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ORIGINAL PAPER

The impact of frowning and doubt on deductive reasoning

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Abstract
Human reasoning involves a balance between fast, intuitive responses and slower, deliberative thinking. While deliberation is effortful and often unpleasant, its motivational triggers remain unclear. Drawing on appraisal theory, we propose that the emotion of doubt—characterized by uncertainty and cognitive blockage—acts as a trigger for deliberation. In this pre-registered study ($N=414$), participants solved deductive reasoning problems varying in cognitive conflict (conflict vs. non-conflict) while being instructed to frown or not, based on the facial feedback hypothesis. Doubt and several indices of deliberation were measured after each trial. Results showed that conflict problems elicited greater doubt and arousal, and that doubt was positively associated with self-reported cognitive effort. Frowning amplified these emotional effects, increasing doubt and arousal, though it had limited impact on behavioral measures of deliberation (e.g., response times, answer changes). These findings suggest that doubt, as a negative emotional response to conflict, plays a motivational role in engaging deliberation. Frowning may modulate this process by enhancing the emotional salience of conflict. The results support an integrated model of reasoning in which emotion,particularly doubt, helps regulate the shift from intuitive to deliberative thought.

Keywords Reasoning · Emotion · Doubt · Cognitive conflict · Intuition

Introduction

A dominant paradigm in the psychology of reasoning postulates that human reasoning involves two distinct cognitive mechanisms, with varying terminologies used to name these mechanisms (Epstein, 1994; Evans, 2006; James, 1890; Kahneman, 2003; Sloman, 1996; Stanovich & West, 2000). Although some have contested a strict two-system view of reasoning (Grayot et al., 2024; Keren & Schul, 2009; Melnikoff & Bargh, 2018), the present study does not rely on a specific assumption regarding the nature of intuition and deliberation (e.g., whether they are qualitatively different or two extremes of a continuum). Rather, our work follows on from the recent theoretical work of De Neys (Bago & De Neys, 2020; De Neys, 2018; Neys, 2023; De Neys & Pennycook, 2019).

Those kinds of dual-process theories 2.0 postulate that while *deliberation* is a conscious, controlled process requiring deep, analytical thinking that is both mentally demanding and resource-intensive, *intuition* operates automatically and relies on effortless cognitive processes. Given that deliberation is both effortful and unpleasant (David et al., 2024; Stanovich, 2018), a central challenge in reasoning theories is to explain what triggers the activation of such tiresome and uneconomical process. The present study explored the idea that a negative emotional experience, doubt, is at the heart of the switch from intuition to deliberation.

Current models of reasoning propose that deliberation is activated when the organism detects a failure of intuition (Evans & Stanovich, 2013; Kahneman, 2011). A particular type of failure occurs when multiple conflicting intuitions arise simultaneously and form what has been named a "cognitive conflict". A large body of evidence shows that

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cognitive conflict often leads to the activation of deliberative reasoning (De Neys, 2012, 2014; De Neys et al., 2010; De Neys & Pennycook, 2019), and these findings imply that cognitive conflict can be detected through a monitoring system.

This monitoring system has been suggested to consist in second-order metacognitive judgments regarding the quality of intuitions. Thompson et al. (2011), for example, have described a metacognitive experience called "Feeling of Rightness" (FOR). FOR would result from a self-assessment of one's confidence in an answer's rightness. Fluent, familiar and non-conflictual intuitions would generate a strong FOR, meaning that deliberation is unnecessary (Thompson et al., 2013, 2018; Thompson & Johnson, 2014). Conversely, a weak FOR means that deliberation has to be activated to resolve the problem at hand. Other labels have been used to describe the monitoring system, such as "Feeling of Error" (FOE; Ackerman & Thompson, 2017; Fernandez Cruz et al., 2016; Gangemi et al., 2015), "Feeling of Wrongness" (FOW; (Ackerman & Thompson, 2017) or "Response Uncertainty" (RU; De Neys, 2023).

Irrespective of the label used, FOR, FOE, FOW or RU have all been conceptualised as processes that are primarily cognitive in nature (i.e., quantitative appraisals of intuitions' strength) and they all rely on a metacognitive framework. However, such framework leaves insufficiently explained the issue of motivation. Specifically, when an intuition is assessed as uncertain or weak, why would one be motivated to engage in costly deliberation? Why not simply settle for the suboptimal intuition? Presumably, a distal explanation lies in evolution: not caring about our mistakes would make us very vulnerable. However, the proximal explanation remains insufficiently explained. We propose that the answer lies in a model that incorporates emotion within the reasoning process.

Previous models have posited an effective link between emotion and reasoning. However, these tend to maintain a categorical distinction between emotion and reasoning, viewing emotions as exerting an influence on reasoning rather than as part of it (Bless et al., 1996; Clore & Huntsinger, 2007; Schwarz, 2012). We propose here to instead conceive emotions as a mediator of reasoning, and not only as a moderator. That is, emotion may be a constitutive step within the mechanism itself. This account would allow us to explain the motivation to engage in thinking, rather than simply modulating a mode of reasoning (intuition or deliberation) that is already motivated.

More specifically, the Appraisal Theory of Emotion may be particularly relevant to dual-process reasoning models. According to this theory, affective reactions stem from an evaluation of the congruency between the situation and the individual goals, which then generates physiological responses, action tendencies, and motor expressions that motivate action (Moors et al., 2013; Scherer & Moors, 2019). The motivation for deliberation may thus arise from a negative emotion triggered by the appraisal of a situation where individuals' goals diverge from situational offerings. Such emotion, which can be named doubt (Cortial et al., 2025a, 2025b; Dewey, 1910) is akin to experiences of confusion or anxiety. And, as the latter, it is inherently unpleasant and motivate participants to deliberate (Cortial et al., in review). Metacognitive experiences, such as FOR, FOE, FOW, or RU, being theorized as relying on affective cues to construct themselves (Thompson et al., 2011; Thompson & Morsanyi, 2012), would subsequently guide the efforts required to resolve the problem created by the unpleasant feeling of doubt.

We argue that doubt cannot be merely understood as lack of knowledge or as a metacognitive judgment about the reliability of an intuition. A person could be uncertain without doubting, if that uncertainty has no negative consequence for them. Doubt may arise when uncertainty is assessed as a threat, i.e., as a problematic gap between the individual's goals and the situation they are facing.

Thus, doubt would be a motivational emotion that drives us to seek resolution. It is not a lack of confidence in an intuitive response that triggers reflection, but the stakes attached to the situation (Cortial et al., 2025a). When responding correctly is important (exam, competition, personal goal), the absence or the plurality of immediate responses becomes problematic and prompts deliberation.

This conception challenges models of reasoning that explain cognitive mobilization solely by the degree of metacognitive certainty. A person may be certain that they do not know the answer, and certain that they can find it, but nevertheless engage in intense reasoning if the situation is perceived as threatening. In that case, the triggering of deliberation would depend less on metacognitive uncertainty than on the overall assessment of the situation.

In this sense, doubt would result from an appraisal process that can integrate the relevance of the situation to the individual's goals, its consequences, the perceived ability to cope with it, and the degree of control exercised (Moors et al., 2017; Scherer & Moors, 2019). These assessments determine the extent to which uncertainty is experienced as a threat and, consequently, the intensity of the cognitive effort mobilized. Previous knowledge, beliefs, and emotional experiences modulate this process. In short, we think that doubt should be understood as the emotional signal of a desynchronization between expectations and environment, and its function would be to motivate the engagement in costly reasoning processes.

Thus, we have previously argued that doubt can be characterised by three important features: uncertainty, unpleasantness, and the feeling of being blocked (Cortial et al., 2025a). First, uncertainty is a central feature of doubt, which emerges in situations of perplexity, confusion or unsureness. Interestingly, the labels used in several reasoning models (Response Uncertainty, De Neys, 2023; Feeling of Error, Ackerman & Thompson, 2017; Fernandez Cruz et al., 2016; Gangemi et al., 2015; or Feeling of Rightness, Thompson et al., 2011) explicitly refer to this notion of uncertainty. This feeling of uncertainty is not only related to the problem itself, but can also come from personal features, such as personality traits or the mindware of individuals (Berenbaum et al., 2008; Fergus & Rowatt, 2014; Šrol & De Neys, 2021). Second, the unpleasant dimension of doubt is linked to the fact that a weak intuition should be appraised as "threatening" and elicit a negatively valenced emotion. Accordingly, while fluent and familiar intuitions are linked to positive affect (Morsanyi & Handley, 2012; Thompson, 2009; Thompson et al., 2011; Thompson & Morsanyi, 2012; Trippas et al., 2016; Zizak & Reber, 2004), the cognitive system appraises cognitive disfluency as a harmful phenomenon (Dreisbach & Fischer, 2012, 2015; Proulx et al., 2012). People prefer predictability over uncertainty (Gawronski & Strack, 2012; Mendes et al., 2007; Proulx et al., 2012) and discontinuity is unpleasant (Hajcak, 2012; Hajcak & Foti, 2008; Topolinski et al., 2009). Finally, and related to the first and second points, doubt emerges when there is a gap between what an individual wants and what is available in their environment (i.e., situations of blockage), which is supported by appraisal theories of emotion (Moors et al., 2017; Moors & Fischer, 2019).

In sum, we hypothesize that weak intuitions generate an unpleasant state of uncertainty and cognitive blockage, which we name 'doubt'. The objective of the present study was to provide empirical support for this hypothesis. Our first aim was to replicate findings from a previous study showing that cognitive conflict in reasoning problems (De Neys & Pennycook, 2019) generates doubt, and that such negative emotion is associated with an increase in deliberation.

