Memory & Cognition
https://doi.org/10.3758/s13421-021-01143-8

How cognitive conflict affects judgments of learning: Evaluating the contributions of processing fluency and metamemory beliefs

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Accepted: 20 January 2021

Abstract

Previous research has documented that cognitive conflict affects basic cognitive processes such as memory, reasoning, and attention allocation. However, little research has explored whether its effect can be extended to higher cognitive processes such as metacognitive monitoring. The current study took a novel variant of a Stroop task that employed words presented in a color opposite to the color of the object itself (e.g., *heart,* presented in green) or same as the color of the object (e.g., *forest,* presented in green) as targets, an important form of metacognitive monitoring—judgments of learning (JOLs) was used as the measurement index to investigate the influence of cognitive conflict on metacognitive monitoring and to delineate the potential mechanisms underlying the cognitive conflict effect on JOLs. In Experiment 1, results showed that participants gave higher JOLs to consistent than to conflict words, even though cognitive conflict had little influence on memory recall. Experiment 2, employing a self-paced study task, found that conflict words were processed less rapidly than consistent ones, and the difference in processing fluency significantly mediated the cognitive conflict effect on JOLs. Experiment 3 employed an observer–learner task; the mediation analysis showed a complete mediation role of metamemory beliefs (observation JOLs) in the relationship between word type and JOLs. In Experiment 4, research results suggested that participants' beliefs about processing fluency played an important role in the cognitive conflict effect. To conclude, cognitive conflict is a reliable factor affecting higher cognitive processes (metamemory monitoring). Both processing fluency and metamemory beliefs tend to contribute to the cognitive conflict effect.

Keywords Cognitive conflict · Judgments of learning · Fluency · Beliefs

Cognitive conflict refers to a kind of perceptual state in which individuals notice differences between their cognitive structure and external information or within their own cognitive structure (Lee et al., 2003). The cognitive conflict has been often induced by discrepant events which are the information presented clearly contradict individuals' existing experiences (S. Kang et al., 2005). In the laboratory, many manipulations, such as the Stroop task (Stroop, 1935), the Simon task (Simon & Small, 1969), and the flanker task (Gratton et al., 1992), are commonly used to investigate cognitive conflict (Q. Li et al., 2017). In recent years, several studies have shown evidence that cognitive conflict plays an important role in memory (Ptok et al., 2020; Rosner et al., 2015), attention allocation (Akpınar et al., 2009; Bjørn & Karsten, 2012; H. Kang et al., 2010) and conceptual learning (Başer, 2006; Stavy & Berkovitz, 1980; Watson, 2007). Similarly, one might expect that the cognitive conflict might influence the higher-order cognitive processes, such as metacognitive monitoring. The converse, the influence of metacognitive monitoring on cognitive conflict has been demonstrated (Questienne et al., 2016; Thompson & Johnson, 2014). Thus, we asked in the current study whether cognitive conflict may likewise influence metacognitive monitoring (e.g., memory monitoring in this study, assessed via judgments of learning [JOLs]), and explored the mechanisms underlying the cognitive conflict effect on metacognition monitoring. In several experiments, we used a novel variant of a Stroop task that employed words presented in a color opposite to the color of the object itself (e.g., *heart,* presented in green) or the same as the color of the object (e.g., *forest,* presented in green) to manipulate cognitive conflict at study. If metacognitive monitoring is sensitive to

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Published online: 05 March 2021

cognitive conflict, we assume that lower JOLs were given to conflict words than those to consistent ones.

Since the 1980s, the cognitive conflict has been widely utilized as an effective teaching strategy in educational settings. As noted previously, many studies have proved that introducing cognitive conflict during learning can effectively boost learning outcomes. For example, Krebs et al. (2015) observed better memory for faces presented in a conflict gender label versus a consistent gender label. Students in the experimental group received cognitive-conflict-based physics instruction, whereas the control group was taught by traditionally designed physics instruction, and results showed that mean scores on the conceptual learning of students in the experimental group were significantly higher than those of the control group (Başer, 2006). All these findings converge on the general idea that cognitive conflict plays an important role in basic cognitive process.

Recent studies suggested that there might be a strong link between cognitive conflict processing and metacognitive monitoring (Parker, 2006; Questienne et al., 2016; Thompson & Johnson, 2014). For instance, Thompson and Johnson (2014) proposed that for the participants whose feeling of rightness (FOR) judgments were sensitive to conflict, they tend to engage more analytic thinking to solve conflict problems, suggesting that metacognition (e.g., FOR) contributes to conflict resolution. Questienne et al. (2016) observed that subjective feelings of conflict can trigger the Gratton effect (conflict adaptation effect) in a masked priming task. That is to say, the cognitive conflict effect (e.g., Stroop effect) was smaller following a conflict stimulus than following a consistent one. Such findings indicate that the metacognitive experience of cognitive conflict can initiate adaptive control.

It is worth noting that previous studies have explored the role of metacognition in conflict adaptation and resolution (Questienne et al., 2016; Thompson & Johnson, 2014), but, to our knowledge, no research has been conducted to explore the impact of cognitive conflict on metacognitive monitoring. As an important form of metacognitive monitoring, judgments of learning (JOLs) refer to a subjective prediction about the remembering likelihood of learned materials (G. Chen & Fu, 2004). The current study takes JOLs as a measurement index of metacognitive monitoring to explore whether cognitive conflict can influence higher-order cognitive processes. To foreshadow, the answer is affirmative.

