

Does reasoning hurt?

The role of negative emotions in triggering deliberative reasoning.

A b s t r a c t

Human thinking has long been posited to involve two different cognitive processes, also known as intuition and deliberation. While deliberation is effortful and cognitively costly, intuition is effortless. A central issue for reasoning theories is to account for the trigger of deliberation. Compelling theories explain the trigger of deliberative processes but have difficulties integrating the empirical and theoretical findings linking emotion to cognition. Here we propose to look at the issue of deliberation in the light of emotions. Inspired by philosophers of pragmatism, we postulate the existence of a negative valence emotion called doubt, which is associated with encountering an inconsistent or indeterminate situation which troubles the normal interaction between an individual and their environment. Those situations can generate varying degrees of doubt that reasoners attempt to eliminate with the use of deliberation. We believe that this addition to the models of reasoning helps explain current findings regarding how deliberative reasoning is triggered, our motivation to use deliberation, as well as the tendency to prefer intuition.

In 1798, some European explorers discovered a particularly strange animal in newly colonized Australia. Endowed with a beak and fur, webbed feet and laying eggs, it was swimming, walking and it was poisonous. There is still something to be surprised about when we face a platypus today. One important aspect of its discovery is that the English scientists who received the first specimens believed it was a hoax. They even fashioned theories allowing them to exclude the possible existence of such a thing. For some, it made much more sense that the creature was the work of an Asian taxidermist who had sewed a duck's beak onto a quadruped body. For others, however, it was necessary to reframe existing models so that they could accommodate oviparous mammals. The latter scientists concluded that this animal must belong to a new category: monotremes (see Moyal, 2010, for details about the platypus' history). As this introductory example illustrates, giving meaning to an unexplained event often requires the formulation of a hypothesis. How is that process triggered? In other words, why do humans engage into reflection in the first place?

While in recent years, experimental psychologists have increasingly explored this question (De Neys, 2023; De Neys & Glumicic, 2008; Pennycook et al., 2015; Thompson et al., 2011), this issue has long been studied by pioneer philosophers of pragmatism, including William James, Charles S. Peirce or John Dewey. The contribution of pragmatism to the problem of the origin of reflection has been somewhat obscured in contemporary psychology. However, we believe that the field can draw from pragmatist models elaborated a century ago because it offers an interesting answer to the question of why humans engage into reflection, which is known as 'deliberation' or 'deliberative reasoning' in the field of psychology.

Philosophers of pragmatism have argued that the reason why humans engage in deliberative reasoning in the first place is because they experience *doubt*, "an uneasy and dissatisfied state from which we struggle to free ourselves and pass into the state of belief" (Peirce, 1877, p. 4). Critically, doubt has been primarily acknowledged by pragmatists as something we *feel*. In other words, it is a "feeling of a discrepancy, or difficulty" [...]. In cases of striking novelty or unusual perplexity, the difficulty [...] is likely to present itself at first as a shock, as emotional disturbance, as a more or less vague feeling of the unexpected, of something queer, strange, funny, or disconcerting." (Dewey, 1910, p. 74).

Psychologists have long postulated that human reasoning, which allows us to make sense of the situations we find ourselves in, involves two distinct cognitive processes. These are often referred to as intuition and deliberation. While deliberation is a controlled and conscious process which engages a deep, analytical type of reasoning and is effortful and cognitively costly, intuition is automatic and exclusively relies on effortless processes (Epstein, 1994; Evans, 2006; James, 1890; Kahneman, 2003; Sloman, 1996; Stanovich & West, 2000). A central issue for reasoning theories is to account for processes that may trigger deliberation, which they tend to do by focusing mainly on processes that are cognitive in nature (De Neys, 2023; Thompson et al., 2011). Yet, drawing from philosophers of pragmatism, we believe that current psychological theories may not take sufficient account of the observations that emotional processes are involved in switching from intuition to deliberation. At the very least, we argue here that emotional causes for deliberation should be considered. Our goal here is to better specify the process that underlies the switch from fast to slow thinking (Bago & De Neys, 2020; De Neys, 2023; De Neys & Bonnefon, 2013; De Neys & Glumicic, 2008), and to propose that a negative-valence emotion, doubt, is at the heart of this process.