The second aim of the study was to further examine the link between doubt and reasoning through an experimental manipulation of doubt, using frowning. Specifically, the facial feedback hypothesis postulates that people's facial expression can impact their subjective emotional state (see Coles et al., 2019, for a meta-analysis). Accordingly, the action of frowning should increase the subjective experience of doubt. Although studies suggest that several negative emotions such as sadness (Larsen et al., 1992), or aggression (Marzoli et al., 2013) may be linked to frowning, a body of evidence shows that uncertainty and doubt are caused by frowning. This idea is substantiated by findings showing that frowning (and the activation of the corrugator's muscle) is related to experiences of uncertainty (Bitti et al., 2014), low confidence (Stepper & Strack, 1993), disfluency (Cacioppo et al., 1986; Pope & Smith, 1994; Scherer & Ellgring, 2007; Smith, 1989), and cognitive conflict (Berger et al., 2020; Lindström et al., 2013). Frowning is also associated with mental effort and concentration (Stepper & Strack, 1993; Tourangeau & Ellsworth, 1979). We thus predicted that asking participants to frown should increase their subjective experience of doubt. We then explored whether the frowning-related increase in doubt would result in an increase in deliberation. While a seminal study has shown that participants provided more correct responses to reasoning problems when frowning (compared to a puffy cheeks control condition; Alter et al., 2007), subsequent investigations have failed to replicate this effect (Thompson et al., 2013).

Methodological problems may be at the root of the heterogeneity in findings. On the one hand, Alter et al.'s study (2007) used accuracy as a measure of deliberation. However, given that intuition can also lead to logical and unbiased answers, an increase in accuracy may not necessarily reflect an increase in deliberation (Alter et al., 2013; De Neys, 2012; Neys, 2023; De Neys & Pennycook, 2019). In addition, while the effect of facial feedback is robust, it has a small effect size (Coles et al., 2019). The study of Thompson et al. (2013) may have lacked power to detect an effect ($N=72$ participants).

First, we manipulated the presence of conflict between the logicality and the believability of conclusions in deductive reasoning problems (conflict variable: conflict vs. no conflict). We also manipulated frowning, by asking participants to frown in some trials and not frown in others (frowning variable: frown vs. no frown). Both variables were manipulated using a within-participant design. We used a two-response paradigm in order to dissociate intuitive from deliberative reasoning (Thompson et al., 2011). We expected an interaction between the frown and conflict variables such that frowning would boost the experience of doubt caused by conflict problems, thus acting as an emotional enhancer. We further expected that levels of deliberation would be related to doubt, such that deliberation would be stronger when doubt is higher, and thus strongest in the conflict-frown condition. Finally, we expected the overall experience of doubt to be related to state anxiety at the end of the study, thereby confirming the negative valence of doubt.

Method

Pre-registration

The study design, research question and analyses were preregistered on the Open Science Framework (https://osf.io/fgnqe).

Participants

French-speaking participants were recruited from a mailing list that encompassed the entire student and employee population of the University Clermont-Auvergne (France). A previous similar experiment (Cortial et al., 2025b) allowed us to expect a low effect size for the impact of cognitive conflict on doubt, namely, d = 0.14. A Jpower (Jamovi module) analysis indicated that a sample of at least 439 participants would allow us to detect an effect (with probability greater than 0.90) assuming a one-sided criterion for detection that allows for a maximum Type I error rate of a=0.05.

Given difficulties recruiting participants, we stopped recruitment after reaching the sample of 432 participants, which was close to the targeted sample size. Eighteen participants were excluded from the analyses due to their failure to pass the attention test incorporated into the experiment. The final sample size for analysis thus comprised 414 participants (296 women, mean age: $M = 22.3$ years, $SD = 6.33$). The majority of participants reported having completed secondary education ($n = 294$), while others reported having completed undergraduate education ($n = 56$), postgraduate education ($n = 62$), or only primary education ($n = 2$).

Materials

Syllogisms

The experiment was run online. Participants were asked to determine the logical validity of syllogisms, which were constructed using categorical versions of two potential conditional inferences: the first being equivalent to the logically valid *Modus Ponens* (If P then Q, P is true, therefore Q is true), and the second being equivalent to the logically invalid *Affirmation of the Consequent* (If P then Q, Q is true, therefore P is true).

Each problem in the study comprised a major premise, a minor premise, and a conclusion (See supplementary material). For example: "All birds can fly. Penguins are birds. Therefore, penguins can fly." For half the problems, the conclusion's logical validity conflicted with its believability, resulting in what was termed "conflict problems." Some problems could be logical, but have an unbelievable conclusion like "Computers are mammals", or they could be illogical, but have a believable conclusion. In the other half of problems, the conclusion's validity did not conflict with its believability, resulting in "non-conflict problems" (see Table 1).

Each participant was presented with twelve syllogisms, derived from the work of Boissin et al. (2023) and translated into French.

Table 1 Examples of syllogisms

Logical	Believable	Unbelievable
	All animal needs to eat. Humans are animals. Therefore, humans need to eat.	**All those who wear uniforms are police officers. Firefighters wear uniforms. Firefighters are police officers.**
Illogical	**All musicians can read sheet music. Pianists can read sheet music. Therefore, pianists are musicians.**	All cow has legs. Dos have legs. Therefore, cows are dogs.

Conflict problems in bold.

Doubt scale

Following each response to a given problem, the participants were asked to indicate whether they had experienced doubt while solving the problem. They were provided with a four-option Likert scale (i.e., "not at all," "not really," "quite so," and "completely") to rate the following three statements: "I felt blocked", "I felt doubt", and "I found the reflection unpleasant." These statements encompass the cognitive appraisal component, the subjective manifestation of doubt, and its negative valence. The scale demonstrated satisfactory internal consistency, with a Cronbach's alpha value of 0.84. We computed the mean levels of doubt for each conflict condition and each participant.

Arousal

Following the doubt scale, for each problem, participants indicated how aroused they felt "when solving the problem", using a SAM-Manikin arousal scale (from "calm/serene" to "restless/awake/aroused"; Bradley & Lang, 1994). This measure enables us to ensure not only that a physiological reaction occurs as part of an emotional response, but also as a manipulation check allowing us to verify that participants frowned.

State-trait anxiety inventory

At the conclusion of the experiment, the participants completed a state anxiety questionnaire. This questionnaire was a reduced 5-item version of the state subscale of the

State-Trait Anxiety Inventory (STAI), (Zsido et al., 2020; Cronbach α=.91 in the latter study). Participants were asked to indicate their level of agreement with five statements describing their emotional state (e.g., "I feel nervous" or "I feel confused") using a 4-option Likert scale (i.e., "strongly disagree," "somewhat disagree," "somewhat agree," and "strongly agree"). The average state-anxiety score for each participant was calculated, and it was subsequently converted into a percentage (Cronbach α=.71 in our study).

Procedure

Prior to starting the experiment, participants received a comprehensive explanation of the process. They were advised that the task would require approximately 15 min of their undivided attention and that it had to be completed on a computer, and not a mobile device. Initially, a general task overview was provided, instructing participants to evaluate whether a conclusion logically followed (or not) from two premises, setting aside personal beliefs.

Participants were informed that each problem would appear twice, requiring two responses: one based on their immediate intuition, and another after thoughtful reflection. During the first presentation, participants were instructed to respond quickly with the first judgment that comes to mind. Upon the second presentation, they were given unlimited time to reconsider and possibly revise their initial answer. A practice problem was used to familiarize the participants with this dual-response method.

The experimental structure mirrored the paradigm introduced by Bago and De Neys (2017). Each trial began with a fixation cross displayed for 2,000 milliseconds, followed by the major premise shown alone for another 2,000 milliseconds. The minor premise then appeared below the major premise and remained on the screen for an additional 2,000 milliseconds. Subsequently, the conclusion was displayed beneath the minor premise, accompanied by the question: "Does the last statement logically follow from the first two?" with response options "yes" or "no."

Participants had 3,000 milliseconds to provide their intuitive (t1) response, totalling 7,000 milliseconds from the trial's start. To emphasize the time constraint, response buttons turned red 2,000 milliseconds after the conclusion appeared, indicating that only 1,000 milliseconds remained. Irrespective of whether a response had been given within the time constraint, the trial continued with the doubt and arousal scales. The complete reasoning problem was then presented again, allowing participants to provide a final judgment (t2 response) without any time constraint. Finally, given that deliberation is expected to be a costly cognitive process, we asked participants to indicate whether they had "made an effort to think" after each t2 response. Participants selected one of the following two options: (1) I made an effort to think further (scored "1"), or (2) I did not make an effort to think further (scored "0").

Both the accuracy of initial (t1) and final (t2) responses were recorded. We computed the number of correct responses, for both conflict and non-conflict problems. Response times were measured only for t2 responses, as initial responses were collected under time pressure and thus excluded from reaction time analyses. We used three measures as indices of deliberative reasoning. First, we examined response times to provide the second (presumably deliberative) response (t2 RT). Longer t2 RTs indicate a more likely usage of deliberative thinking (De Neys, 2006). Second, we examined the number of response changes between the first (t1) and second (t2) response. A change in response is likely to indicate that participants had re-evaluated their initial response, possibly through deliberative processes (note: even when a response change goes from logical at t1 to non-logical at t2, this could indicate a response re-evaluation and therefore the usage of deliberative reasoning). Finally, we examined the number of "I made an effort to think further" responses, which reflect a Feeling of Cognitive Effort (FCE) in both conflict and non-conflict problems.

