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META-COGNITIVE PROCESSES IN REASONING AND INTUITION: THE ROLE OF FEEDBACK INFORMATION AND INDIVIDUAL THINKING STYLES

Presentata da: Fabio Marinello

Coordinatore Dottorato

Prof.ssa Monica Rubini

Relatore

Prof.ssa Fiorella Giusberti

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Abstract

One composite topic addressed by researchers within cognitive sciences concerns the way people manage their mental effort in order to solve problem, and how people feel about their decision-making process. The theoretical background of this thesis is centred on the extant models describing human mind through a dual-process account. Moreover, a meta-cognitive approach has recently brought new insights in this field, emphasizing the importance of monitoring and control processes in reasoning. The present dissertation adds to this literature by exploring the role of context-related features, and of individual characteristics, that relate to cognitive and meta-cognitive processes in reasoning. The first part is focused on the function of feedback information: in Study 1, participants primed for the adoption of intuitive or reflective thinking processes, got information about their accuracy or inaccuracy during the resolution of reasoning tasks. Study 2 investigates the effects of feedback anticipation, that is how people adapt their mental effort according to the knowledge that their performance will be evaluated. The second part explores individual differences that could predict distinct levels of confidence in one's reasoning process: in Study 3, performance and metacognitive feelings of individuals with a preference for intuitive thinking were compared with those of individuals with a preference for rational thought. Finally, in Study 4, individual characteristics of decision-making style (namely, propensity to experience regret, and maximizing vs satisficing tendencies) were examined as potential predictors of meta-reasoning components. Overall, this thesis highlights the importance of developing a metacognitive perspective inside the psychology of higher cognition.

General introduction

One of the most engaging themes addressed by researchers in the field of cognitive sciences concerns the way people process information in order to reason, solve problems and make decisions. Although the human species is characterized by unique cognitive abilities to reason, the majority of people experience that our thinking can be easily biased. Striking examples range from the consequences of making bad investment decisions based on the mere familiarity of a stock name, to discrimination in job hiring, or court decisions based on false beliefs and stereotypical associations (e.g., Eberhardt, Davies, Purdie-Vaughns, & Johnson, 2006). Cognitive scientist Herbert Simon originally proposed that human judgments are limited by available information, time constraints and cognitive limitations (Bazerman, 2017). Then, in the early 1970s, Amos Tversky and Daniel Kahneman started a research program focused on the study of heuristics and biases, challenging the idea that human beings are "rational actors", and providing a theory of information processing aimed to explain how people make estimates or choices. It is nowadays recognized, as shown in the last 40 years by several studies in experimental psychology, that humans often reason in a way that is inaccurate or imperfect, and that we do not naturally choose the ideal method or the best solution, but show instead systematic deviations from the rules of logic, probability or rational choice theory. Reasoning and decision-making studies used to attribute this *bias* to the human tendency to base our judgment on fast intuitive impressions rather than on more deliberate reasoning (e.g., Evans, 2008; Kahneman, 2011; Stanovich & West, 2000; Thompson, Turner, & Pennycook, 2011). In and by itself, this *intuitive thinking* can be useful because it is typically fast and effortless, allowing, for istance, to take instant decisions in circumstances that present very strict time constraints. However, in certain situations, intuitive thinking might cue responses that conflict with logical considerations and bias our decision-making. Even if today thinking bias is considered not to be merely attributable to intuitive processes, the debate that was born around this issue, and more generally about the characteristics of human rationality, has given rise to numerous researches that still aim at finely describing the architecture of the mind through the operation of intuitive and deliberate thinking processes, and their functional relationships. Surprisingly, while systematic reasoning errors have been a focal point of such research since the 1970s, only a minimum of attention has been paid to metacognitive processes in reasoning (meta-reasoning), that is those processes that monitor and control the proper functioning of reasoning. Monitoring processes operate in the background and represent states of certainty or uncertainty about how well a set of processes has unfolded, or how likely they are to be successful. Control processes operate on the initiation or cessation of mental effort. In other words, when we face a problem, if we are confident in our answer, we will act on it. If we are unsure, then we hesitate, gather more information, try different tacks, etc. If we feel incapable of performing it, then we may seek help or give up. The importance of understanding the basis of these states of certainty, as well as the role they play for an efficient allocation of mental resources, can be revealed by different studies in social psychology and also fields outside of psychology, where *overconfidence* was, for example, recognized in students overestimating their performance on exams (Clayson, 2005) or physicians overestimating the accuracy of their diagnoses (Christensen-Szalanski & Bushyhead, 1981). High levels of confidence were used to explain the excessively high rate of trading in the stock market despite the costs of trading (Odean, 1999), considered a cause for labor strikes and litigation (Neale and Bazerman, 1985), and even attributed a role in the nuclear accident at Chernobyl and in the explosion of the Space Shuttle Challenger (Plous, 1993).