Deliberative reasoning is extremely expensive in mental resources compared to intuitive reasoning (Evans & Stanovich, 2013). Therefore, a fundamental question is why the cognitive system would appeal to deliberative reasoning at all. One response has been to argue that there are situations in which our mindware (Perkins, 1995; Stanovich et al., 2011) is not able to solve the problem at hand through automatic intuitions and, when this happens, deliberative reasoning is activated. For example, the oviparous mammal mentioned above did not fit into any previously encountered box, leading to a failure of intuitive reasoning to explain it. This made it necessary for 18th-century scientists to deliberate in order to explain its existence. However, why should one care at all when intuitive reasoning fails to provide a satisfying solution? Why not keep going irrespective of whether one has, or has not, successfully solved a problem? Given the cognitive system's propensity for miserliness (Stanovich, 2018; Stanovich et al., 2011) the evidence that the mental effort involved in thinking is unpleasant (David et al., 2024), it appears necessary to justify why it would choose to engage costly resources, instead of just 'giving up' on explaining a problematic situation, and simply go on with the flow of intuitions.

To address the question of why we engage in deliberative reasoning, we first describe what prominent current models of reasoning have to say about this question. Second, we explain how the addition of a pivotal component to current models, namely, doubt, offers new insight into some of the blind spots of these models. Third, we discuss the nature of doubt and the empirical support for its pivotal role in reasoning.

1. Monitoring of poor intuitions

As mentioned above, current models of reasoning propose that deliberative reasoning is activated when intuitive reasoning has failed (Evans & Stanovich, 2013; Kahneman, 2011). This idea relies on two important assumptions, namely, (1) that intuition can fail, and (2) that such failure can be detected.

As it may have been the case in early dual-process theories, intuition failures do not refer here to the logical invalidity of the intuition (Kahneman, 2011), but rather to its weak “fierce” or “assertiveness”. Several kinds of those “poor intuitions” have been described in the literature. An intuition can be considered a failure, or poor, when it does not appear in a smooth way, *i.e.*, intuitions that take a long time to emerge (Ackerman & Thompson, 2017; Thompson et al., 2013), or that do not emerge at all. Alternatively, another type of failure is when several inconsistent intuitions arise simultaneously and compete for the response, a phenomenon which has been described as a cognitive conflict (De Neys, 2012, 2014; De Neys et al., 2010; De Neys & Pennycook, 2019). The latter conflicting intuitions promote several incompatible paths of action (each having different strengths) that cannot be executed at the same time. The strength of each path of action has been equated to the processing fluidity or the speed of the intuition (Bago & De Neys, 2020), as well as to the automation level associated with the intuition (*i.e.*, how easy it is to bring out this intuition, De Neys, 2023; Stanovich, 2018). These intuitions can be qualified as poor because they are somehow unsatisfying. They do not offer a direct, simple, and assertive response to a current problem. Current models thus propose that such unsatisfying intuitions lead to the activation of deliberative reasoning (De Neys, 2023; Pennycook et al., 2015; Thompson et al., 2011).

The quality of an intuition has often been proposed to be assessed through second order judgments. For example, Thompson et al. (2011) have described a metacognitive experience called

“Feeling Of Rightness” (FOR), which results from a self-appraising of our confidence in our answer’s rightness. Fluent, familiar and non-conflictual intuitions would generate a strong FOR (Thompson et al., 2013, 2018; Thompson & Johnson, 2014), meaning that deliberation is unnecessary. A weak FOR means that deliberation has to be activated to fight against the cognitive disfluency. Another terminology has been used in the literature to describe FOR: Response Uncertainty (RU; De Neys, 2023). Although the direction of RU is opposite to the direction of FOR (i.e., RU decreases when FOR increases), both FOR and RU are second-order judgments that would assess the quality of an intuition.

A strategy to demonstrate the existence of such second order judgements about our intuitions involves so-called incongruent reasoning problems, which can generate two simultaneous intuitions, one which is logically valid (i.e., an intuition that is compatible with logico-mathematical principles) and one which is not (i.e., a heuristic-based intuition that is incompatible with logico-mathematical principles). Consider for example the deduction: "All trees have roots. Oaks have roots. Therefore, oaks are trees." Although at first glance the argument might seem logically valid, it is in reality a fallacious form of reasoning known as affirming the consequent. Indeed, not only trees have roots (e.g. Hair also has roots) and the conclusion “oaks are trees” therefore does not logically follow from the premises (i.e., Oaks could be hair, and not trees). Here, there is a conflict between a conclusion that seems believable to us and the logic of the argument, which is invalid (Evans et al., 1983). Such incongruent problems have been shown to promote a cognitive conflict, where two incompatible intuitions emerge in parallel (De Neys et al., 2008, 2010). With such problems, although people often do not succeed in thwarting the erroneous (heuristic-based) intuition, they tend to report less confidence (or more uncertainty) in their response (compared to congruent problems), showing that something has been detected (even when it has not led to a correction of the erroneous response; Bago & De Neys, 2019; Botvinick, 2007; De Neys, 2012; De Neys et al., 2008, 2010; De Neys & Glumicic, 2008; De Neys, 2023; De Neys & Pennycook, 2019; Pennycook et al., 2015).