The 12 problems were divided into two blocks. In one block, participants were explicitly instructed to frown, with the instruction accompanied by a picture of someone frowning. In the other block, no specific request was made. It is important to note that frowning was requested only during the problem-solving part of each trial (and not during the questionnaire parts). The order of the blocks was randomized, such that half of the participants frowned during the resolution of the first six problems and relaxed for the remaining six, and vice versa for the other half of the participants.

An attention test was randomly presented during the course of the experiment, where participants had to check the sixth box of a 10-box panel and to choose the "no" box from two choices (yes/no). At the end of the study, the participants completed the state anxiety subscale of the STAI.

Analysis

Analyses of the data were conducted using the gamlj package implemented in Jamovi. Number of correct T1 and T2 responses, number of response changes, and number of "I made an effort to think further" responses were analysed using Logistic Mixed Models, while RT, doubt levels, and arousal levels were analysed using Linear Mixed Models. Mixed models are particularly suitable for these data because they allow for the simultaneous modeling of fixed effects (experimental manipulations such as Conflict and Frown) and random effects (variability between participants), which accounts for the correlation of repeated measurements within individuals and the differences in baseline performance across participants. All full models included in their fixed effects an intercept, a main effect of Conflict (i.e., Conflict versus non-conflict), a main effect of Frown (i.e., Frown versus No Frown), and the interaction between these factors. All models had maximal random effects structure, with by-subject random intercepts and slopes for Conflict, Frown, and their interaction (Dean & Nielsen, 2007; Stroup et al., 2024).

Finally, we also performed Pearson correlations on the mean scores calculated for each participant and each condition.

Ethics

Participants gave an informed consent to participate before beginning the experiment, and they were informed that participation was anonymous. Given that participation was voluntary and performed online, the participants could interrupt their participation at any moment if they wished to do so, with no consequence. The experiment was approved by the Ethics Committee of the University of Clermont-Auvergne (IRB00011540-2023-17).

Results

Impact of conflict and frowning on correct responses

On average, participants reached a number of logical t1 responses significantly higher for non-conflict problems ($M_{non-conflict}$ = 4.45 out of 6; SD=1.68) than for conflict problems ($M_{conflict}$ = 1.14 out of 6; SD=1.55), β = −9.908, SE=0.669, $\chi^2(1)$=219.04, p <.001. Although final responses (t2) were overall more accurate than initial responses ($M_{non-conflict}$ = 5.26, SD=1.01, vs. $M_{conflict}$ = 2.23, SD=1.78), the accuracy gap between non-conflict and conflict problems remained large, β = −4.511, SE=0.239, $\chi^2(1)$=355.3, p <.001.

Our analysis revealed no effect of frowning instructions on t1 accuracy, β = −0.58, SE = 0.651, $\chi^2(1)$=0.796, p =.37, nor on t2 accuracy, $\chi^2(1)$=0.01, p =.92. However, the interaction between Conflict and Frown was significant for t1, β = −3.801, SE=1.343, $\chi^2(1)$=8.013, p =.005, and there was a trend for t2, β = −0.796, SE=0.451, $\chi^2(1)$=2.88, p =.09. Instruction to frown tended to increase the number of correct responses in conflict problem (see Fig. 1).

Impact of conflict and frowning on doubt

Doubt was significantly higher in conflict problems (M=0.41, SD=0.34) than in non-conflict problems (M=0.33, SD=0.31), β=0.356, SE=0.047, F(1,1519)=57.11, p <.001. There was also a significant main effect of Frowning on doubt, β = −0.356, SE=0.0661, F(1,414)=29.01, p <.001, and an interaction between Frowning and Conflict, β = −0.227, SE=0.0988, F(1,417)=5.26, p =.022 (see Fig. 2), such that instruction to frown boosted the impact of conflict on doubt.

Arousal levels were also significantly higher in the conflict condition (M = 2.01, SD = 1.09) than in the non-conflict condition (M = 1.93, SD = 1.07), β = 0.069, SE = 0.019, F(1,416) = 102.64, p = .001. Additionally, there was a main effect of instruction to frown, with higher levels of arousal in the frowning (M = 2.05, SD = 1.08) than in the non-frowning condition (M = 1.89, SD = 1.08), β =-0.165, SE = 0.0328, F(1,405) = 25.29, p < .001 (see Fig. 3)

Impact of conflict and frowning on deliberation

We observed a significant effect of Conflict on Response Change, β=51.825, SE=0.58, $\chi^2(1)$=9.873, p =.002 (see Table 2). However, the models did not demonstrate a main effect of Frowning, $\chi^2(1)$=0.014, p=.91, nor an interaction between Conflict and Frowning, $\chi^2(1)$=0.013, p=.91. Similar results were found for the t2 RT measure, whereby there was a main effect of Conflict, β=0.1005, SE=0.199,