Here, I will consider how people's states of certainty might be generated or affected by different factors, focusing on predictors of confidence that might rely both on individual characteristics of a reasoner, and in the features of specific decisional environments or situations. Even if some theoretical and experimental approaches have tried to understand the different components that are involved in the decision-making and reasoning process, they are far from being clear and integrate. In the present thesis, I aim to provide new insights on mechanisms underlying the way we approach and solve problems, put effort in making our decisions, and how we monitor them and feel about them. Thus, a cognitive and metacognitive approach will be used, taking into account the main theories regarding the complex interaction between reasoning processes and feelings of confidence.

CHAPTER 1

Intuition and deliberation

Despite little consensus of what *intuitive thinking* means (Janoff-Bulman, 2010), definitions are consistent with the idea that intuitions are fast and spontaneous. The centrality of speed emerged in the philosophical concept of intuition, intended as a process that involve "immediate apprehension" (Rorty, 1967, p. 74), and described as "the immediate perception of connection between ideas" (Osbeck, 2001, p. 121). The importance of speed has been highlighted again in more recent evolutionary perspectives that point to the advantages of being able to process information and respond quickly to environmental stimuli (Epstein, 1994; Haidt, 2001; Reber, 1992). Moreover, intuition has been told to involve direct apprehension that is "not mediated by other reasoning or representation" (Osbeck, 2001, p. 123), and several authors, debating the virtues of fast decisions (e.g. Gladwell, 2005), described intuition as a form of direct and instant knowledge of a truth, which can manifest itself without reasoning, so requiring little effort. Thus, intuitive thinking has also been frequently defined resorting to its opposite, that is an effortful and deliberate analytic reasoning (Evans, 2010a; Hogarth, 2001). The distinction between intuitive and analytic thinking is common in the psychological literature, and various functional characteristics have been studied (e.g. Neisser, 1963; Shiffrin & Schneider, 1977; Sloman, 1996). Piagetian research tradition, for example, has long described cognitive development as a growth in reasoning capacities, observing that children's responses to problems tend to conform less often to the prescriptions of logic than adults' ones (e.g. Bjorklund & Blasi, 2005). In order to promote a better understanding of intuitive and analytic thinking, several authors suggested to focus on the cognitive and metacognitive processes posited to be involved in decision making (Glockner & Witteman, 2010; Hogarth, 2001; Thompson, 2014) and identified Dual Process Theories of higher cognition (Evans & Stanovich, 2013; Kahneman, 2011;

Stanovich, 2011) as the theories that give the broader explanation about the features of intuitive and analytic thinking.

Dual-process theories of higher cognition

From Systems to Types

Dual Process Theories of reasoning and decision-making suggested a distinction between two kinds of thought, a System 1, variously characterized as fast, automatic, implicit, parallel, and low capacity, and a System 2, described as slower, rule-based, serial, deliberate, and capacity-dependent. These labels were presented by Stanovich (1999) who brought together the numerous theories that had proliferated over the decades by listing them and their different names for the two processes, aiming to bring some coherence and integration to this literature. I shall emphasize from the beginning that the main critics of dual-process theories, disputed the idea that there are two cognitive systems with a cluster of defining attributes (e.g Keren and Schul, 2009). The main argument is that the different features of the cluster are not always observed together. This observation is correct but creates a problem only if all the features considered by the different theorists are assumed to be necessary and *defining* features. Instead, from a theoretical point of view, although there is a clear basis for predicting a strongly *correlated* set of features, very few need be regarded as essential and defining characteristics of the two kind of processes (see Table 1; Evans & Stanovich, 2013). Dual process theorists, moreover, considering that the term dual *system* could be ambiguous, as might suggest that exactly two systems underlie the two forms of processing (which is a stronger assumption than most theorists wish to make), recently, found a better agreement in the use of the terms Type 1 and Type 2, in order to underline one main qualitative difference between two sets composed of many different processes (Evans & Stanovich, 2013).

