.35$, $p < 0.01$, $^2 = 0.14$, as shown in Figure 2 [Figure 2: see original paper].

Simple effects tests on the font size × group interaction revealed that participants in the Large-Font-More-Fluent group gave significantly higher JOLs for large-font word pairs than for small-font word pairs, $F(1, 66) = 19.42$, $p < 0.001$, $^2 = 0.23$. In contrast, neither the control group nor the Small-Font-More-Fluent group showed significant differences in JOLs between large- and small-font word pairs ($ps > 0.05$).

2.2.2 Recall Accuracy Recall accuracy for word pairs across the three groups and font sizes is presented in Table 1. A 2 (font size: 48 pt, 18 pt) × 3 (group: Large-Font-More-Fluent, Small-Font-More-Fluent, control) mixed ANOVA on recall accuracy revealed no significant main effects or interaction ($ps > 0.05$).

2.3 Discussion

The results of Experiment 1 indicate that participants' beliefs about "font size affecting processing fluency" influence their JOLs. As expected, when participants believed that large fonts were more fluently processed, they gave significantly higher JOLs for large-font items than for small-font items, demonstrating the font-size effect. However, the control group did not show the font-size effect, possibly because the present study used word pairs whereas previous research typically used single words (e.g., Kornell et al., 2011; Mueller et al., 2014; Rhodes & Castel, 2008). This difference in learning materials may explain why the control group failed to exhibit the font-size effect.

Contrary to expectations, the Small-Font-More-Fluent group did not show higher JOLs for small-font items than for large-font items. Instead, they showed no significant difference in JOLs between font sizes. This suggests that the font-size effect may not be entirely attributable to beliefs about processing fluency and that processing fluency itself may still play a role (see General Discussion for details).

Experiment 2

Mueller and Dunlosky (2017) noted that in font-size effect research, participants hold not only the belief that "large-font items are easier to process" but also that "more fluently processed items are better remembered." The former concerns beliefs about how learning material characteristics affect processing fluency, while the latter concerns beliefs about how processing fluency affects memory performance. Experiment 1 demonstrated that the former belief (about "font size affecting processing fluency") represents an important source of the font-size effect. Experiment 2 aimed to investigate the latter belief (about "processing fluency affecting memory performance"). We again manipulated beliefs through instructions: one group was led to believe that more fluently processed items yield better memory performance (hereafter, the Fluency-Improves-Memory group), another group was led to believe that processing fluency does not affect memory (the Fluency-Unrelated-to-Memory group), and a control group received no instructions. If the belief that "more fluently processed items are better remembered" —commonly held in previous font-size effect research—also influences JOLs, then the Fluency-Improves-Memory group and the control group should exhibit the font-size effect. Additionally, because the instructions in the Fluency-Improves-Memory group may strengthen the influence of this belief, the font-size effect may be larger in this group than in the control group. In contrast, the Fluency-Unrelated-to-Memory group should show JOLs consistent with their instructed belief: no significant difference between large- and small-font items, meaning the font-size effect would disappear.

3.1.1 Participants

The sample size for Experiment 2 was determined using the same method as Experiment 1. Eighty-nine university students (10 male) with a mean age of 20.16 ± 1.90 years participated. All had normal or corrected-to-normal vision and were randomly assigned to the Fluency-Improves-Memory group (n = 32), the Fluency-Unrelated-to-Memory group (n = 33), or the control group (n = 24). None had previously participated in similar psychology experiments. Participants received compensation after completing the experiment.

3.1.2 Materials

The materials were identical to those used in Experiment 1.

3.1.3 Design

We employed a 2 (font size: 48 pt, 18 pt) × 3 (group: Fluency-Improves-Memory, Fluency-Unrelated-to-Memory, control) mixed design, with font size as a within-subjects factor and group as a between-subjects factor. The dependent variables were JOL values and recall accuracy.

3.1.4 Procedure

The procedure for Experiment 2 was similar to Experiment 1, with the only difference being the instruction manipulation. The Fluency-Improves-Memory group received instructions stating: "Large fonts are processed more fluently than small fonts. This ease of processing reduces cognitive load and facilitates memory, making large-font items more memorable than small-font items." The Fluency-Unrelated-to-Memory group received instructions stating: "Large fonts are processed more fluently than small fonts, but psychological research has found that large fonts are not necessarily easier to remember than small fonts. Easier processing does not equal better memory." The control group received no instructions.