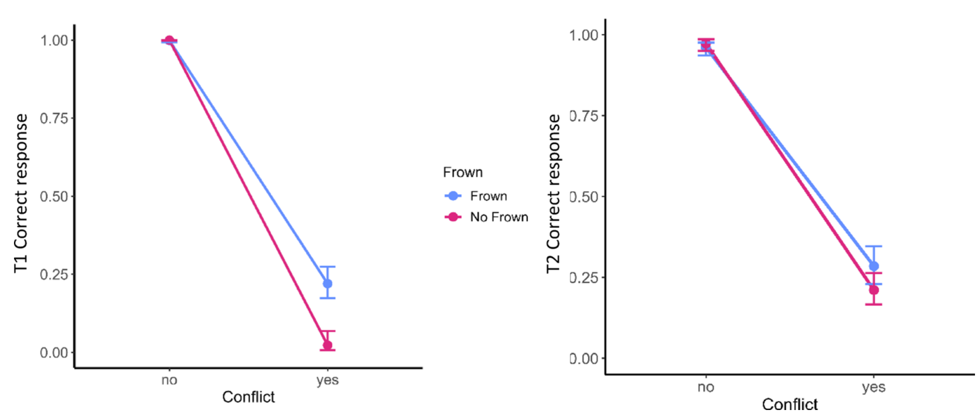

Fig. 1 Interaction Between frown and conflict on Correct response at t1 and t2

Fig. 2 Impact of Conflict and Frowning manipulations on level of doubt

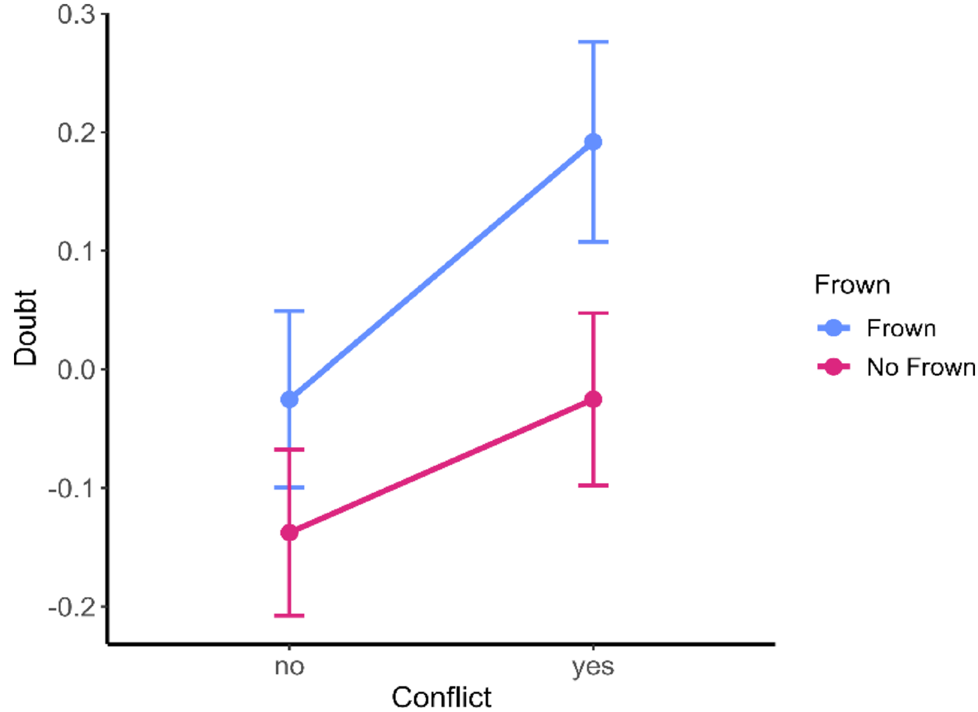

Fig. 3 Impact of Conflict and Frowning manipulations on level of arousal

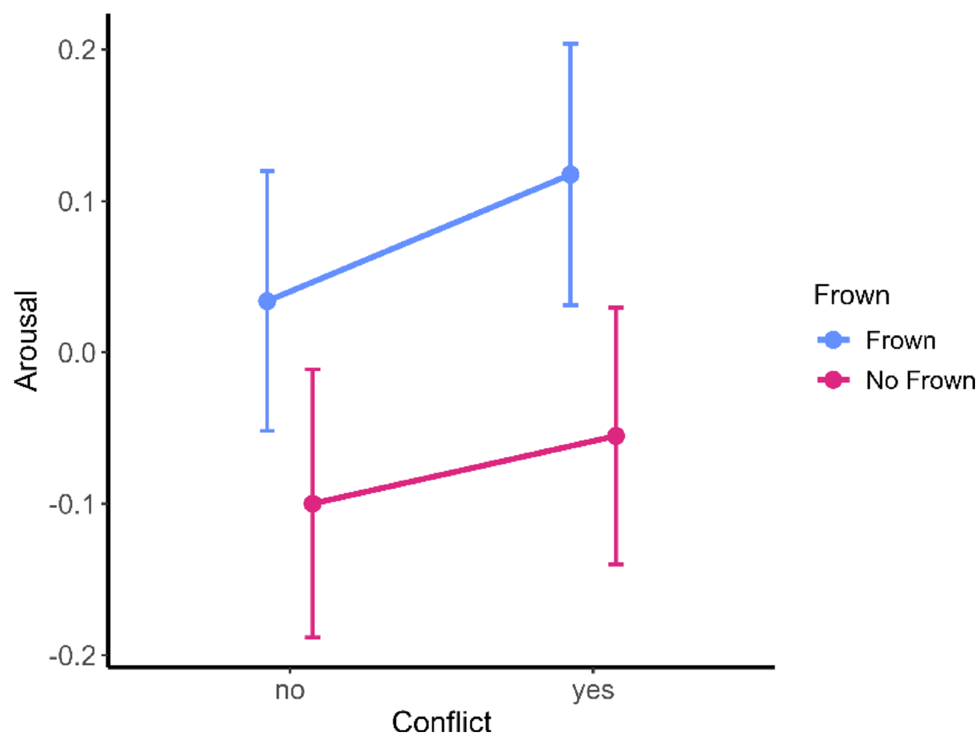

Table 2 ChangeResp and RT means difference across conflict and frown conditions

	Conflict		Non-Conflict	
	Frown	No Frown	Frown	No Frown
Response Change (freq)	0.12 (0.32)	0.13 (0.34)	0.06 (0.25)	0.07 (0.25)
t2 RT (ms)	7117 (7588)	7280 (7990)	6176 (5437)	6177 (4481)

$F(1,414) = 25.51$, $p < .001$ (see Table 2), but no main effect of Frowning, $F(1, 415) = 2.34$, $p = .13$, and no interaction effect, $F(1, 415) = 1.36$, $p = .24$.

Finally, the analyses revealed both an effect of Conflict on FCE, $\beta = 0.456$, $SE = 0.135$, $\chi^2(1) = 11.48$, $p < .001$, and an effect of Frowning, $\beta = -0.517$, $SE = 0.141$, $\chi^2(1) = 13.524$, p

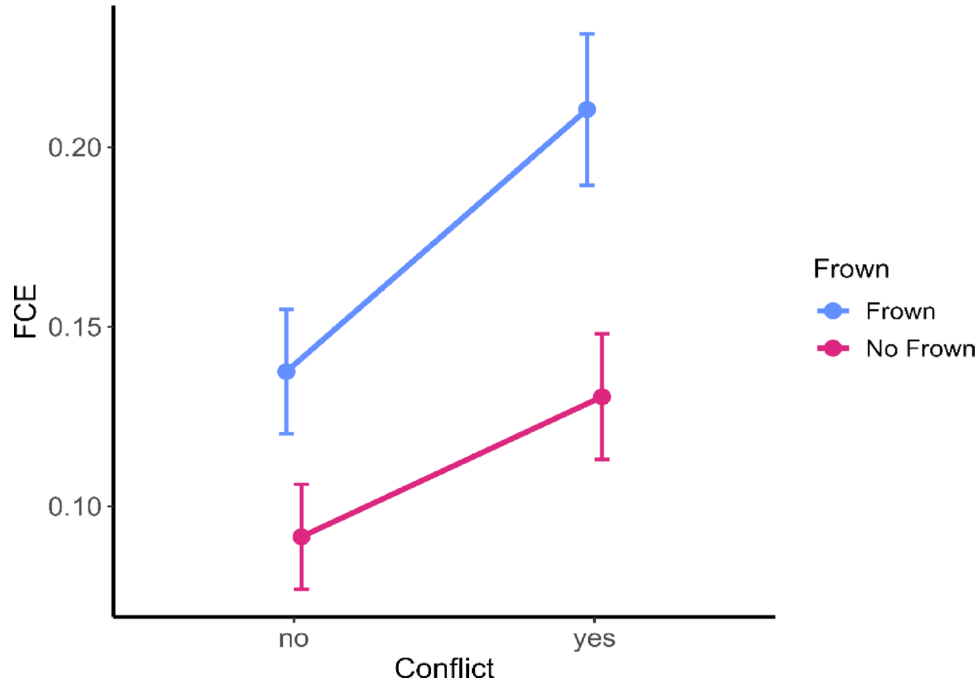

Fig. 4 Impact of Conflict and Frowning manipulations on Feeling of effort

Table 3 General correlation table

		Conflict	Non-Conflict
Doubt			
	Anxiety	0.51***	0.45***
	FCE	0.48***	0.41***
	RespChange	0.08	0.04
	t2 RT	0.16**	0.20***
	AccT1	0.12*	−0.18***
	AccT2	0.19***	−0.05
Anxiety			
	FCE	0.34***	0.26***
	RespChange	0.13**	0.06
	t2 RT	0.16**	0.17***
	AccT1	−0.02	0.01
	AccT2	0.03	0.04
FCE			
	RespChange	0.24***	0.14*
	t2 RT	0.32***	0.32***
	AccT1	0.24***	−0.03
	AccT2	0.32***	−0.04
RespChange			
	t2 RT	0.26***	−0.02
	AccT1	0.09	0.05
	AccT2	0.27***	−0.56***
t2 RT			
	AccT1	0.15***	−0.06
	AccT2	0.29***	0.07
AccT1			
	AccT2	0.79***	0.24***

The table presents Pearson's r correlation values; * p <.05,** p <.01, *** p <.001.

<.001 (see Fig. 4). However, there was no significant interaction, $\chi^2(1)=0.189$, p =.66 (see Fig. 4).

Relationship between emotional measures and deliberation

We examined whether the emotional responses (measured using doubt, arousal and state-anxiety scales) were related with the various deliberation metrics: FCE, t2 RTs, and frequency of response changes from t1 to t2. We also tested whether the number of correct responses at t1 (AccT1) and t2 (AccT2) were related to the other measures, using Pearson's correlations. The analyses revealed positive associations between the three emotional measures (see Table 3). The analyses also showed positive relationships between the deliberation indices, especially in conflict trials. Finally, there were positive relationships between emotional and deliberation indices, though no significant link was observed between doubt and number of response changes (see Table 3). Finally, we note that, while doubt was positively related with conflict correct responses, it was negatively related with non-conflict correct responses.

Exploratory mediation analysis

So far, our analyses have measured the relation between frowning and doubt independently of the relation between frowning and deliberation. However, we hypothesize that it is not the act of frowning that makes us deliberate more, but rather that frowning increases doubt, which in turn increases the use of deliberation. To assess this hypothesis, we report here the results of exploratory mediation analyses. Although these analyses were not preregistered and their results would need to be treated with caution, we believe that they may help gain a clearer understanding of the effect of frowning on deliberation and whether it is mediated by doubt.

Mediation analyses were conducted using the jAMM module in Jamovi (version 2.3.28). Doubt was specified as the mediator, frowning, conflict, and their interaction as independent variables, and each deliberation-related measure (RTs, response changes, and FCE) was included as dependent variable of separate mediation analyses. Indirect effects were estimated using a regression-based approach. Following the recommendations of Preacher and Hayes (2008), statistical inference for indirect effects relied on bias-corrected bootstrap confidence intervals based on 5,000 resamples, an approach that does not assume normality of the sampling distribution of indirect effects. Resulst shows the same pattern of results for each of our deliberation variables. First, the effects of frowning and conflict were significantly mediated by doubt (in RTs, respectively $\beta = 212.73$, 95% BC C.I. [111.29, 333.39], $p < .001$ and $\beta = 214.34$, 95% BC C.I. [110.69, 335.73], $p < .001$; in Response Changes, respectively, $\beta = 0.0045$, 95% BC C.I. [0.0020, 0.0085], $p = .004$ and $\beta = 0.0040$, 95% BC C.I. [0.0016, 0.0080], $p = .011$; in FCE, respectively, $\beta = 0.0259$, 95% BC C.I. [0.0143, 0.0384], $p < .001$ and $\beta = 0.0261$, 95% BC C.I. [0.01443, 0.0387], $p < .001$, see Fig. 5).

Second, the Conflict*Frown interaction had no significant mediating effect (in RTs, $\beta = 137.54$, 95% BC C.I. [−54.50, 352.89], $p = .18$; in Response change, $\beta = 0.0029$, 95% BC C.I. [-8.85^{e-4}, 0.0085], $p = .21$ and in FCE, $\beta = 0.017$, 95% BC C.I. [−0.0071, 0.0410], $p = .17$).

Discussion

In the present study, we aimed to replicate previous results showing that a negative emotion arises when intuitive reasoning fails to provide a straightforward answer to a problem, specifically when two intuitions can emerge simultaneously and come into conflict (Cortial et al., 2025b). We examined whether the level of doubt was related with the engagement in deliberation. Finally, in line with the facial feedback hypothesis (Coles et al., 2019), we investigated whether asking participants to frown would increase the experience of doubt and, consequently, whether this would increase the level of deliberation.