Another important objective of this study is to explore the mechanisms underlying the cognitive conflict effect on JOLs. The cue-utilization framework (Koriat, 1997) proposed that JOLs are inferential and are based on different types of cues. The core of this theory is to distinguish different types of cues by classifying them into three categories: intrinsic cues, extrinsic cues, and mnemonic cues. Intrinsic cues refer to the intrinsic properties of learning materials, such as word frequency, concreteness, semantic cohesion, and so on. Extrinsic cues are specific to the characteristics of the learning task, such as study duration, study strategy, test format, and so on. Mnemonic cues are characterized as the perceptual experience of information processing, such as accessibility and subjective processing fluency. So, how does a given factor affect JOLs? The dual-process model, proposed by Koriat (2000, 2007), assumes that metacognitive monitoring includes two systems: (1) theory-based monitoring and (2) experience-based monitoring. The former refers to the monitoring process based on certain theories or beliefs about how memory operates (such as beliefs that longer study duration is associated with superior retention); the latter refers to the monitoring process based on subjective processing experience, such as processing fluency.

The role of processing fluency in JOL formation has been extensively established. Studies have shown that fluent learning experience drives learners to offer higher JOLs (Besken & Mulligan, 2013; Carpenter et al., 2013; Susser et al., 2016; Undorf et al., 2017; Yang et al., 2018). For instance, it has been documented that words identified quicker in a lexical decision task received higher JOLs (e.g., Mueller et al., 2016); semantically related word pairs, which were studied quicker, were rated as more likely to be remembered than unrelated ones (e.g., Undorf & Erdfelder, 2015); words presented in large font size (e.g., 48 pt), which were identified more rapidly in a continuous identification task, were estimated as more likely to be recalled on a later memory test than small (e.g., 18 pt) ones (e.g., Yang et al., 2018). These findings converge on the contribution of processing fluency to JOL formation.

Besides processing fluency (an experience-based cue), metamemory beliefs about how memory operates are another important cue (a theory-based cue) for JOL formation. According to the analytic processing (AP) theory (Mueller & Dunlosky, 2017), people search for a variety of diagnostic cues and apply their beliefs about how these cues can alter memory retrieval to inform JOLs and to reduce prediction uncertainty. Many cues affect JOLs through metamemory beliefs, such as font size (Kornell et al., 2011; Mueller et al., 2014; Yang et al., 2018), concreteness (Witherby & Tauber, 2017), semantic relatedness (Mueller et al., 2016), animacy (P. Li et al., 2016), physical weight (Alban & Kelley, 2013), and so on (e.g., Jia et al., 2016; Undorf et al., 2017). For instance, Mueller et al. (2016) found that their participants held a strong belief that semantically related word pairs (e.g., *pond–frog*) are easier to remember than unrelated ones (e.g., *computer-drink*), and this belief contributed significantly to JOL formation by driving participants to offer higher JOLs to related pairs. Thompson and Johnson (2014) observed that people do have beliefs that cognitive conflict may impair response accuracy in a reasoning task. Accordingly, it is reasonable to assume that people may also believe that cognitive conflict has a negative effect on memory retention, and this belief may contribute to the cognitive conflict effect on JOLs, leading to lower JOLs to conflict items than those to consistent ones.

In recent years, there has been a new debate about how different factors affect JOLs: Do they affect JOLs through processing fluency or beliefs (or a combination of both: beliefs about fluency)? Some researchers proposed that metamemory beliefs are the major source contributing to JOL formation, but processing fluency plays little or even no role (Mueller et al., 2016). For instance, Mueller (2016) found that participants believed that identical pairs (e.g., *cat–cat*) are easier to remember than related pairs (e.g., *cat–dog*), and participants reported that they believed identical words were easier to encode. Such findings imply that participants held a belief that superior processing fluency is related to better memory. To further investigate whether people's beliefs about processing fluency (i.e., beliefs that the easier the processing, the better the retention) feed into JOLs, Mueller and Dunlosky (2017) instructed participants to make item-by-item JOLs for words presented in either blue or green color. The results showed that even though word color had no actual influence on processing fluency and memory retention, participants provided higher JOLs to blue or green words when they were informed that words presented in that color were easier to process. Along the same lines, Y. Chen et al. (2019) found that manipulating people's beliefs about fluency by belief-strengthening paradigm and counterbelief paradigm could correspondingly alter the font size effect on JOLs. Specifically, Y. Chen et al. (2019) observed that people's JOLs were significantly higher for large words when they were informed that large words were easier to process than small ones (belief-strengthening group), whereas JOLs were not significantly different between large and small words when they were told that small words were easier to process than large ones (counterbelief group). Mueller and Dunlosky's (2017) and Y. Chen et al.'s (2019) findings jointly suggested that beliefs about fluency can inform JOLs. However, Yang et al.'s (2018) results suggested that fluency may not affect JOLs through beliefs about fluency (for related findings, see Undorf et al., 2017).