Irrespective of the name they employ (i.e., FOR or RU), current models always assume that the activation of deliberation depends on the strength of the metacognitive assessment (i.e., deliberation is more likely to be engaged if FOR is low or if RU is high (De Neys, 2023; Thompson et al., 2011). In the case of very weak or absent intuitions, the system is blocked and requires the activation of

deliberation to progress. In the case of conflicting intuitions, the conflict magnitude would depend on the balance between the strength of each intuition. When two intuitions have equivalent strength, then a strong conflict arises in the system, which must be resolved through the activation of deliberation. If the conflict is unbalanced (i.e., one intuition is substantially stronger than the other), deliberation becomes less necessary and therefore less likely to be activated (De Neys & Pennycook, 2019). In sum, the general idea of current models can be described as follows: the emergence of a poor intuition leads to a metacognitive appraisal of low rightness/high wrongness, which – if it reaches a threshold – activates deliberative reasoning (Pennycook et al., 2015).

Critically, however, the precise nature of the metacognitive appraisal remains conceptually imprecise. On the one hand, the terms RU or FOR appear to instantiate a process which is primarily cognitive in nature: a quantitative appraisal of the strength of intuitions. On the other hand, these terms also imply that the metacognitive appraisal is something that one experiences. In all the models described above, the metacognitive experiences have been described as implicit or unconscious. Reasoners know that something is wrong, but they cannot quite put their finger on what. This underlying idea is captured by the usage of terms such as “gut feeling” (De Neys et al., 2010), “implicit” knowledge (Bago & De Neys, 2020), “experienced uncertainty” (De Neys, 2023), “subjective experience” (Ackerman & Thompson, 2017), “metacognitive experience” (Thompson et al., 2011), “sense of correctness” (Thompson et al., 2011), or the very term “*feeling*” (of rightness) (Thompson et al., 2011). In sum, current models all seem to ascribe an embodied dimension to the unsatisfying intuitions they describe. To our knowledge, however, they leave that dimension mostly underspecified.

In the present paper, we wish to argue that, by exploring such ‘embodied’ dimension, one may find the answer as to why the cognitive system chooses to engage into cognitively costly deliberation, instead of just giving up on solving the problem. In order to do so, we aim to bring together current models of reasoning and the large body of literature linking cognition, embodiment, and emotion (e.g. Bechara et al., 1997; Blanchette & Richards, 2010; Clore & Huntsinger, 2007; Damasio, 1994, 1996; Inzlicht et al., 2015).

2. The emotional dimension of poor intuitions

Current dual-system models of reasoning explain the appraisal of intuitions by referring to self-monitoring processes. Whether it is System 1 (intuition) monitoring itself and determining the level of RU (De Neys, 2023), System 2 (deliberation) monitoring System 1 (Kahneman, 2011; Stanovich & West, 2000), or a potential System 3 (Evans, 2009), the process is typically described in terms of computing, calculating or measuring the outcome of intuitive reasoning. We would like to raise the idea that this appraisal process involves an emotional dimension, which has been much overlooked. This is supported both by theoretical considerations and by empirical findings.

From a theoretical perspective, the fluency (e.g., familiarity) associated with strong intuitions is generally associated with positive affect (i.e., pleasantness; Thompson, 2009; Thompson et al., 2011; Zizak & Reber, 2004). In contrast, the cognitive system appraises cognitive disfluency, which is the source of poor intuitions, as a harmful phenomenon (Dreisbach & Fischer, 2012, 2015; Proulx et al., 2012). According to the Appraisal Theory, an emotion is a reaction to the appraisal of the valence (positive or negative) of stimuli (e.g., objects or situations) in the external or the internal environment (Frijda, 1986; Lazarus et al., 1970; Parkinson & Manstead, 1992; Reisenzein, 2001; Roseman, 1984; Smith, 1989; Smith & Lazarus, 1990). A stimulus is appraised as positive (or attractive) if it is congruent with the goals of the organism, and negative (or repulsive) if it is incongruent with such goals. In the context of reasoning, that framework suggests that weak or conflicting intuitions may be appraised as a threat because they could signal a failure to satisfyingly solve a problem. As such, poor intuitions may elicit an emotional response, and the latter could be of a negative valence.

Previous empirical findings suggest that conflicting intuitions may indeed elicit a negative emotional response. Well established results show that experienced conflict increases arousal in image coding (Kuzinas et al., 2016), the Simon task (Van Steenbergen & Band, 2013), the Stroop task (Hoshikawa & Yamamoto, 1997), speech processing (Zhang et al., 2010) or familiarity judgments (Morris et al., 2008). Moreover, this association has been observed in reasoning tasks using measures of pupil dilation (Purcell et al., 2023) or electrodermal activity (De Neys et al., 2010), which are both markers of an emotional experience (Bradley et al., 2008; Pace-Schott et al., 2019).