Table 1. Clusters of attributes frequently associated with Dual-Process Theories of Higher Cognition

Type 1 process (intuitive)	**Type 2 process (reflective)**
Defining features	
Does not require working memory	Requires working memory
Autonomous	Cognitive decoupling; mental simulation
Typical correlates	
Fast	Slow
High capacity	Capacity limited
Parallel	Serial
Nonconscious	Conscious
Biased responses	Normative responses
Contextualized	Abstract
Automatic	Controlled
Associative	Rule-based
Experience-based decision making	Consequential decision making
Independent of cognitive ability	Correlated with cognitive ability
System 1 (old mind)	**System 2 (new mind)**
Evolved early	Evolved late
Similar to animal cognition	Distinctively human
Implicit knowledge	Explicit knowledge
Basic emotions	Complex emotions

The definition of Type 2 processing

Even if it might seem weird, it's probably a better choice to start from the definition of Type 2 processes, as understanding their properties will help to understand the other Type of mental processing, too. According to most dual process theorists nowadays (e.g. Evans & Stanovich, 2013), the defining characteristic of Type 2 processes is represented by the engagement of working memory. The large literatures on working memory and executive function (Baddeley, 2007) have established that there is a general purpose system used in many higher cognitive functions and that the capacity of this system varies reliably between individuals. Measures of working memory capacity have been shown to be predictive of performance in a wide variety of cognitive tasks (Barrett, Tugade, & Engle, 2004) and highly correlated with fluid intelligence (Colom, Rebollo, Palacios, Juan-Espinosa, & Kyllonen, 2004; Kane, Hambrick, & Conway, 2005). It is the engagement of this working memory system specifically that Jonathan Evans (e.g., 2008, 2010) has emphasized in the definition of Type 2 processing, observing that it underlies many of the typically observed correlates: that it is slow, resource-limited and controlled. He has also suggested that Type 2 thinking enables uniquely human facilities, such as hypothetical thought, mental simulation, and consequential decision-making (Evans, 2007a, 2010b). Keith Stanovich and Rich West have focused much of their research program on individual differences in both cognitive ability, intelligence and thinking dispositions, showing that Type 2 aspects of performance on a wide range of reasoning and decision-making tasks are selectively correlated with intelligence measures, whereas features attributed to Type 1 processing are largely independent of such measures. (Stanovich, 1999, 2009b, 2011; Stanovich & West, 2000). Because working memory capacity and general intelligence are known to be highly correlated, this framework connects with Evans's emphasis on the engagement of working memory in Type 2 processing. Stanovich (Stanovich, 2011; Stanovich & Toplak, 2012) has also strongly emphasized the features that he calls *cognitive decoupling* in his definition of Type 2 processing. The so-called cognitive decoupling operations represent in fact the ability to prevent our representations of the real world from becoming confused with imagination, allowing, for instance (and compatibly with Evan's view of Type 2 processes), to reason hypothetically.

The definition of Type 1 processing

On the other hand, the defining characteristic of Type 1 processes is their autonomy. They do not require "controlled attention", which is another way of saying that they make minimal demands on working memory resources. Hence, Stanovich (2004, 2009a, 2011) has argued that the execution of Type 1 processes is mandatory when their triggering stimuli are encountered and they are not dependent on input from high-level control systems. These autonomous processes have other correlated features (their execution tends to be rapid, they do not put a heavy load on central processing capacity, they tend to be associative) but these correlated features are not defining. Into the category of autonomous processes would go some processes of emotional regulation, encapsulated modules for solving specific adaptive problems that have been posited by evolutionary psychologists, and the automatic firing of overlearned associations (see Barrett & Kurzban, 2006; Carruthers, 2006; Evans, 2008; Kahneman & Klein, 2009; Shiffrin & Schneider, 1977; Sperber, 1994). These disparate categories make clear that Type 1 processes have some heterogeneity: the many kinds of Type 1 processing have in common the property of autonomy, but otherwise, their neurophysiology might be considerably different. For example, Type 1 processing encompasses processes of implicit learning and conditioning, but also many rules, stimulus discriminations, and decision-making principles that have been practiced to the point of automaticity (Kahneman & Klein, 2009; Shiffrin & Schneider, 1977) might be processed in a Type 1 manner.

Supporting evidence

Evolutionary perspective

A key feature of Type 2 processing that makes humans unique, is represented by cognitive decoupling, that is the ability to distinguish supposition from belief and to aid rational choices by running thought experiments. Although rudimentary forms of higher order control can be observed in mammals and other animals (Toates, 2006), the controlled processing in which they can engage is very limited by comparison with humans, who have unique facilities for language and meta-representation as well as greatly enlarged frontal lobes (Evans, 2010b). Evans and Stanovich (2013) are in agreement that the facility for Type 2 thinking became uniquely developed in human beings, effectively forming a new mind which coexists with an older mind based on instincts and associative learning, and gives humans the distinctive forms of cognition that define the species (Evans, 2010b; Evans & Over, 1996; Stanovich, 1999, 2004, 2011). It is evident that humans resemble other animals in some respects but are very different in others: quite obviously, no other animal can engage in the forms of abstract hypothetical thought that underlie science, engineering, literature, and many other human activities. More basically, other animals are much more limited in their meta-representational and simulation abilities (Penn, Holyoak, & Povinelli, 2008), thus leading to limitations (compared with humans) in their ability to carry out forms of behaviour that depend on prior appraisal of possible consequences.