Some problems can be found in the above discussion. First, in the study of Y. Chen et al. (2019), there was no significant difference in JOLs between large and small words in the control group and counterbelief group, indicating that perceptual fluency may still be significantly influencing JOLs. If JOLs were driven by beliefs about fluency, participants who believed that words in smaller font were easier to process should have given those items larger JOLs, suggesting that the beliefs about fluency manipulated through the counterbelief paradigm and the processing fluency that participants experienced in the experiment cancel each other out. Second, in Yang et al.'s (2018) study, researchers employed the learner-observer paradigm to explore whether font size affects JOLs through beliefs about fluency. Participants were asked to learn 100 English words as quickly and accurately as they could in a continuous identification (CID) task; fluency (RTs) and JOLs were collected in the study task. Then, they were instructed to view 100 English words (replaced by letter string) from another participant and make observation JOLs to predict the likelihood that another participant would remember the item. The multilevel mediation analysis found no evidence that beliefs about fluency (observation JOLs) mediate the fluency (RTs) effect on JOLs. Given that the beliefs about fluency were collected in two tasks, which might contribute to the null difference in the indirect effects. In view of the above problems, it is worth further explorations on whether beliefs about fluency can affect JOLs.

In summary, the current study aims to explore two important questions: (1) Can cognitive conflict affect JOLs? And (2) if so, does it affect JOLs through processing fluency or metamemory beliefs (or a combination of both: beliefs about fluency)? The current study conducted four experiments to explore these two questions. In Experiment 1, the principal stimuli were words presented in a color opposite to the color of the object itself (e.g., *heart,* presented in green) in the conflict condition or same as the color of the object (e.g., *forest,* presented in green) in the consistent condition. Item-by-item JOLs were compared between conflict and consistent words to explore the cognitive conflict effect on JOLs. Experiments 2 investigated the role of processing fluency in the cognitive conflict effect on JOLs by employing a self-paced study task. In Experiment 3, metamemory beliefs about the influence of cognitive conflict on memory were measured by employing an observer-learner paradigm. Experiment 4 introduced a new variable (e.g., font size) and employed a belief-strengthening paradigm to explore the role of beliefs about fluency in the impact of cognitive conflict on JOLs.

Experiment 1

In Experiment 1, the influence of cognitive conflict on JOLs was explored. Participants studied words presented in a color opposite to the color of the object itself or the same as the color of the object. Immediately following the presentation of each word, participants made a JOL regarding the probability that the word would be recalled on a later test. If participants regarded conflict items as more memorable than consistent items, we hypothesized, there exists a cognitive conflict effect on JOLs.

Method

Participants

To determine the required sample size, we conducted a power analysis using G*Power (Faul et al., 2007). According to a pilot study (Cohen's *d* was 0.60), 24 students were required to detect a significant (α = .05) cognitive conflict effect on JOLs at 0.8 power. Accordingly, 24 participants (M_{age} = 21.43, *SD* = 1.99; 12 females) were recruited from the University of Jinan. Participants reported normal or corrected-to-normal vision and received a gift as compensation. The Ethics Committee at the Department of Psychology, University of Jinan, approved Experiments 1–4.

Materials

The principal stimuli were 40 two-character Chinese nouns selected from the Modern Chinese Frequency Dictionary (Wang, 1986). All words were intrinsically associated with typical red or green features (e.g., *heart, forest*). Each word had a word frequency ranging from 0.00023 to 0.00647 and the number of strokes ranging from 14 to 29. In addition, words were rated with respect to other variables, including familiarity, concreteness, and imagery (see Table 1). Four of them were used for practice, and the others (18 conflict words and 18 consistent words) were employed in the formal experiment.

Design and procedure

The experiment involved a within-subjects design (word type: conflict vs. consistent). Stimuli in the conflict condition were the words presented in a color opposite to the color of the object itself (such as *heart* [presented in green], *kelp* [presented in red]). By contrast, consistent stimuli were the words presented in the same color as the object per se (such as *forest* [presented in green], *hawthorn* [presented in red]). Half of the words were assigned into the conflict condition, and the others were divided into the consistent condition. Word assignment was counterbalanced across participants.

Before the formal experiment, participants were given four trails for practice. The formal experiment consisted of three phases: study, distraction, and test. In the study phase, all 36 words were presented one-by-one, in random order, for 3 s each. Immediately following the presentation of each word, participants were required to make a JOL to predict the likelihood that he/she would be able to recall that item on a later memory test. JOLs were reported on a scale ranging from 0% (*I am sure I will not recall it*) to 100% (*I am sure I will recall it*). Following the study phase, participants engaged in a 2-min distractor task, during which they were instructed to solve arithmetic problems. Then, they were given unlimited time to recall as many words as possible in any order and write their answers on a blank piece of paper.

Results and discussion

Mean JOLs and recall performance for conflict and consistent words are listed in Table 2. Lower JOLs were given to conflict words than to consistent ones, difference = -8.13, 95% CI = [−13.12, −3.14], $t(23) = -3.37$, $p < .001$, $d = 0.53$. However, there was actually no difference in recall performance between conflict and consistent words, difference = 0%, 95% CI [−0.07, 0.06], $t(23) = -0.07$, $p = .94$, $d = 0.02$. These results reflect a dissociation between JOLs and memory: cognitive conflict significantly affects JOLs but not memory retention itself.