Additional evidence for the emotional nature of the organism's reaction to poor intuitions comes from measures of brain activity. Specifically, reasoning about incongruent (conflicting) logical problems (base rate problems; Tversky & Kahneman, 1973) has been associated with the Anterior midCingulate Cortex (AmCC) and dorsal Anterior Cingulate Cortex (dACC) activity (De Neys et al., 2008). These regions have also been found to be activated when participants have to inhibit beliefs in order to respond logically to a problem (Goel et al., 2000; Goel & Dolan, 2003), as well as when they have to overcome perceptual mismatches during a reasoning task (Prado & Noveck, 2007). The anterior cingulate cortex (ACC) is a relatively large brain region that is traditionally divided into a dorsal cognitive division and a rostro-ventral affective division (Bush et al., 2000). Notably, the ventral ACC has typically been associated with negative valence emotions such as anxiety, sadness (Drevets & Raichle, 1998), or pain (Rainville, 2002). This region, which plays a role in learning how to avoid aversive events (Kim et al., 2006), has been shown to be involved in behaviors motivated by aversion to negative emotions (Shackman et al., 2011). For example, it has been hypothesized "that the core function common to negative affect, pain, and cognitive control [all three managed by the AmCC] is the need to determine an optimal course of action in the face of uncertainty, that is, to exert control." (Shackman et al., 2011, p. 8). In line with this hypothesis, lesions of this brain area hinder the accurate recognition of facial expressions linked to negative emotions and they impair cognitive control (measured using a Stroop task; Tolomeo et al., 2016). In sum, faced with an ambiguous situation, such as during a cognitive conflict, the ACC would be activated (De Neys et al., 2008). Though there is no one-to-one correspondence between brain areas and cognitive or affective processes, this is consistent with the idea that ambiguous situations trigger an emotional reaction. We propose that strong RU or weak FOR are different names for an emotional experience, that we label using the umbrella term 'doubt'. In the following section, we explore the nature of doubt and how the empirical literature on emotion and cognition currently supports the existence of this 'switch' emotional state, postulated to be the trigger of deliberative reasoning.

3. The emotional nature of doubt

Imagine coming home after a long day of work only to find your friends suddenly jumping out from behind the furniture and shouting "happy birthday!" This unexpected event would interrupt the

normal course of your actions and puzzle you. To restore continuity, you may try to connect today's date with this unexpected fact. You may feel a sense of surprise, which will be quickly resolved if today really is your birthday. However, if the same scenario were to happen three months later with unfamiliar people, you would likely experience deep confusion. You might have multiple intuitions to explain the situation (perhaps "they have the wrong day or apartment" or "I am being robbed in a sadistic manner"). You may even experience a sudden surge in state anxiety, until someone provides an answer ("it is a birthday surprise for your roommate").

The emotional dimension of doubt, which is the focus of the present paper, can echo different concepts in the literature. In fact, several different emotional states may capture the concept of doubt, namely, the states of surprise, confusion, or anxiety. While all these emotions involve a feeling of apprehension, they differ in terms of their timescale. Surprise is a short-lived emotion which rapidly finds resolution (Ekman, 1982). Confusion is a long-lived emotion which takes more time to resolve. State anxiety is an emotion which may not find an easy resolution at all (Miceli & Castelfranchi, 2005). If these affective states really do belong to the same broad category of doubt, they should share similar general characteristics. Specifically, they should (1) arise from an indeterminate situation, *i.e.* when our interaction with the environment is no longer automatic and straightforward, (2) have a negative valence, and (3) trigger deliberative reasoning. We address the empirical support for these assertions in the sections below.

3.1. Short-lived doubt: Surprise

One major characteristic of surprise is that it is a fleeting emotional state, with a quick resolution: puzzlement is rapidly replaced by comprehension. In this sense, surprise should not be confused with the impression of novelty. It is possible to have an impression of facing something new without being disturbed by it. Imagine for example going to a new movie theater. Even if the location, the entrance and the rest of the environment are indeed new, the experience as such is not surprising if nothing contradicts our predictions (*i.e.* of what we expect to encounter in a movie theater). In fact, surprise is an emotion that arises in response to a situation where a strong contrast exists between expectation and reality (Teigen & Keren, 2003), in other words, when a new stimulus (*i.e.*, a change) is schema-

discrepant (Meyer et al., 1997). It is thus believed to arise in response to the challenge of explaining unexpected events (Foster & Keane, 2015) or reconciling current experience with prior expectations (Keane & Maguire, 2006; Pezzo, 2003). These challenges can be attributed to intuition's failure in retrieving appropriate intuitions necessary for the continuation of normal action in such situations (Kahneman & Miller, 1986). Thus, the experience of surprise can be viewed as a direct consequence of unsatisfying intuitions.