First, the results show that conflict problems generate a stronger experience of doubt than non-conflict problems. In addition, they showed that two measures of deliberation (t2 reactions times and Feeling of Cognitive Effort) were positively related to doubt. We note that the doubt scores were strongly related to arousal and state anxiety, confirming that conflict in deductive reasoning problems triggers a negative emotion. Finally, scores of state anxiety were related to all three indices of deliberation, which gives further support to the idea that deliberation is generally unpleasant and linked to a negative emotional state (David et al., 2024). Our study replicates previous results (Cortial et al., 2025b) and align with findings on reasoning, where conflict has been linked to emotional measures and, more precisely, physiological measures such as pupil dilation (Purcell et al., 2023) and electrodermal activity (De Neys et al., 2010).

Another important finding of this study was that, consistent with the facial feedback hypothesis (Coles et al., 2019), frowning boosted the emotional experience of doubt in relation to cognitive conflict. This boost was observed in both doubt and arousal scores. Mimicking the physical characteristics of doubt led to an increase in the subjective experience of that emotion. There was also some evidence that the boost in doubt was followed by an increase in deliberation. Specifically, the "Feeling of Cognitive Effort" (FCE) was larger in the frowning than in the non-frowning condition. However, the other two indices of deliberation (t2 RTs et response changes) were not impacted by the instruction to frown manipulation. Also, the impact of frowning on FCE did not vary significantly across conflict conditions, suggesting that the impact of frowning may have been somewhat orthogonal to that of conflict. Given that FCE was the only measure of deliberation that was impacted by frowning, we remain careful in our interpretation that frowning successfully increased the use of deliberative reasoning.

However, we note that our results offer a conceptual replication of Alter et al. (2007). Like them, we observed an increase in the number of correct responses when participants frowned, especially in the conflict condition. Frowning leaves the number of logical responses unchanged when participants encounter non-conflict problems. Since the problems are simple, there is likely a ceiling effect, preventing participants from improving because they are already very good at solving this type of problems.

If that interaction effect can indeed be perceived as an increase in the use of deliberation, but a growing body of literature shows that logical performance does not depend on the activation of deliberation and, moreover, that many correct responses emerge at the level of intuition (Bago & De Neys, 2019; Charbit et al., 2025; Raoelison et al., 2020, 2021; Thompson et al., 2018). All the more so since if this effect was observed for both t1 (intuitive) and t2 (deliberate) responses, it was even stronger for t1 responses. We believe that this result clarifies the heterogeneous results between the study of Alter et al. (2007) and of Thompson et al. (2013). Indeed, although we observed an increase in performance associated with instruction to frown, as noted by

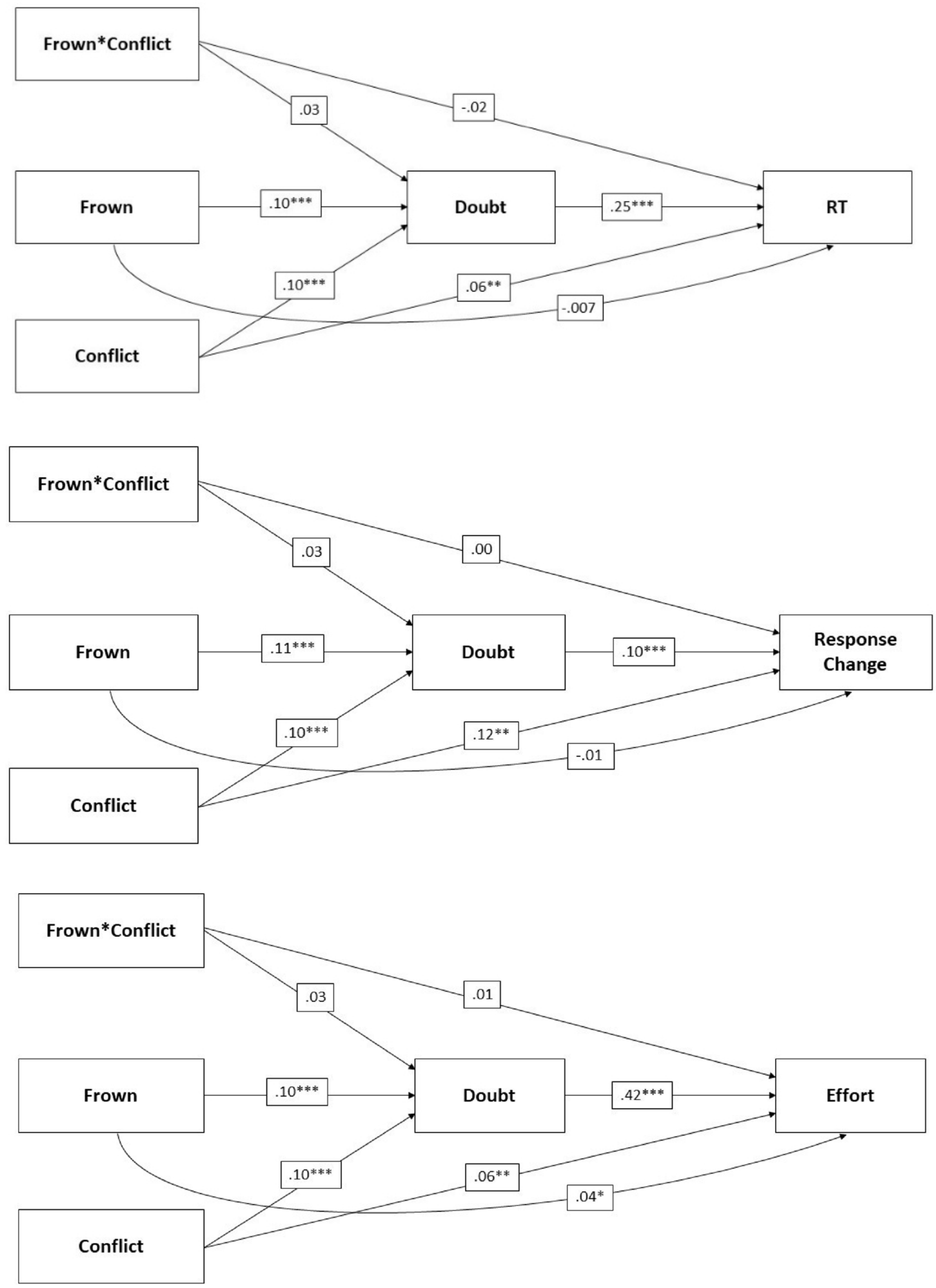

Fig. 5 Mediation path and coefficients for Response Time, Response change and Effort

Alter et al. (2007), our study suggests that this effect may be partly explained by increased deliberative reasoning (Alter et al., 2013). However, it is unlikely to be the sole cause, as argued by Thompson et al. (2013), especially since the greatest improvement occurred at the first stage (T1), where deliberation is less likely to have played a significant role.

It is likely that performance in T1 benefited from greater task engagement and/or distrust towards one's intuitions (pushing participants to choose the "other answer" due to an increased "doubting mood"). Even though intuition is conceptualized as automatic, it nevertheless requires processing of problem information (e.g., semantic processing, and retention in working memory), which would benefit from increased attention. This idea would explain why participants who doubt more are less accurate at t1 non-conflict problems. Being in a "doubting mood" and searching for a trap in a simple (non-conflict) problem will mechanically lower the number of correct answers.

However, another possible interpretation is that "doubting mood" takes the form of a "Take the other answer" heuristic (and therefore a very strong intuition), thereby enhancing accuracy already at T1. The conclusion would be that doubt does not cause deliberation but implies a change in heuristics. Although this interpretation is plausible, deliberation was operationalized through multiple indicators beyond accuracy, all of which were associated with doubt. In addition, the Frown condition was linked to higher levels of FCE. Together, these results suggest a close relationship between doubt and deliberation that cannot be reduced to accuracy effects alone.

Our findings suggest two ways to interpret the dichotomy between intuition and deliberation. On the one hand, that distinction could be interpreted categorically, whereby intuition and deliberation are qualitatively different. From this perspective, doubt would then act as a switch, such that its presence would indicate an entry into a deliberative mode. On the other hand, our findings are not incompatible with a more continuous distinction (Dunwoody et al., 2000; Lieder & Griffiths, 2020; Shenhav, 2024; Shenhav et al., 2021). This would assume instead that organisms face the possibility of using more and more cognitive energy (thus moving from intuition which emerges very fluidly to deliberation of the decoupling type, which requires enormous effort; Pennycook et al., 2015; Stanovich, 2009) without having to imagine different and mutually exclusive systems in terms of their function (De Neys, 2023; Neys, 2025).

In sum, by creating doubt, frowning motivates to engage in a deeper treatment of problems and, if the context allows it, to mobilize deliberative reasoning (Alter, 2013; Alter et al., 2013). This is also suggested by our exploratory mediation analyses.

Given that the analyses were not pre-registered, their results should be treated with some caution. Nevertheless, the results were fully congruent with our pre-registered hypotheses. The analyses revealed that both frowning and cognitive conflict increased deliberation indirectly via doubt. The indirect effects of frowning and conflict were nearly identical, reflecting that both manipulations similarly heightened doubt, which in turn promoted more deliberation. Interestingly, simple linear mixed models examining direct effects on RT and Response Change showed a significant effect of conflict but no effect of frowning. This apparent discrepancy is explained by the fact that frowning operates primarily through an indirect pathway: while it does not directly increase the use of deliberation, it elevates doubt, which then leads to increased cognitive efforts. In contrast, conflict influences deliberation both directly and indirectly via doubt. Importantly, the interaction between frowning and conflict was not significant, indicating that the effects of the two manipulations were largely additive and independent. Overall, these results support our model in which embodied cues (frowning) enhance deliberation through their effect on the emotion of doubt, highlighting a mechanism by which both bodily states and cognitive conflict contribute to the rise of an emotion which causes deliberative reasoning.