Experiment 2

Experiment 1 showed a dissociation between JOLs and memory: cognitive conflict significantly affected JOLs, but had little effect on memory itself. Experiment 2 aims to explore the underlying mechanisms of this metamemory illusion.

Previous studies have explored the mechanisms through which different factors affect JOLs, and the current debate mainly focuses on whether these factors affect JOLs through processing fluency or beliefs (or beliefs about fluency). According to the dual-process theory proposed by Koriat (2000, 2007), processing fluency is an important foundation for a given factor to influence JOLs. Studies have shown that

Table 1 Characteristics of control variables for conflict and consistent words in Experiments 1–4

Dimension	Conflict, *M (SD)*	Consistent, *M* (SD)	*t*
Word frequency	.0011 (.0013)	.0014 (.0019)	−0.62, *n.s.*
Stroke number	18.94 (4.08)	19.50 (4.89)	−0.37, *n.s.*
First stroke number	9.89 (3.98)	9.11 (4.27)	0.57, *n.s.*
Second stroke number	9.06 (2.80)	10.39 (2.85)	−1.42, *n.s.*
Familiarity	4.43 (0.59)	4.40 (0.65)	0.72, *n.s.*
Concreteness	4.50 (0.52)	4.38 (0.62)	1.65, *n.s.*
Imagery	4.48 (0.58)	4.36 (0.55)	1.70, *n.s.*

Note. A stroke is defined as writing from pen down to pen up when one writes on a digitizer with a stylus pen (Liu et al., 1996). The number of strokes in Chinese is similar to the number of letters in English. Moreover, the Chinese words (i.e., 心脏, *heart*) in our experiments are composed of two words (i.e., “心” and “脏”), so we distinguished the number of strokes in the first word from the number of strokes in the second word.

Table 2 Basic descriptive statistics for conflict and consistent words in Experiments 1–3

Conditions	Conflict	Consistent
Experiment 1		
JOLs	54.03 (14.93)	62.16 (15.47)
Recall performance	0.26 (0.12)	0.26 (0.12)
Experiment 2		
JOLs	59.58 (14.71)	70.02 (14.77)
Recall performance	0.24 (0.13)	0.25 (0.13)
Self-paced study time	5.41 (3.44)	4.74 (3.01)
Experiment 3		
Observation JOLs	48.76 (16.73)	67.54 (21.18)
Global predictions	0.40 (0.13)	0.58 (0.17)
JOLs	47.54 (16.09)	60.76 (19.53)
Recall performance	0.26 (0.14)	0.29 (0.16)

self-paced study time could be an important measure of processing fluency (e.g., Ball et al., 2014; Undorf & Erdfelder, 2015). In the current study, if conflict words are processed less fluently than consistent ones, it would take more time for participants to study conflict words. To explore whether processing fluency contributes to the conflict effect on JOLs, a Bayesian mediation analysis would be conducted to unravel whether self-paced study time mediates the relationship between word type and JOLs.

Method

Participants

Given that the cognitive conflict effect on JOLs was also explored in Experiment 2, we planned the same sample size as in Experiment 1. Twenty-eight students (15 females; M_{age} = 22.29 years, SD = 1.49) participated in Experiment 2. They reported normal or corrected-to-normal vision and received a gift as compensation. Two participants were interrupted during the experiment, and another one explicitly failed to understand the task, so these three participants' data were excluded from the analysis.

Materials, design, and procedure

The materials were the same as those used in Experiment 1. The experimental procedure is similar to that in Experiment 1. The only difference was that participants were told that they have self-paced time to study each word. They were given unlimited time to study each word, and pressed the keyboard as soon as they finished. Immediately following the presentation of each word, participants rated their confidence (0%~100%) that they would be able to recall that item on a later memory test. Following the learning phase, participants engaged in a 2-min distractor task, and then they were given unlimited time to recall as many words as they could from the study list.

Results and discussion

Mean JOLs, recall performance, and self-paced study time are summarized in Table 2. JOLs for conflict words were significantly lower than were those for consistent words, difference = −10.44, 95% CI [−15.20, −5.68], $t(24) = -4.53$, $p < .001$, d = 0.71. But there was no significant difference in recall accuracy between conflict and consistent words, difference = −1%, 95% CI [−0.07, 0.05], $t(24) = -0.23$, $p = 0.82$, $d = 0.08$. Self-paced study time was significantly longer for conflict words than for consistent words, difference = 0.67 s, 95% CI [0.19, 1.14], $t(24) = 2.91$, $p = 0.01$, $d = 0.21$.