Given that discontinuity is unpleasant (Hajcak, 2012; Hajcak & Foti, 2008; Topolinski et al., 2009), that surprise is associated with the interruption of the expected course of actions (Horstmann, 2006), and that people generally prefer predictability over uncertainty (Gawronski & Strack, 2012; Mendes et al., 2007; Proulx et al., 2012), surprise can be safely inferred to have a negative valence¹. Thus, considering the various lines of evidence discussed above and the findings from several studies (Noordewier et al., 2016; Noordewier & Breugelmans, 2013; Topolinski & Strack, 2015), we suggest, albeit cautiously, that surprise is generally associated with a negative valence.

There is also compelling evidence for the idea that surprise motivates individuals to deliberate. For example, surprise has been argued to motivate individuals to transition from a routine state to a more analytical and thoughtful state (Strack & Deutsch, 2004). It has also been suggested that surprise prompts individuals to engage their attention, to make more expensive cognitive efforts, and/or to use deeper processing strategies, in order to make sense of an unexpected situation (Meyer et al., 1991; Muis et al., 2015; Pezzo, 2003; Topolinski & Strack, 2015). Finally, surprise has been described as cognitive tuning that promotes the transition from intuitive reasoning to deliberation (Bless, 2007; Deutsch & Strack, 2008; Schwarz, 2002).

One study has explored the impact of surprise on the feeling of difficulty and response time in numerical problems (Touroutoglou & Efklides, 2010). Results indicated a positive correlation between surprise and feeling of difficulty, which in turn was positively correlated with response times. Given that the time it takes to answer a problem is a proxy for the engagement of deliberation (De Neys, 2006),

¹ Note that surprise has also been proposed to be a positive-valence emotion (Fontaine et al., 2007; Valenzuela et al., 2010) or a neutral one (Russell, 2003). However, given that surprise is rapidly resolved and short-lived, it can be confounded with the emotion that replaces it (e.g., relief or satisfaction; see Ekman, 1982; Noordewier & Breugelmans, 2013).

these data support the idea that surprise favors deliberation. In sum, surprise may be both a weak form of doubt and a negative emotional state that signals unsatisfying intuitions and trigger deliberation.

3.2. Long-lived doubt: Confusion

Confusion “arises out of information-oriented appraisals of the extent to which incoming information aligns with existing knowledge structures and whether there are inconsistencies and other disfluencies in the information stream.” (D’Mello et al., 2014, p. 154). At the heart of this definition is the idea that confusion is a reaction to a problem in the continuity of our interaction with the environment. It differs from surprise in that it is not fleeting and is longer-lasting, though surprise can also lead to confusion (D’Mello & Graesser, 2012; D’Mello & Graesser, 2014; Loewenstein, 1994; Vogl et al., 2019).

An interesting feature of confusion is that it is characterised by specific facial expressions. These have notably been explored in studies that focused on the activity of the Corrugator Supercilii muscle, which causes a frown (Bitti et al., 2014; Durso et al., 2012). Through a detailed analysis using the Facial Action Coding System (FACS) classification developed by Ekman and Friesen (1978), Bitti et al. (2014) found that a sentence such as “I am not certain to know it” is associated with facial expressions that involve the raising of the inner and outer brows. A sentence such as “I do not know, but I can try to retrieve this information...” is also associated with a lowering of the brows and a tightening of the eyelids (Bitti et al., 2014). Given that frowning, through the activation of the corrugator, is linked to 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), it is likely that confusion is a negative-valence aversive emotion (Hussain et al., 2011; Kool et al., 2010). Moreover, as Darwin already suggested (1872), furrowing one's brow is also associated with a form of laborious thought provoked by encountering an obstacle, something complex, or something unpleasant. This suggests that the use of a same facial expression may be a sign of cognitive effort, encountering obstacles, deliberation, confusion, and negative feelings, which also suggests that these are related.

Confusion is a shared emotion that can be readily identified. This is notably suggested by a study in which students were asked to observe and note, over the course of their normal life on the campus, the situations in which different facial expressions occur in various daily contexts. Confusion was the most commonly reported emotion (14% of the observations, in joint first place with happiness; Rozin & Cohen, 2003). Importantly, the study identified five main causes for confusion. While four of them were related to cognitive effort (and thus, potentially, to the engagement of deliberation), one was related to the experiences of incongruency (see *Table 2*). These findings support the notion that confusion is associated with the engagement of deliberation.