The positive relationship between state anxiety and measures of deliberation further supports the idea that doubt is at the heart of deliberative thinking. Although it is well established that anxiety decreases cognitive abilities by polluting working memory (Ashcraft & Kirk, 2001; Blanchette & Caparos, 2016; Channon & Baker, 1994; Darke, 1988; Derakshan & Eysenck, 1998; Kensinger & Corkin, 2003; Moran, 2016), our results show that state anxiety also promotes deliberation. In this regard, anxiety cannot be considered solely as an obstruction to cognitive functioning (Blanchette, 2014; Blanchette & Caparos, 2013; Fernando et al., 2016; MacKuen et al., 2010; Valentino et al., 2008).

We will now raise some limitations of the present work. First, the increase in doubt linked to frowning did not result in an increase in t2 RTs and response changes (the two other indices of deliberation used in this study). This may be explained by the fact that we used a within-participant design. While such design increases the power to detect an effect, it may have caused carry-over effects, making it harder to detect a link between frowning, doubt and deliberation.

Second, it is theoretically possible that the observed effects were primarily driven by implicit priming (namely, the idea of frowning rather than the actual motor execution), we believe that there is converging indirect evidence suggesting that at least some participants did physically frown in the frowning condition. In particular, the differences observed in self-reported doubt and arousal between the frowning and non-frowning conditions provide a compelling theoretical manipulation check. Moreover, the use of a within-participant design rules out the possibility that the effect resulted from group differences, indicating that the observed changes were driven by the experimental conditions themselves. That said, we acknowledge that it remains difficult to definitively disentangle the respective contributions of motor execution and implicit priming. Importantly, this limitation does not undermine the value of the present findings. If anything, an effect driven by implicit priming would be particularly striking, as it would suggest that the mere idea of frowning is sufficient to influence doubt and deliberative processing. Overall, our results indicate that frowning, whether enacted through direct compliance with instructions or induced implicitly, appears to modulate both emotional states and reasoning processes.

Third, since this study was performed online, we cannot ascertain that people consistently frowned when asked to do so. However, the finding of an impact of frowning on doubt and arousal provides indirect evidence that the instructions were generally followed by the participants. Another limitation of our study is that the control condition consisted in "not frowning" and did not include any alternative action (such as Puffy cheeks; Alter et al., 2007; Thompson et al., 2013). However, we note that our results are coherent with those of previous studies, so this limitation is arguably not a major issue. Finally, the problems we used were limited to deductive-reasoning syllogisms. The results will have to be generalized to other instances of complex/conflict reasoning problems (Tversky & Kahneman, 1974; Frederick, 2005). Other studies have demonstrated that these types of problems also result in reduced confidence in responses. It is thus likely that the findings of this study would extend to other types of reasoning problems (Bago & De Neys, 2017; Białek & De Neys, 2016; De Neys et al., 2008; Thompson & Johnson, 2014).

In sum, frowning may be the source of a weak emotional reactions which, first, gives rise to a need to use cognitive effort, this need translates into a vague feeling of mistrust or heightened task engagement, thereby helping to explain the observed positive effect of frowning on reasoning accuracy. Second, which accounts for the correlation between doubt and the use of deliberation. In both conflict and non-conflict problems, higher levels of doubt tended to promote increased cognitive effort.

The present work provides new evidence supporting the idea that the field of reasoning should draw inspiration from the Appraisal Theory of Emotion (Moors & Fischer, 2019) in order to account for the dynamics at play during the shift from intuition to deliberation. Such theoretical framework highlights the important role that emotion plays, first to signal the discrepancy between an intuitive output and an individual's goals, and second to motivate the individual to engage in costly deliberative thinking.

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Data availability Raw data can be downloaded from our OSF page: https://doi.org/10.17605/OSF.IO/WB6QE.

Declarations

Competing interests The authors declare no competing interests.

References

Ackerman, R., & Thompson, V. A. (2017). Meta-reasoning: Monitoring and control of thinking and reasoning. *Trends in Cognitive Sciences, 21*(8), 607–617. https://doi.org/10.1016/j.tics.2017.05.004

Alter, A. L. (2013). The benefits of cognitive disfluency. *Current Directions in Psychological Science, 22*(6), 437–442. https://doi.org/10.1177/0963721413498894

Alter, A. L., Oppenheimer, D. M., & Epley, N. (2013). Disfluency prompts analytic thinking—But not always greater accuracy: Response to Thompson et al. (2013). *Cognition, 128*(2), 252–255. https://doi.org/10.1016/j.cognition.2013.01.006

Alter, A. L., Oppenheimer, D. M., Epley, N., & Eyre, R. N. (2007). Overcoming intuition: Metacognitive difficulty activates analytic reasoning. *Journal of Experimental Psychology: General, 136*(4), 569–576. https://doi.org/10.1037/0096-3445.136.4.569

Ashcraft, M. H., & Kirk, E. P. (2001). The relationships among working memory, math anxiety, and performance. *Journal of Experimental Psychology: General, 130*(2), 224–237. https://doi.org/10.1037/0096-3445.130.2.224

Bago, B., & De Neys, W. (2017). Fast logic?: Examining the time course assumption of dual process theory. *Cognition, 158*, 90–109. https://doi.org/10.1016/j.cognition.2016.10.014

Bago, B., & De Neys, W. (2019). The Smart System 1: Evidence for the intuitive nature of correct responding on the bat-and-ball problem. *Thinking & Reasoning, 25*(3), 257–299. https://doi.org/10.1080/13546783.2018.1507949

Bago, B., & De Neys, W. (2020). Advancing the specification of dual process models of higher cognition: A critical test of the hybrid model view. *Thinking & Reasoning, 26*(1), 1–30. https://doi.org/10.1080/13546783.2018.1552194

Berenbaum, H., Bredemeier, K., & Thompson, R. J. (2008). Intolerance of uncertainty: Exploring its dimensionality and associations with need for cognitive closure, psychopathology, and personality. *Journal of Anxiety Disorders, 22*(1), 117–125. https://doi.org/10.1016/j.janxdis.2007.01.004

Berger, A., Mitschke, V., Dignath, D., Eder, A., & Steenbergen, H. (2020). The face of control: Corrugator supercilii tracks aversive conflict signals in the service of adaptive cognitive control. *Psychophysiology*, *57*(4), 1–13. https://doi.org/10.1111/psyp.13524

Białek, M., & De Neys, W. (2016). Conflict detection during moral decision-making: Evidence for deontic reasoners' utilitarian sensitivity. *Journal of Cognitive Psychology, 28*(5), 631–639. https://doi.org/10.1080/20445911.2016.1156118

Bitti, P. E. R., Bonfiglioli, L., Melani, P., Caterina, R., & Garotti, P. (2014). Expression and communication of doubt/uncertainty through facial expression. *Ricerche di Pedagogia e Didattica, 9*(1), 159–177. https://doi.org/10.6092/issn.1970-2221/4296

Blanchette, I. (2014). *Emotion and reasoning*. Psychology Press, Taylor & Francis Group.

Blanchette, I., & Caparos, S. (2013). When emotions improve reasoning: The possible roles of relevance and utility. *Thinking & Reasoning*, *19*(3–4), 399–413. https://doi.org/10.1080/13546783.2013.791642

Blanchette, I., & Caparos, S. (2016). Working memory function is linked to trauma exposure, independently of post-traumatic stress disorder symptoms. *Cognitive Neuropsychiatry*, *21*(6), 494–509. https://doi.org/10.1080/13546805.2016.1236015

Bless, H., Schwarz, N., Clore, G. L., Golisano, V., Rabe, C., & Wölk, M. (1996). Mood and the use of scripts: Does a happy mood really lead to mindlessness? *Journal of Personality and Social Psychology*, *71*(4), 665–679. https://doi.org/10.1037/0022-3514.71.4.665

Bradley, M. M., & Lang, P. J. (1994). Measuring emotion: The self-assessment manikin and the semantic differential. *Journal of Behavior Therapy and Experimental Psychiatry, 25*(1), 49–59. https://doi.org/10.1016/0005-7916(94)90063-9