To explore whether self-paced study time mediated the cognitive conflict effect on JOLs, we conducted a multilevel Bayesian mediation analysis via the R *bmlm* package (Vuorre, 2017). In the multilevel mediation analysis, word type (conflict = 0; consistent = 1) was taken as the independent variable, self-paced study time as the mediator, and JOLs as the dependent variable. The results showed that the total effect of word type on JOLs was 10.54, 95% CI [5.64, 15.24]. The direct effect of word type on JOLs was 10.12, 95% CI [5.30, 14.70]. The indirect effect of word type on JOLs through self-paced study time was 0.38, 95% CI [0.02, 1.02], indicating that consistent words increase JOLs indirectly by increasing perceptual fluency. Fluency (self-paced study time) explained 4% of the word type on JOLs. The mediation results indicate that cognitive conflict decreases JOLs at least partially through decreasing processing fluency.

Experiment 3

Experiment 2 explored the role of processing fluency in the cognitive conflict effect on JOLs and found that processing fluency is at least a part of the source for the effect formation. Experiment 3 intended to evaluate the contribution of metamemory beliefs to the cognitive conflict effect on JOLs by using the observer-learner paradigm. To remove the influence of fluency experience, each item was replaced by a "conflict" or "consistent" cue. Therefore, participants made JOLs only based on their belief because they did not process any actual words. Participants were asked to observe the learning process of another person, to make item-by-item JOLs, global JOLs, and explanations about why they had this estimation. These explanations might give insights into the kinds of beliefs people hold about the cognitive conflict effect on memory. Afterward, participants were requested to perform a study task that was the same as in Experiment 1.

Method

Participants

Because the study task of Experiment 3 is the same as that of Experiment 1, we planned the same sample size as in Experiment 1. Thirty-one students (M_{age} = 23.26 years, *SD* = 2.83; 18 females) participated in Experiment 3. They reported normal or corrected-to-normal vision and received a gift as compensation. One participant was excluded from the subsequent analysis because she was interrupted during the experiment.

Materials, design, and procedure

The materials were the same as those used in Experiment 1. Experiment 3 involved a within-subjects design (cue type: conflict vs. consistent) and consisted of three tasks: observation, study, and test.

Participants were given the following instructions in the observation task:

> "You will observe the learning process of another participant who has undergone the same learning task. They were asked to learn 36 words (18 words presented in a color opposite to the color of the object itself, 18 words presented in the same color as the color of the object itself), all 36 words were presented one-by-one, in random order, and for 3 s each. Following the study phase, participants engaged in a 2-min distractor task, and then they were given unlimited time to recall as many words as they could from the study list.

However, instead of seeing the exact words the participant studied, you will see the cue of "conflict" or "consistent" in place of all the specific words. The cue will be displayed to you in the same format and duration as those in his/her learning phase. After viewing each item (i.e., "conflict" or "consistent"), you need to predict the likelihood that he or she would be able to remember it on a 0-100 scale, where 0 means that you are sure he/she would not remember it and 100 means you are sure he/she would remember it."

They pressed the ENTER key to trigger the practice trial and formal experiment. Specifically, the procedure was the same as that in Experiment 1, except that the consistent and conflict words were correspondingly replaced by "conflict" and "consistent." Participants made a JOL to predict the likelihood that the "other participant" would remember that word later. At the end of the observation task, participants estimated the number of words (out of 18) of each word type that the "other participant" in the experiment would recall and explain the reason why they estimated better recall of conflict words (if he/she provided higher global JOLs to conflict words) or consistent words (if he/she provided higher global JOLs to consistent words). For example, when a given participant's estimate favored conflict words, he or she would answer the following question: Why do you think conflict words would be better remembered than consistent ones? Participants' explanations were recorded on a blank sheet.

Following the observation phase, participants were given the instruction for the study and test task. The procedure of these tasks was the same as in Experiment 1.

Results and discussion

The means (and standard deviations) of observation JOLs, global predictions, JOLs and recall performance for conflict and consistent words are presented in Table 2. A paired-samples *t* test revealed that participants' observation JOLs for "conflict" words were significantly lower than were those for "consistent" words, difference = −18.78, 95% CI [−26.36, −11.20], $t(29) = -5.07$, $p < .001$, $d = 0.98$. Consistently, global JOLs for consistent words were significantly higher than were those for conflict words, difference = −18%, 95% CI [−0.25, −0.11], $t(29) = -5.03$, $p < .001$, $d = 1.19$. JOLs for conflict words were significantly lower than were those for consistent words in study task, difference = −13.22, 95% CI [−18.40, −8.05], $t(29) = -5.23$, $p < .001$, $d = 0.74$. But there was no significant difference in recall accuracy between conflict and consistent words, difference = −3%, 95% CI [−0.08, 0.03], $t(29) = -0.98$, $p = 0.34$, $d = 0.20$.

To explore whether metamemory beliefs mediated the cognitive conflict effect on JOLs, the PROCESS macro (Model 4) developed by Hayes (2015) was employed. In this path for the mediator model, we assigned word type as the independent variable, JOLs as the dependent variable and metamemory beliefs (observation JOLs) as the mediator. The results shown in Table 3 indicated that word type had a significantly predictive effect on JOLs ($\beta = 0.70$, $p < .01$). However, the relationship between word type and JOLs was completely attenuated and became nonsignificant after metamemory beliefs (observation JOLs) was added to the model ($\beta = 0.16$, $p = 0.48$). Bootstrap method indicated that the indirect effect of word type on JOLs through metamemory beliefs (observation JOLs) was 0.54, 95% CI [0.30, 0.82]. The mediation effect accounted for 77.14% of the total effect. Therefore, results of the mediation analysis showed a complete mediation role of metamemory beliefs (observation JOLs) in the relationship between word type and JOLs.