3.2 Results and Analysis

We excluded data from four participants who did not follow instructions and eight participants who did not believe the instructions. Among these, five were from the Fluency-Improves-Memory group (effective rate = 84%) and three from the Fluency-Unrelated-to-Memory group (effective rate = 82%). We analyzed the remaining 77 participants' data using SPSS 20.0. Descriptive statistics for all variables are presented in Table 2 .

3.2.1 Judgments of Learning JOLs for different font sizes across the three groups are shown in Table 2. A 2 (font size: 48 pt, 18 pt) × 3 (group: Fluency-Improves-Memory, Fluency-Unrelated-to-Memory, control) mixed ANOVA on JOL values revealed a significant main effect of font size, $F(1, 74) = 24.62$, $p < 0.001$, $^2 = 0.25$, with higher JOLs for large-font items ($M = 43.22$, $SD = 17.11$) than for small-font items ($M = 39.21$, $SD = 15.74$). The main effect of group was not significant, $F(2, 74) = 1.41$, $p > 0.05$. Importantly, the interaction between font size and group was significant, $F(2, 74) = 10.34$, $p < 0.001$, $^2 = 0.22$, as shown in Figure 3 [Figure 3: see original paper].

Simple effects tests on the font size × group interaction revealed that control group participants gave higher JOLs for large-font word pairs than for small-font word pairs, with the difference approaching significance, $F(1, 74) = 3.89$, $p = 0.05$. To further compare the relative support for the null and alternative hypotheses (Rouder, Speckman, Sun, Morey, & Iverson, 2009), we calculated the corresponding Bayes factor. The results indicated a Bayes factor of 1.2 in favor of the alternative hypothesis, meaning the data were 1.2 times more likely under H_1 than under H_0. According to Wagenmakers et al.' s (2018) decision criteria, this provides weak evidence for H_1 (that JOLs differ between font sizes). The Fluency-Improves-Memory group showed significantly higher JOLs for large-font word pairs than for small-font word pairs, $F(1, 74) = 42.23$, $p < 0.001$, $^2 = 0.36$. In contrast, the Fluency-Unrelated-to-Memory group showed no significant difference in JOLs between large- and small-font word pairs, $F(1, 74) = 0.04$, $p > 0.05$, consistent with our hypothesis.

3.2.2 Recall Accuracy Recall accuracy for word pairs across the three groups and font sizes is presented in Table 2. A 2 (font size: 48 pt, 18 pt) × 3 (group: Fluency-Improves-Memory, Fluency-Unrelated-to-Memory, control) mixed ANOVA on recall accuracy revealed no significant main effects or interaction ($ps > 0.05$).

3.3 Discussion

The results of Experiment 2 were consistent with our hypothesis, demonstrating that beliefs about "processing fluency affecting memory performance" also influence JOLs. Specifically, the Fluency-Improves-Memory group exhibited the font-size effect, giving higher JOLs for large-font word pairs than for small-font word pairs. The control group also showed higher JOLs for large-font items than for small-font items, with the difference approaching significance. Moreover, the effect was larger in the Fluency-Improves-Memory group than in the control group. In contrast, the Fluency-Unrelated-to-Memory group showed no font-size effect. These results indicate that individuals believe more easily processed items are more memorable, consistent with previous research (Besken & Mulligan, 2013; Yue, Castel, & Bjork, 2013).

General Discussion

The present study investigated how beliefs about processing fluency influence JOLs and revealed the cognitive mechanism underlying the font-size effect. Two experiments examined the effects of beliefs about "font size affecting processing fluency" and "processing fluency affecting memory performance" on JOLs. The results showed that when participants believed large fonts were more fluent (Experiment 1, Large-Font-More-Fluent group) or that greater fluency led to better memory (Experiment 2, Fluency-Improves-Memory group), they gave significantly higher JOLs for large-font word pairs than for small-font pairs. Conversely, when participants believed small fonts were more fluent (Experiment 1, Small-Font-More-Fluent group) or that fluency was unrelated to memory (Experiment 2, Fluency-Unrelated-to-Memory group), no significant differences emerged in JOLs between large- and small-font items, and the font-size effect disappeared. These findings demonstrate that beliefs about processing fluency serve as an important cue for JOLs and represent a crucial source of the font-size effect.