Cacioppo, J. T., Petty, R. E., Losch, M. E., & Kim, H. S. (1986). Electromyographic activity over facial muscle regions can

differentiate the valence and intensity of affective reactions. *Journal of Personality and Social Psychology, 50*(2), 260–268.
Channon, S., & Baker, J. (1994). Reasoning strategies in depression: Effects of depressed mood on a syllogism task. *Personality and Individual Differences*, *17*, 707–711. https://doi.org/10.1016/0191-8869(94)90148-1
Charbit, L., Boissin, E., Raoelison, M., & Neys, W. D. (2025). Emergence of the smart intuitor: How cognitive ability shapes adolescent reasoning. *Thinking & Reasoning*. https://doi.org/10.1080/13546783.2025.2527672
Clore, G. L., & Huntsinger, J. R. (2007). How emotions inform judgment and regulate thought. *Trends in Cognitive Sciences, 11*(9), 393–399. https://doi.org/10.1016/j.tics.2007.08.005
Coles, N. A., Larsen, J. T., & Lench, H. C. (2019). A meta-analysis of the facial feedback literature: Effects of facial feedback on emotional experience are small and variable. *Psychological Bulletin, 145*, 610–651. https://doi.org/10.1037/bul0000194
Darke, S. (1988). Anxiety and working memory capacity. *Cognition and Emotion*, *2*(2), 145–154. https://doi.org/10.1080/02699938808408071
David, L., Vassena, E., & Bijleveld, E. (2024). The unpleasantness of thinking: A meta-analytic review of the association between mental effort and negative affect. *Psychological Bulletin*. https://doi.org/10.1037/bul0000443
De Neys, W. (2006). Dual processing in reasoning: Two systems but one reasoner. *Psychological Science, 17*(5), 428–433. https://doi.org/10.1111/j.1467-9280.2006.01723.x
De Neys, W. (2012). Bias and conflict a case for logical intuitions. *Perspectives on Psychological Science, 7*, 28–38. https://doi.org/10.1177/1745691611429354
De Neys, W. (2014). Conflict detection, dual processes, and logical intuitions: Some clarifications. *Thinking and Reasoning*. https://doi.org/10.1080/13546783.2013.854725
De Neys, W. (2018). *Dual Process Theory 2.0*. Routledge.
De Neys, W. (2023). Advancing theorizing about fast-and-slow thinking. *Behavioral and Brain Sciences*. https://doi.org/10.1017/S0140525X2200142X
De Neys, W. (2025). Defining deliberation for dual-process models of reasoning. *Nature Reviews Psychology*. https://doi.org/10.1038/s44159-025-00466-6
De Neys, W., & Pennycook, G. (2019). Logic, fast and slow: Advances in dual-process theorizing. *Current Directions in Psychological Science, 28*(5), 503–509. https://doi.org/10.1177/0963721419855658
De Neys, W., Moyens, E., & Vansteenwegen, D. (2010). Feeling we're biased: Autonomic arousal and reasoning conflict. *Cognitive, Affective & Behavioral Neuroscience, 10*(2), 208–216. https://doi.org/10.3758/CABN.10.2.208
De Neys, W., Vartanian, O., & Goel, V. (2008). Smarter than we think: When our brains detect that we are biased. *Psychological Science, 19*(5), 483–489. https://doi.org/10.1111/j.1467-9280.2008.02113.x
Dean, C., & Nielsen, J. (2007). Generalized linear mixed models: A review and some extensions. *Lifetime Data Analysis*, *13*(4), 497–512. https://doi.org/10.1007/s10985-007-9065-x
Derakshan, N., & Eysenck, M. W. (1998). Working memory capacity in high trait-anxious and repressor groups. *Cognition and Emotion, 12*, 697–713. https://doi.org/10.1080/026999398379501
Dewey, J. (1910). *How we think*. D.C. Heath.
Dreisbach, G., & Fischer, R. (2012). Conflicts as aversive signals. *Brain and Cognition*, *78*(2), 94–98. https://doi.org/10.1016/j.bandc.2011.12.003
Dreisbach, G., & Fischer, R. (2015). Conflicts as aversive signals for control adaptation. *Current Directions in Psychological Science*, *24*(4), 255–260. https://doi.org/10.1177/0963721415569569
Dunwoody, P. T., Haarbauer, E., Mahan, R. P., Marino, C., & Tang, C.-C. (2000). Cognitive adaptation and its consequences: A test of cognitive continuum theory. *Journal of Behavioral Decision Making, 13*(1), 35–54. https://doi.org/10.1002/(SICI)1099-0771(200001/03)13:1%253C35::AID-BDM339%253E3.0.CO;2-U
Epstein, S. (1994). Integration of the cognitive and the psychodynamic unconscious. *American Psychologist*, *49*(8), 709–724. https://doi.org/10.1037/0003-066X.49.8.709
Evans, J. S. B. T. (2006). The heuristic-analytic theory of reasoning: Extension and evaluation. *Psychonomic Bulletin & Review, 13*(3), 378–395. https://doi.org/10.3758/BF03193858
Evans, J. S. B. T., & Stanovich, K. E. (2013). Dual-Process Theories of Higher Cognition: Advancing the Debate. *Perspectives on Psychological Science, 8*(3), 223–241. https://doi.org/10.1177/1745691612460685
Fergus, T. A., & Rowatt, W. C. (2014). Intolerance of uncertainty and personality: Experiential permeability is associated with difficulties tolerating uncertainty. *Personality and Individual Differences, 58*, 128–131. https://doi.org/10.1016/j.paid.2013.10.017
Fernandez Cruz, A. L., Arango-Muñoz, S., & Volz, K. G. (2016). Oops, scratch that ! Monitoring one's own errors during mental calculation. *Cognition, 146*, 110–120. https://doi.org/10.1016/j.cognition.2015.09.005
Fernando, A., Sivakumaran, B., & Suganthi, L. (2016). Message involvement and attitude towards green advertisements. *Marketing Intelligence & Planning*. https://doi.org/10.1108/MIP-11-2015-0216
Frederick, S. (2005). Cognitive reflection and decision making. *Journal of Economic Perspectives*, *19*(4), 25–42. https://doi.org/10.1257/089533005775196732
Gangemi, A., Bourgeois-Gironde, S., & Mancini, F. (2015). Feelings of error in reasoning—In search of a phenomenon. *Thinking & Reasoning*, *21*(4), 383–396. https://doi.org/10.1080/13546783.2014.980755
Gawronski, B., & Strack, F. (2012). *Cognitive consistency : A fundamental principle in social cognition* (pp. xiii–494). Guilford Press.
Grayot, J. D., Beck, L., & Heijmeskamp, T. (2024). Dual process theory and the challenges of functional individuation. *Phenomenology and the Cognitive Sciences*. https://doi.org/10.1007/s11097-024-10000-3
Hajcak, G. (2012). What we've learned from mistakes: Insights from error-related brain activity. *Current Directions in Psychological Science, 21*(2), 101–106. https://doi.org/10.1177/0963721412436809
Hajcak, G., & Foti, D. (2008). Errors are aversive: Defensive motivation and the error-related negativity. *Psychological Science, 19*(2), 103–108. https://doi.org/10.1111/j.1467-9280.2008.02053.x
James, W. (1890). *Principles of psychology*. Dover.
Kahneman, D. (2003). A perspective on judgment and choice: Mapping bounded rationality. *American Psychologist*, *58*(9), 697–720. https://doi.org/10.1037/0003-066X.58.9.697
Kahneman, D. (2011). *Thinking, fast and slow* (1st ed). Farrar, Straus and Giroux.
Kensinger, E. A., & Corkin, S. (2003). Effect of negative emotional content on working memory and long-term memory. *Emotion, 3*, 378–393. https://doi.org/10.1037/1528-3542.3.4.378
Keren, G., & Schul, Y. (2009). Two is not always better than one: A critical evaluation of two-system theories. *Perspectives on Psychological Science*, *4*(6), 533–550. https://doi.org/10.1111/j.1745-6924.2009.01164.x
Larsen, R. J., Kasimatis, M., & Frey, K. (1992). Facilitating the Furrowed Brow : An unobtrusive test of the facial feedback hypothesis applied to unpleasant affect. *Cognition and Emotion, 6*(5), 321–338. https://doi.org/10.1080/02699939208409689

Lieder, F., & Griffiths, T. L. (2020). Resource-rational analysis: Understanding human cognition as the optimal use of limited computational resources. *Behavioral and Brain Sciences*, *43*, e1. https://doi.org/10.1017/S0140525X1900061X

Lindström, B. R., Mattsson-Mårn, I. B., Golkar, A., & Olsson, A. (2013). In your face: Risk of punishment enhances cognitive control and Error-Related activity in the corrugator supercilii muscle. *PLOS ONE*, *8*(6), e65692. https://doi.org/10.1371/journal.pone.0065692

MacKuen, M., Wolak, J., Keele, L., & Marcus, G. (2010). Civic engagements: Resolute partisanship or reflective deliberation. *American Journal of Political Science*, *54*, 440–458. https://doi.org/10.1111/j.1540-5907.2010.00440.x

Marzoli, D., Custodero, M., Pagliara, A., & Tommasi, L. (2013). Sun-induced frowning fosters aggressive feelings. *Cognition and Emotion*, *27*(8), 1513–1521. https://doi.org/10.1080/02699931.2013.801338

Melnikoff, D. E., & Bargh, J. A. (2018). The mythical number two. *Trends in Cognitive Sciences, 22*(4), 280–293. https://doi.org/10.1016/j.tics.2018.02.001

Mendes, W. B., Blascovich, J., Hunter, S. B., Lickel, B., & Jost, J. T. (2007). Threatened by the unexpected: Physiological responses during social interactions with expectancy-violating partners. *Journal of Personality and Social Psychology, 92*(4), 698–716. https://doi.org/10.1037/0022-3514.92.4.698

Moors, A., & Fischer, M. (2019). Demystifying the role of emotion in behaviour: Toward a goal-directed account. *Cognition and Emotion*, *33*(1), 94–100. https://doi.org/10.1080/02699931.2018.1510381

Moors, A., Boddez, Y., & De Houwer, J. (2017). The power of goal-directed processes in the causation of emotional and other actions. *Emotion Review, 9*(4), 310–318. https://doi.org/10.1177/1754073916669595