In total, 25 participants offered higher global JOLs to consistent words, and their explanations were as follows: (1) 25 participants reported that consistent words would be easier to remember and encode, and (2) nine of them further explained that it was easier for them to remember consistent

Table 3 Testing the mediation effect of metamemory beliefs (observation JOLs) in Experiment 3

Outcome variable	Predictor variable	R	R^2	F	β	t
JOLs	Word type	0.35	0.12	8.19	0.70	2.86**
JOLs	Word type	0.65	0.42	20.58	0.16	0.71
	Observation JOLs				0.61	5.39***

$^*p < .05$. $^{**}p < .01$. $^{***}p < .001$.

words because it was easier to generate an image to represent them. Four participants responded that conflict words would be better remembered because they were special and impressive. One participant responded that there was no significant difference in recall performance between conflict and consistent words. In line with the AP and cue-utilization theories, these beliefs may contribute to the cognitive conflict effect on JOLs.

Experiment 4

The results in Experiment 3 confirmed the mediating effect of metamemory beliefs (observation JOLs) between cognitive conflict and JOLs, and these explanations about why they had these estimates indicate that participants believe more easily processed words are more memorable. That is to say, people's beliefs about processing fluency might inform JOLs. Recently, researchers proposed that beliefs about processing fluency may play a vital role in JOL formation (Y. Chen et al., 2019; Mueller & Dunlosky, 2017). As mentioned earlier, to avoid the contradiction between counterbelief instruction and real fluency experience, in this study, only belief-strengthening paradigm was taken into consideration. Experiment 4 introduced a new variable (font size) and explore the role of beliefs about fluency in the cognitive conflicts effect on JOLs. According to Experiment 2, consistent words are associated with superior processing fluency than conflict ones, and according to the font size effect (Yang et al., 2018), large words are easier to be perceived than small ones. We manipulated beliefs about processing fluency through introducing different experimental instructions. Specifically, in a cognitive conflict group, the instructions highlighted the processing fluency difference between conflict and consistent words; by contrast, in a font size group, the fluency difference between large and small words was emphasized. If processing fluency affects JOLs through beliefs about fluency (i.e., believing that more fluently processed items are easier to remember), we expect a larger cognitive conflict effect on JOLs when the processing fluency difference between conflict and consistent words is highlighted, and a larger font size effect when the fluency difference between large and small words is emphasized.

Method

Participants

Given that the cognitive conflict effect on JOLs was also explored in Experiment 4, we planned the same sample size as in Experiment 1. Fifty-five students (M_{age} = 21.38 years, SD = 1.37; 28 females) were recruited from the University of Jinan. They reported normal or corrected-to-normal vision and received a gift as compensation. At the very end of the experiment, all participants filled a brief questionnaire to report whether they believed the experimental instructions. Seven participants were removed from data analyses because they did not believe the instructions, leaving final data from 48 participants. They were randomly allocated to a cognitive conflict or a font size group, with 24 participants in each group.

Materials and design

The materials were the same as those used in Experiment 1. The design of Experiment 4 was a 2 (cognitive conflict: conflict vs. consistent) × 2 (font size: 48 pt vs. 18 pt) × 2 (instruction: cognitive conflict vs. font size) mixed design, with cognitive conflict and font size manipulated within subjects and instruction manipulated between subjects.

Procedure

Participants first read the corresponding instructions. The instructions for the cognitive conflict group were as follows:

> "It has been proved that when a word was presented in a color consistent with its natural color (e.g., *heart*, presented in red), it is easier for people to form a mental image to represent it than when presented in a color contradicting to its natural color (e.g., forest, presented in red). Put differently, for college students, it is easier for the brain to process the words whose printed color is consistent with its natural color than when the printed color and natural color are conflicting."

The instructions for the font size group were as follows:

> "It has been proved that large words are easier to be perceived and processed than small words because the eye has a large angle of view for processing large words. In other words, for college students, it is easier to process large words than to process small ones."

After reading the instructions, participants were given four practice trials to familiarize themselves with the experiment. The formal experiment consisted of the same three stages: study, distraction, and recall test. In the study phase, all 36 words (with nine in each of the four conditions: conflict/large, conflict/small, consistent/large, and consistent/small) were presented one-by-one, in random order, for 3 s each. After the presentation of each word, a JOL rating was made to predict the likelihood that he/she would be able to recall that item on a later memory test. Immediately following the study stage, participants undertook a 2-min distractor task to solve arithmetic problems. Finally, they completed a self-paced free-recall test.