Our results strongly support the beliefs hypothesis within Koriat' s (2000, 2007) dual-process model while also offering insights for its refinement. As noted earlier, the dual-process model posits that people may engage in metacognitive monitoring through two distinct systems: theory-based monitoring (based on beliefs about memory) and experience-based monitoring (based on subjective experiences like processing fluency). These two processes are considered fundamentally different and separate (Koriat, 2007). However, some researchers argue that processing fluency and beliefs are sometimes closely linked and may interact to jointly influence JOLs (Dunlosky et al., 2015; Mueller & Dunlosky, 2017). For example, people may develop beliefs based on their experiences with processing fluency, which then influence their JOLs (Finn & Tauber, 2015). Similarly, Mueller and Dunlosky (2017) suggested that in font-size effect studies, participants notice variations in font size during learning and form a seemingly plausible but erroneous belief that large fonts are easier to process than small fonts. Additionally, participants believe that more easily processed items are better remembered and will yield better performance (Bjork, Dunlosky, & Kornell, 2013; Simon & Bjork, 2001). In both experiments of the present study, when instructions induced participants to believe that "large fonts are processed more fluently than small fonts" (Experiment 1) or that "more fluent processing leads to better memory" (Experiment 2), the experimental groups showed stronger font-size effects than the control groups, who received no instructions. This suggests that the instructions activated beliefs consistent with participants' pre-existing beliefs, which may have been further strengthened by the instructions, resulting in more pronounced font-size effects. These findings indicate that beliefs about processing fluency serve as an important basis for JOLs, consistent with Mueller and Dunlosky' s (2017) results. Together with Mueller and Dunlosky' s (2017) research, the present study suggests that although beliefs are important cues for metacognitive monitoring, the specific content of these beliefs is closely tied to the processing fluency of the learning materials themselves. That is, people develop beliefs based on the processing fluency of materials and use these beliefs to make JOLs. Therefore, we argue that the dual-process model' s view of experience-based and theory-based systems as separate needs revision, and future research should further develop and test the model from an interactive perspective.

Notably, although our results support the beliefs hypothesis, they do not completely rule out the influence of processing fluency itself on JOLs. In Experiment 1, the Small-Font-More-Fluent group showed no significant difference in JOLs between large- and small-font word pairs and did not exhibit the expected effect (higher JOLs for small-font items). This may be because the processing fluency experienced from the learning materials still influenced JOLs. In the present study, participants in the Small-Font-More-Fluent group may have experienced large fonts as more fluent and small fonts as less fluent, which conflicted with the belief induced by the instructions (that small fonts are processed more fluently than large fonts). Under these conditions, the influence of experienced processing fluency and instructed beliefs on JOLs worked in opposite directions, resulting in the disappearance of the font-size effect. This interpretation differs from Mueller and Dunlosky' s (2017) claim that the font-size effect is unrelated to processing fluency itself. However, because the present study did not directly measure processing fluency, we cannot determine its specific role in the font-size effect. Further research is needed to clarify the respective contributions of beliefs about processing fluency and processing fluency itself to the font-size effect.

Furthermore, our findings offer insights for overcoming metacognitive illusions. Both experiments showed that font size affected JOLs but not actual recall performance, consistent with previous research (Mueller et al., 2014; Rhodes & Castel, 2008) and indicating that participants experienced metacognitive illusions. However, when instructions induced beliefs inconsistent with participants' prior beliefs (e.g., Small-Font-More-Fluent group, Fluency-Unrelated-to-Memory group), no significant differences emerged in either JOLs or recall performance between large- and small-font items, suggesting that the metacognitive illusion disappeared. Thus, changing erroneous beliefs is an effective way to eliminate metacognitive illusions. Researchers have noted that students' beliefs are influenced by courses, tasks, and instruction (Hofer, 1999; Nist & Holschuh, 2005). Therefore, teachers can use appropriate instructional guidance (e.g., explicitly informing students that certain features of learning materials are unrelated to memory performance) to help students recognize their unreasonable beliefs, thereby eliminating metacognitive illusions and promoting more accurate monitoring and more effective self-regulated learning.

In conclusion, the present study demonstrates that beliefs about processing fluency influence JOLs and represent an important source of the font-size effect. These findings provide further evidence for the beliefs hypothesis within Koriat' s (2000, 2007) dual-process model and suggest that the model may need to be revised by integrating the experience-based and theory-based systems. Additionally, our results have practical implications for education: instructional guidance that changes students' erroneous beliefs can eliminate metacognitive illusions and promote effective learning.

Conclusion

Through two experiments examining how beliefs about processing fluency influence JOLs, this study explored the cognitive mechanism underlying the font-size effect. The main conclusions are as follows:

1. Individuals' beliefs about "font size affecting processing fluency" influence their JOLs.
2. Individuals' beliefs about "processing fluency affecting memory performance" influence their JOLs.
3. Beliefs about processing fluency represent an important source of the font-size effect and serve as a critical cue for making JOLs.

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