Moors, A., Ellsworth, P. C., Scherer, K. R., & Frijda, N. H. (2013). Appraisal theories of emotion: State of the art and future development. *Emotion Review, 5*(2), 119–124. https://doi.org/10.1177/1754073912468165

Moran, T. P. (2016). Anxiety and working memory capacity: A meta-analysis and narrative review. *Psychological Bulletin, 142*(8), 831–864. https://doi.org/10.1037/bul0000051

Morsanyi, K., & Handley, S. J. (2012). Logic feels so good—I like it ! Evidence for intuitive detection of logicality in syllogistic reasoning. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 38*(3), 596–616. https://doi.org/10.1037/a0026099

Pennycook, G., Fugelsang, J. A., & Koehler, D. J. (2015). What makes Us think? A three-stage dual-process model of analytic engagement. *Cognitive Psychology*, *80*, 34–72. https://doi.org/10.1016/j.cogpsych.2015.05.001

Pope, L. K., & Smith, C. A. (1994). On the distinct meanings of smiles and frowns. *Cognition & Emotion, 8*(1), 65–72. https://doi.org/10.1080/02699939408408929

Proulx, T., Inzlicht, M., & Harmon-Jones, E. (2012). Understanding all inconsistency compensation as a palliative response to violated expectations. *Trends in Cognitive Sciences, 16*(5), 285–291. https://doi.org/10.1016/j.tics.2012.04.002

Purcell, Z. A., Roberts, A. J., Handley, S. J., & Howarth, S. (2023). Eye Movements, pupil Dilation, and conflict detection in reasoning: Exploring the evidence for intuitive logic. *Cognitive Science*, *47*(6), e13293. https://doi.org/10.1111/cogs.13293

Raoelison, M., Boissin, E., Borst, G., & De Neys, W. (2021). From slow to fast logic : The development of logical intuitions. *Thinking & Reasoning, 27*(4), 599–622. https://doi.org/10.1080/13546783.2021.1885488

Raoelison, M., Thompson, V. A., & De Neys, W. (2020). The smart intuitor: Cognitive capacity predicts intuitive rather than deliberate thinking. *Cognition*, *204*, 104381. https://doi.org/10.1016/j.cognition.2020.104381

Scherer, K. R., & Ellgring, H. (2007). Are facial expressions of emotion produced by categorical affect programs or dynamically driven by appraisal? *Emotion, 7*(1), 113–130. https://doi.org/10.1037/1528-3542.7.1.113

Scherer, K. R., & Moors, A. (2019). The emotion process: Event appraisal and component differentiation. *Annual Review of Psychology*, *70*(1), 719–745. https://doi.org/10.1146/annurev-psych-122216-011854

Schwarz, N. (2012). Feelings-as-Information theory. In P. Van Lange, A. Kruglanski, & E. Higgins (Eds.), *Handbook of theories of social psychology : Volume 1* (pp. 289–308). SAGE Publications Ltd. https://doi.org/10.4135/9781446249215.n15

Shenhav, A. (2024). The affective gradient hypothesis: An affect-centered account of motivated behavior. *Trends in Cognitive Sciences*, *28*(12), 1089–1104. https://doi.org/10.1016/j.tics.2024.08.003

Shenhav, A., Prater Fahey, M., & Grahek, I. (2021). Decomposing the motivation to exert mental effort. *Current Directions in Psychological Science*, *30*(4), 307–314. https://doi.org/10.1177/09637214211009510

Sloman, S. A. (1996). The empirical case for two systems of reasoning. *Psychological Bulletin*, *119*(1), 3–22. https://doi.org/10.1037/0033-2909.119.1.3

Smith, C. A. (1989). Dimensions of appraisal and physiological response in emotion. *Journal of Personality and Social Psychology*, *56*, 339–353. https://doi.org/10.1037/0022-3514.56.3.339

Šrol, J., & De Neys, W. (2021). Predicting individual differences in conflict detection and bias susceptibility during reasoning. *Thinking & Reasoning*, *27*(1), 38–68. https://doi.org/10.1080/13546783.2019.1708793

Stanovich, K. E. (2009). Distinguishing the reflective, algorithmic, and autonomous minds: Is it time for a tri-process theory? In J. St. B. T. Evans & K. Frankish (Éds.), *In two minds: Dual processes and beyond* (pp. 55–88). Oxford University Press. https://doi.org/10.1093/acprof:oso/9780199230167.003.0003

Stanovich, K. E. (2018). Miserliness in human cognition: The interaction of detection, override and Mindware. *Thinking & Reasoning*, *24*(4), 423–444. https://doi.org/10.1080/13546783.2018.1459314

Stanovich, K. E., & West, R. F. (2000). Individual differences in reasoning: Implications for the rationality debate? *Behavioral and Brain Sciences*, *23*(5), 645–665. https://doi.org/10.1017/S0140525X00003435

Stepper, S., & Strack, F. (1993). Proprioceptive determinants of emotional and nonemotional feelings. *Journal of Personality and Social Psychology*, *64*(2), 211–220.

Stroup, W. W., Ptukhina, M., & Garai, J. (2024). *Generalized linear mixed models: Modern concepts, methods and applications* (2e éd.). Chapman and Hall/CRC. https://doi.org/10.1201/9780429092060

Thompson, V. A. (2009). Dual-process theories: A metacognitive perspective. In J. St. B. T. Evans & K. Frankish (Éds.), *In two minds: Dual processes and beyond* (pp. 171–196). Oxford University Press. https://doi.org/10.1093/acprof:oso/9780199230167.003.0008

Thompson, V. A., & Johnson, S. (2014). Conflict, metacognition, and analytic thinking. *Thinking & Reasoning, 20*, 215–244. https://doi.org/10.1080/13546783.2013.869763

Thompson, V. A., & Morsanyi, K. (2012). Analytic thinking : Do you feel like it? *Mind & Society, 11*(1), 93–105. https://doi.org/10.1007/s11299-012-0100-6

Thompson, V. A., Pennycook, G., Trippas, D., & Evans, J. S. B. T. (2018). Do smart people have better intuitions? *Journal of Experimental Psychology: General, 147*(7), 945–961. https://doi.org/10.1037/xge0000457

Thompson, V. A., Prowse Turner, J. A., & Pennycook, G. (2011). Intuition, reason, and metacognition. *Cognitive Psychology, 63*(3), 107–140. https://doi.org/10.1016/j.cogpsych.2011.06.001

Thompson, V. A., Turner, J. A. P., Pennycook, G., Ball, L. J., Brack, H., Ophir, Y., & Ackerman, R. (2013). The role of answer fluency and perceptual fluency as metacognitive cues for initiating analytic thinking. *Cognition, 128*(2), 237–251. https://doi.org/10.1016/j.cognition.2012.09.012

Topolinski, S., Likowski, K. U., Weyers, P., & Strack, F. (2009). The face of fluency: Semantic coherence automatically elicits a specific pattern of facial muscle reactions. *Cognition and Emotion*, *23*(2), 260–271. https://doi.org/10.1080/02699930801994112

Tourangeau, R., & Ellsworth, P. C. (1979). The role of facial response in the experience of emotion. *Journal of Personality and Social Psychology*, *37*(9), 1519–1531. https://doi.org/10.1037/0022-3514.37.9.1519

Trippas, D., Handley, S. J., Verde, M. F., & Morsanyi, K. (2016). Logic brightens my day: Evidence for implicit sensitivity to logical validity. *Journal of Experimental Psychology. Learning, Memory, and Cognition, 42*(9), 1448–1457. https://doi.org/10.1037/xlm0000248

Tversky, A., & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *Science*, *185*(4157), 1124–1131. https://doi.org/10.1126/science.185.4157.1124

Valentino, N. A., Hutchings, V. L., Banks, A. J., & Davis, A. K. (2008). Is a worried citizen a good citizen? Emotions, political information seeking, and learning via the Internet. *Political Psychology, 29*(2), 247–273.

Zizak, D. M., & Reber, A. S. (2004). Implicit preferences: The role(s) of familiarity in the structural mere exposure effect. *Consciousness and Cognition, 13*, 336–362. https://doi.org/10.1016/j.concog.2003.12.003

Zsido, A. N., Teleki, S. A., Csokasi, K., Rozsa, S., & Bandi, S. A. (2020). Development of the short version of the Spielberger state—Trait anxiety inventory. *Psychiatry Research*, *291*, 113223. https://doi.org/10.1016/j.psychres.2020.113223

Cortial, C., Prado, J., & Caparos, S. (2025a).Reconceptualizing MetacognitiveExperience in Dual-Process Reasoning: The Role of Emotion in Triggering Deliberation. Cognitive Science, 49(7), e70084. https://doi.org/10.1111/cogs.70084

Cortial,C., Prado, J., & Caparos, S. (2025b). Reasoning does hurt: Deliberation is associated with heightened levels ofdoubt. Thinking & Reasoning, (0), 1-33. https://www.tandfonline.com/doi/full/10.1080/13546783.2025.2531067?src=exp-la

Cortial c., Prado, J. & Caparos S., (in review). Does reasoning hurt? The role of negative emotions in triggering deliberative reasoning

Boissin, E., Caparos, S., & De Neys, W. (2023). No easy fix for belief bias during syllogistic reasoning? *Journal of Cognitive Psychology*, *35*(4), 401-421. https://doi.org/10.1080/20445911.2023.2181734

Preacher, K. J., & Hayes, A. F. (2008). Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. *Behavior Research Methods*, *40*(3), 879-891. https://doi.org/10.3758/BRM.40.3.879

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