Results and discussion

Mean JOLs are shown in Fig. 1. A 2 (cognitive conflict: conflict vs. consistent) × 2 (font size: 48 pt vs. 18 pt) × 2 (instruction: cognitive conflict vs. font size) mixed analysis of variance (ANOVA) showed a main effect of cognitive conflict, $F(1, 46) = 43.07$, $p < .001$, $\eta^2 = 0.48$, indicating that participants' JOLs were higher for consistent words ($M = 65.39$, $SD = 15.38$) than were those for conflict words ($M = 54.71$, $SD = 17.10$). The main effect for font size was significant, $F(1, 46) = 43.76$, $p < .001$, $\eta^2 = 0.49$, with higher JOLs for large words ($M = 64.95$, $SD = 15.22$) than for small words ($M = 55.14$, $SD = 16.85$). There was no main effect of instruction, $F(1, 46) = 0.13$, $p = .73$, $\eta^2 = 0.01$.

Of critical interest, the interaction between cognitive conflict and instruction was significant, $F(1, 46) = 18.75$, $p < .001$, $\eta^2 = 0.29$, suggesting that experimental instructions about processing fluency modulate the cognitive conflict effect on JOLs. The simple effect analyses showed that when participants were told that consistent words were easier to process, JOLs for consistent words were significantly higher than were those for conflict words, $F(1, 46) = 59.33$, $p < .001$, $\eta^2 = 0.56$, reflecting the cognitive conflict effect on JOLs. By contrast, when participants were told that large words were easier to process, no significant difference in JOLs was found between consistent and conflict words, $F(1, 46) = 2.49$, $p = .12$, $\eta^2 = 0.05$.

The interaction between font size and fluency instruction emerged, $F(1, 46) = 20.02$, $p < .001$, $\eta^2 = 0.30$, suggesting that experimental instructions about processing fluency modulate the font size effect on JOLs. The simple effect analyses showed that when participants were informed that consistent words were easier to process, no significant difference in JOLs was found between large and small words, $F(1, 46) = 2.29$, $p = .14$, $\eta^2 = 0.05$. But when participants were told that large words were easier to process, JOLs for large words were significantly higher than were those for small words, $F(1, 46) = 61.49$, $p < .001$, $\eta^2 = 0.57$.

There was no main effect of three-way interaction amongst cognitive conflict, font size, and instruction, $F(1, 46) = 0.77$, $p = .38$, $\eta^2 = 0.02$. The above analyses were reconducted, but the dependent variable was replaced by recall performance, and the results showed no main effect of any factors, nor was there any significant interactions (ps > .05).

General discussion

The current study investigated the impact of cognitive conflict on metacognitive monitoring (i.e., JOLs) and the contributions of processing fluency, metamemory beliefs, and beliefs about fluency in the cognitive conflict effect on JOLs. In Experiment 1, participants offered lower JOLs to conflict than

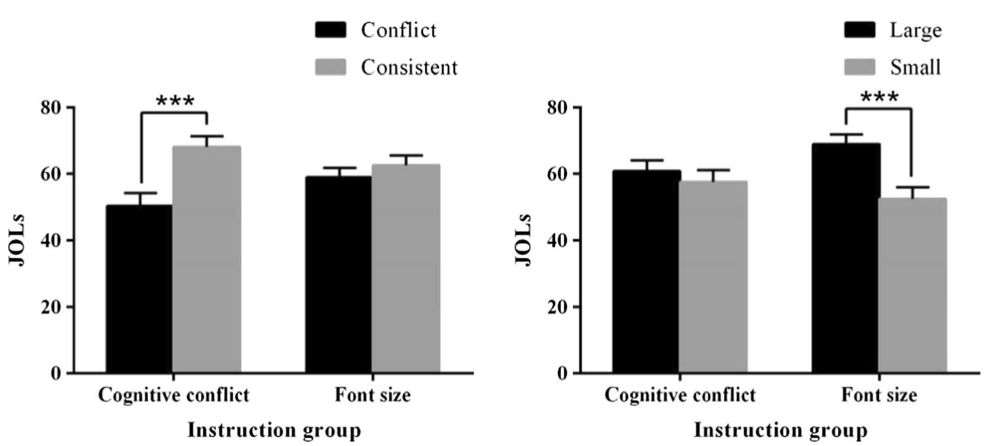

Fig. 1 The Mean JOLs by target words, font size, and instruction group in Experiment 4. Note. Error bars represent standard errors of the means. ***$p < .001$

to consistent words, even though cognitive conflict had little influence on memory retention. Experiment 2 showed that processing fluency, measured by the self-paced study task, significantly contributed to the cognitive conflict effect on JOLs. Experiment 3 employed the observer-learner paradigm to measure people's beliefs about the effect of cognitive conflict on memory, and the results showed that metamemory beliefs (observation JOLs) played a completely mediating role in the relationship between cognitive conflict and JOLs. Experiment 4 provided evidence supporting the claim that beliefs about processing fluency contribute to the cognitive conflict effect on JOLs. These results consistently suggest that cognitive conflict is a reliable factor affecting metacognitive monitoring, and furthermore, processing fluency and metamemory beliefs (or a combination of both: beliefs about processing fluency) contribute to the impact of cognitive conflict on JOLs.