Table 2.

Percentage distribution of confusion observations across different situational categories.

Categories	Percentage of confusion occurrences
	(rounded)
After a question	35.7%
Doing homework/learning	27.3%
In class/listening to a teacher	19.1%
Something unexpected/weird	13.1%
Make a decision/plan/think	4.8%

Note. Adapted from (Rozin et Cohen, 2003)

Finally, a replication of Alter et al.'s study (2007) showed that frowning when solving a problem increases thinking time and the engagement of processing resources (Thompson et al., 2013). While these findings may require further investigation, they are consistent with other studies suggesting that frowning is linked with deliberation (Gagnon et al., 2021). It is also important to note that confusion also appears to be beneficial for learning (Craig et al., 2004; S. D'Mello et al., 2014; vanlehn et al., 2003; Vogl et al., 2019, 2020). It supports the idea that confusion motivates information seeking in order to get out of the confusion state. In mathematics classes, curiosity (caused by a solvable confusing situation) and confusion may be beneficial for learning through deeper processing and the resolution of cognitive conflict (Kapur, 2008; Kapur & Kinzer, 2009). In summary, confusion, which is a negative affect, arises in situations of troubled interactions with the environment and promotes reflection.

3.3. Unresolved doubt: Anxiety

State anxiety is an emotion characterized by physiological arousal and the subjective feelings of apprehension, dread, and tension (Spielberger, 1966). Unlike fear, “The object of anxiety is not a danger, but an event which implies a possible and uncertain danger.” (Miceli & Castelfranchi, 2005, p. 294). Anxiety triggers a need for “epistemic control”, namely, the need to get out of uncertainty and to make our environment predictable again (Miceli & Castelfranchi, 2005). At the heart of anxiety lies uncertainty, namely, not knowing whether a situation will bring a positive or a negative outcome (Barlow, 2000; Miceli & Castelfranchi, 2014). Because anxiety is triggered by uncertainty, like surprise and confusion, it is the direct result of indeterminate situations. In this respect, it is a form of over-doubting, because one of the characteristics of anxiety is to never find a solution to the root problems. The valence of anxiety is uncontroversially negative (Endler & Kocovski, 2001; Spielberger, 1966). In this section, we discuss state anxiety, which is an emotion triggered by a current situation, by opposition with trait anxiety, which is the general and stable predisposition of an individual to respond to a given trigger with state anxiety (Endler & Kocovsky, 2001; Spielberger, 1966). In what follows, for the sake of brevity, we will use the term anxiety to mean the emotion (state anxiety) and not the predisposition (trait anxiety).

There is converging evidence that anxiety triggers deliberation. Anxiety is accompanied by what is called rumination, which consists in self-reflection (Morrow & Nolen-Hoeksema, 1990) and brooding (negative thoughts; Nolen-Hoeksema, 1991, 2000; Nolen-Hoeksema et al., 1994). The first subcomponent of rumination (reflection) illustrates the engagement in problem solving through deliberation (Treyner & Gonzalez, 2003). Accordingly, the emergence of abstract thoughts (a by-product of deliberation) attenuates the somatic responses linked to anxiety (Borkovec et al., 1993; Mathews, 1990). The second subcomponent (brooding) is likely the result of a pessimistic metacognitive assessment (“I will not find the solution to this problem”), due to the maintenance of the disturbances in time and the difficulty to find resolution.

If anxiety promotes deliberation, then one should observe manifestations of cognitive load under anxious states. Consistent with this hypothesis, a large number of studies have shown that anxiety

saturates working memory and decreases the general availability in cognitive resources (e.g. Ashcraft & Kirk, 2001; Blanchette & Caparos, 2016; Channon & Baker, 1994; Darke, 1988; Derakshan & Eysenck, 1998; Kensinger & Corkin, 2003; Moran, 2016). Furthermore, there are also observed effects of motivation to deliberate in anxious situations in political reasoning (Fernando et al., 2016; Mackuen et al., 2010; Valentino et al., 2008).

As stated earlier, anxiety could be understood as a heightened form of confusion, which emerges when a problem appears to be very difficult to solve or even unsolvable. Interestingly, in the context of long-lasting uncertainty – when a problematic situation cannot get resolved – the experience of anxiety becomes more and more unbearable, and can push individuals to prefer the depressed state associated with dawning certainties, rather than the anxious state associated with uncertainty (Miceli & Castelfranchi, 2005). This finding is consistent with the argument that anxiety, and doubt in general, are powerful forces which motivate us to solve the unsatisfying situation and promote deliberative reasoning.

In sum, upon a thorough examination of the characteristics of surprise, confusion, and anxiety, it appears that these emotions occur in response to indeterminate interactions with the environment and that they have an unpleasant nature. Engaging in deliberative thinking seems to be a reaction motivated by the experience of these negative emotions. In this regard, our postulate that doubt is the emotion that enables us to move from an intuitive to a deliberative mode of reasoning is merely a reinterpretation of the processes already described in the literature about human thinking.

3.4. The case of curiosity

When addressing the question of our motivation to deliberate, another emotion seems to emerge. Curiosity, which triggers exploratory behaviors (Vogl et al., 2019), can be understood as the result of either an unfulfilled prediction (Gruber & Ranganath, 2019) or a gap between what we know and what we want to know, namely, a lack of information (Loewenstein, 1994). Curiosity seems to be strongly linked to the desire to engage cognitive resources, and therefore to deliberate.

It has been proposed that there are two types of curiosity (Litman, 2010, 2012): while curiosity of interest (I-type) focuses on the sensation of pleasure associated with the discovery of new ideas,

curiosity of deprivation (D-type) focuses on the sensation of displeasure associated with a lack to be filled on a subject. D-type curiosity can be linked to anxiety, which gives it a negative valence (Hong et al., 2017). Therefore, D-type curiosity is comparable to uncertainty and doubt, has a negative valence, and represents a strong motivation to engage in deliberative reasoning (van Lieshout et al., 2021).

I-type curiosity, on the other hand, does not provoke anxiety and “is related to the anticipated pleasure from finding out information of a more casual, unessential, entertaining, or aesthetically pleasing nature, such as juicy gossip, an amusing anecdote, or an entertaining story”. (J. Litman, 2005, pp. 799–800). In this sense, I-type curiosity is also a sensation of deprivation, but it is small enough that it can be easily overcome by projecting the pleasure experienced by fulfilling it. In sum, surprise and I-type curiosity are negative emotions that appear when a situation is quickly resolved. Confusion and D-type curiosity are negative emotions that appear when a situation is more difficult to resolve, but can be resolved. Anxiety is the type of negative emotion that appears when a situation cannot be resolved.

In the present paper, we will limit ourselves to mentioning surprise, confusion, anxiety and curiosity. Other emotions may share their characteristics (such as ambiguity, worry, stress, perplexity, etc.) and are variants of the core concept of doubt. We propose that the general concept of doubt as a supra-ordinal emotion encompassing the above-mentioned examples, makes it possible to define the link between emotion, motivation, and deliberative reasoning.

4. The aversive nature of doubt

The supra-ordinal emotion of doubt has two core characteristics. First, it comes from an indeterminate situation where intuitions are poor. Second, it is unpleasant. We argue that one important way to get rid of doubt is deliberation. In fact, several lines of evidence suggest that deliberation does lead to reducing a negative emotional state. To start with, working memory, which is central to reasoning (De Neys et al., 2008), has been related both to negative affect reduction (Hendricks & Buchanan, 2016) and to enhanced emotional control (Schmeichel et al., 2008). Strategies of emotional regulation also include cognitive changes (e.g., reappraisal; Goldin et al., 2008; Gross, 1998), and involve altering the meaning or relevance of an event through deliberative thinking. These strategies are particularly effective at modifying anxiety-provoking situations (Gross & Thompson, 2007). In fact, the difficulty in reappraisal is one of the major explanations for anxiety disorders (Campbell-Sills & Barlow, 2007).

Finally, the ACC is involved in the reduction of negative affect (Ochsner et al., 2002). Therefore, the literature shows that engaging in deliberative reasoning does alleviate a negative emotional state.

Given that deliberation is doubtful and therefore unpleasant, one may wonder why people do not always jump on the first intuition that comes to mind, in order to eliminate doubt as quickly as possible, without involving deliberation at all. This is because the cost of deliberation is lower than the anticipated cost of experiencing doubt again, deliberation is thus the “lesser of two evils”. We strive to avoid future occurrences of doubt. Poor deliberation will lead to constant fallbacks into doubt if the solutions we find are not valid enough, namely, not usable in future similar contexts. In other words, taking some time to think more deeply and analytically (which involves accepting some level of ‘suffering’) maximizes our chances of reducing future occurrences of doubts.

In sum, the purpose of deliberation is to automatize adequate and adaptable responses by updating our mindware, in order to reduce future needs to deliberate. The more automated our responses are, the easier it is for us to invoke and utilize them in different contexts (Boissin et al., 2021; Raelison et al., 2021), which in turn hinders the emergence of doubt. The speed of intuitions allows us to be adaptive to our environment by preventing us from remaining in a state of withdrawal and inaction, characteristic of deliberation, which exposes us to the dangers of our environment.