The results of Experiment 1 showed that cognitive conflict had an impact on JOLs. Specifically, participants predicted that conflict words were less memorable than consistent ones, and gave lower JOLs to conflict words than to consistent ones. Such findings are consistent with the cue-utilization approach (Koriat, 1997), which proposes that JOLs are inferential and are based on different cues (e.g., semantic relatedness, concreteness, animacy, font size). And these results confirmed that participants monitored memory retrieval likelihood according to the cognitive conflict status of learning materials, indicating that cognitive conflict can be regarded as one type of intrinsic cues informing JOLs. However, there was actually no difference in recall performance between conflict and consistent words, reflecting a dissociation between JOLs and memory. The conflict monitoring model of Botvinick et al. (2001) holds that increased task conflict leads to stronger encoding and better subsequent memory. The results of this present study are incompatible with the previous studies that suggest a strong relationship between cognitive conflict and memory (Ptok et al., 2020; Rosner et al., 2015). Recent studies demonstrated that making JOLs can influence memory performance (Mitchum et al., 2016; Soderstrom et al., 2015). When participants study a list of related and unrelated word pairs, they recall more related than unrelated pairs when people make JOLs than when they do not make them, and the positive reactivity was a larger contributor than was negative reactivity. These findings suggested that making JOLs helps learning more than hurts it (Janes et al., 2018). Therefore, the detaching phenomenon between JOLs and memory in the experiments may be caused by making JOLs. Making JOLs changes people's learning goals and leads to a stronger encoding of consistent words.

Results derived from Experiment 2 supported the fluency hypothesis of the dual-process model (Koriat, 2000, 2007). Specifically, the mediation results indicated that cognitive conflict decreases JOLs (at least partially) by decreasing processing fluency. This result was consistent with previous studies (Susser & Mulligan, 2015; Undorf & Erdfelder, 2015; Undorf et al., 2017; Yang et al., 2018), supporting the role of processing fluency in JOL formation. For example, Undorf and Erdfelder (2015) observed that ease of processing is an important basis for the relatedness effect on JOLs, and mediation analyses revealed that the relatedness effect on JOLs was significantly mediated by the number of trials to acquisition (Experiment 1), self-paced study time (Experiment 2), and repeated study-test cycles (Experiment 3). In the current study, the contribution of processing fluency to the effect of cognitive conflict on JOLs was only measured by the self-paced study task. Therefore, investigating the role of processing fluency in the effect of cognitive conflict on JOLs by employing other measurement tasks (such as lexical decision, CID) is an important direction for future research.

Experiment 3 documented that participants had beliefs about how cognitive conflict influences memory. Specifically, both item-by-item observation JOLs and global predictions were higher for consistent words than were those for conflict words, and observation JOLs play a complete mediation role between word type and JOLs, suggesting that participants might use beliefs about the relation between cognitive conflict and memory to make predictions. These results support the belief hypothesis of the dual-process model (Koriat, 2000) and consistent with previous studies (Dunlosky et al., 2015; Jia et al., 2016; P. Li et al., 2016; Witherby & Tauber, 2017), supporting the contribution of metamemory beliefs to JOL formation. As suggested by Thompson and Johnson (2014), reasoners' FORs were lower for conflict relative to nonconflict problems, indicating participants had beliefs about how cognitive conflict influence reasoning. According to the AP theory, people may develop beliefs about how different cues influence memory in order to seek available cues to reduce the uncertainty of memory prediction (Mueller & Dunlosky, 2017). In the current study, participants may have a priori and/or gradually develop a new belief that cognitive conflict impairs memory, which in turn drives them to give lower JOLs to conflict words.

Evidence from Experiment 4 proved that beliefs about processing fluency contribute to the cognitive conflict effect, which was consistent with previous research results (Y. Chen et al., 2019; Mueller & Dunlosky, 2017). Current findings supported the AP theory that people's beliefs contribute to JOLs and provided evidence of a close connection between the beliefs hypothesis and the fluency hypothesis of the dual-process model (Koriat, 2000, 2007). Interestingly, according to the AP theory, people will search for cues to reduce the uncertainty of performance predictions, but this study found that once one of the cues was given and emphasized, participants ignored or stopped looking for other cues. The specific mechanisms should be further explored in future research.

The current research is important for at least two reasons. At the theoretical level, the results provide evidence supporting the dual-basis view assuming that JOLs are based on both subjective processing experience and metamemory beliefs. In particular, evidence that beliefs about processing fluency contribute to the cognitive conflict effect appears to integrate two separate systems of theory-based and experience-based monitoring in the dual-process model (2000, 2007). At a practical level, the current study also provides enlightenment to enhance teaching practice. Researchers suggested that metacognitive strategies should be used in curriculum development and teachers' education (Georghiades, 2004). Although it is well-established that cognitive conflict benefits a variety of task performance (e.g., facilitating thinking and reasoning, promoting knowledge comprehension, enhancing conceptual induction), the current study showed the first evidence that people lack appreciation of these benefits (at least to its effect on memory), as reflected by the lower JOLs for conflict items. Therefore, such a dissociation between actual benefits and metacognitive unawareness of the benefits deserves more research attention because the unawareness should significantly abolish its practical utilization in educational settings. In addition, future research should explore practical interventions (e.g., Yan et al., 2016; Yang et al., 2017) to enhance metacognitive appreciation of the benefits of cognitive conflict, which have potentials to drive learners and instructors to create cognitive conflicts during learning and teaching.

Acknowledgements This research was supported by the National social science foundation of China (18BGL123).

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