At first glance, our depiction of the role of deliberation makes it sound as though we never enjoy thinking. We do not imply this. In fact, we may define “thinking” as the flow of our ideas, and while thinking includes deliberating, most of the time we think with no deliberation involved. In other words, even if deliberative processes are occasionally invoked, there is usually no deep analytical reasoning involved in a pleasurable wandering of thoughts. However, even when we do deliberate, it seems reasonable to think that some activities, such as chess or Sudoku, are enjoyable because they make one think. Examination of data from the the Need For Cognition scale (NFC) supports this idea (Cacioppo & Petty, 1982), where high scorers report enjoying deliberation more than low scorers. But do they love the act of deliberation as such? Or, do they prefer to engage in a process of deliberation in order to receive the associated positive emotional reward that stems from overcoming a challenging obstacle? Several findings (e.g., the fact that NFC correlates with feelings of agentivity, control, self-efficacy, curiosity, intrinsic motivation; Cacioppo et al., 1996; Zerna et al., 2024) lead us to believe that high NFC

scorers enjoy intellectual challenge, i.e. they like to put themselves in difficulty to find the solution. And the experience of difficulty and unpleasantness is an inherent aspect of the challenge. This is analogous to the preparation undertaken in the context of a marathon, which is not undertaken for its own sake, but because the challenge motivates the individual. In this perspective, high NFC scorers find themselves in an optimal zone of doubt (just as there is an optimal zone of confusion when learning; D'Mello & Graesser, 2014) where the situation involves deliberation at moderate cost and regularly compensates them with ego-related rewards (of solving a problem).

5. Conclusion

We will summarize here the three assumptions that we believe are important additions to current reasoning models (De Neys, 2023; Pennycook et al., 2015; Thompson et al., 2011). First, doubt arises from poor or unsatisfying intuitions, which occur when interactions between individuals and their environment is no longer fluid and straightforward. Intuitive reasoning fails to provide a smooth solution or provides several inconsistent potential solutions, causing cognitive conflicts. Second, doubt-like emotions (surprise, curiosity, confusion and anxiety) have been demonstrated to possess the characteristics previously outlined, namely that they are unpleasant feelings which arise from indeterminate situations and prompt reflection. Third, the aversive nature of doubt motivates us to use deliberative reasoning to suppress it.

The argument put forth is that the incorporation of an emotional factor into the reasoning process adds a novel dimension to existing models. First, it can explain why the platypus puzzled people so much. Its encounter created a hitch in the scientists' mental representation, which until then clearly separated mammals and oviparous creatures into two rigorously defined categories. Second, it can explain why this hitch caused them to spend cognitive resources. They were motivated by an emotion with a negative valence named 'doubt'. Third, it can explain why early theories dismissed the existence of the platypus. The reason is that reasoning is an unpleasant process, and people seek to avoid prolonged discomfort. One way to achieve this is by rationalizing intuitions that preserve continuity, even if they are wrong or delusional (Festinger, 1957; Kunda, 1990; Wason, 1968). Fourth, it can explain why people continued to ponder and develop a new animal category. The reason is that the hitch persisted even after theorizing that a taxidermist had created the platypus. Questions such as 'Who was he?' and 'Why are

there no visible stitches?' remained and so did doubt. Ultimately, the final version of the theory was considered satisfactory not because it was logically valid or an absolute truth, but because it effectively prevented any future doubts.

At a more abstract level, the idea we defend is that “thinking is not a case of spontaneous combustion” (Dewey, 1910, p. 12). The reasoning process is conditioned by the emotion of doubt. An individual's goal is to automate responses to be effective in the world. Wasting no time in thinking when encountering potential threats is a key ability for adaptation and survival. To achieve this goal, we need excellent cognitive abilities when facing incongruous or indeterminate situations, as well as the motivation to quickly escape from these situations to avoid being at the mercy of our environment for too long. This motivation is rooted in our emotions.

Previous models (De Neys, 2023; Thompson et al., 2011) have shed light on the intuition-to-deliberation switch mechanism. With the present paper, we wish to emphasize the connection between the general mechanism of reasoning and emotions, which has been repeatedly observed but not satisfactorily integrated into existing theoretical models of reasoning (e.g. Bechara et al., 1997; Clore & Huntsinger, 2007; Damasio, 1994, 1996; Inzlicht et al., 2015). We believe that emotions are not in competition with cognition; rather, they are an inextricable part of the mechanism.

We are cognitive misers and need an incentive to resort to effortful thinking. We propose that this emotional incentive is "doubt".

Contribution

Conceptualization : CC

Supervision : JP, SC

Validation : JP, SC

Writing – original draft : CC

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