Experimental manipulations

The strongest evidence for dual process theories comes from direct efforts to dissociate Type 1 and 2 processing. There are experimental manipulations designed to affect one type of processing while leaving the other intact. Common manipulations are designed either to increase Type 2 processing effort, by instruction or motivation, or to suppress it by use of concurrent tasks that load working memory or by use of speeded tasks that allow little time for reflective thought. In the experimental approach, a large part of the arguments supporting dual process theories originated from the observation of the so-called *belief-bias effect* in conditional reasoning. Studies on belief-bias effect were first designed by Jonathan Evans to create a conflict between logical reasoning and prior knowledge about the truth of conclusions. Belief bias is the tendency to judge the strength of arguments based on the plausibility of their conclusion rather than how strongly they support that conclusion. In this paradigm, participants are asked to judge whether conclusions necessarily follow from premises, using syllogisms that differ in both actual validity and the believability of their conclusions. Participants are asked to evaluate syllogisms that are: valid arguments with believable conclusions, valid arguments with unbelievable conclusions, invalid arguments with believable conclusions, and invalid arguments with unbelievable conclusions. Participants are told to only agree with conclusions that logically follow from the premises given. The results suggest that when the conclusion is believable, people erroneously accept invalid conclusions as valid more often than invalid arguments are accepted which support unpalatable conclusions (see Fig. 1). This is taken to suggest that Type 1 beliefs are interfering with the logic carried by Type 2 processes (Evans, 2003). Belief-bias has been shown to be increased and logical accuracy decreased when people operate under time pressure (Evans & Curtis-

Holmes, 2005), which is assumed to inhibit Type 2 reflective reasoning, and other findings have been provided by studies where working memory capacity was manipulated by burdening executive processes with secondary tasks. Results showed that when beliefs were consistent with the logic response, the distractor task had no effect on the production of a correct answer, which supports the idea that Type 1 is automatic and works independently of working memory. Differently, when a conflict between belief and logic was present, the participants' performance was impeded by the decreased availability of working memory. Thus, Type 1 was shown to work independent of working memory, and Type 2 was impeded due to a lack of working memory space (De Neys, 2006).

Type	Argument	Acceptance rate
Valid–believable	*No police dogs are vicious.* *Some highly trained dogs are vicious.* *Therefore, some highly trained dogs are not police dogs.*	89% yes (correct)
Valid–unbelievable	*No nutritional things are inexpensive.* *Some vitamin tablets are inexpensive.* *Therefore, some vitamin tablets are not nutritional* .	56% yes (correct)
Invalid–believable	*No addictive things are inexpensive.* *Some cigarettes are inexpensive.* *Therefore, some addictive things are not cigarettes.*	71% yes (incorrect)
Invalid–unbelievable	*No millionaires are hard workers.* *Some rich people are hard workers.* *Therefore, some millionaires are not rich people.*	10% yes (incorrect)

Fig. 1. Examples of the four types of syllogism used by Evans, Barston, and Pollard (1983) and participant acceptance rates. The data illustrate the typical findings that both belief and logic significantly influence responding. Also, the belief-bias effect is larger for invalid arguments. (Evans & Stanovich, 2013).

Similar findings have been reported for other reasoning and judgment tasks. For example, De Neys (2006a) showed in one experiment that participants making the *conjunction fallacy* on the famous Linda problem (Tversky & Kahneman, 1983, see Fig. 2) responded quicker than those who did not. In a second experiment, they showed a sharp decrease in correct responding on this task when a concurrent working memory load was used.

Linda is 31 years old, single, outspoken and very bright. She majored in philosophy. As a student, she was deeply concerned with issues of discrimination and social justice, and also participated in anti-nuclear demonstrations.

What is more probable?

1. Linda is a bank teller.
2. Linda is a bank teller and is active in the feminist movement.

Fig. 2. The paragraph describing Linda is more similar to that of a feminist bank teller than it is to a stereotypical bank teller. That is, one can more easily imagine Linda as a feminist bank teller, which leads one to conclude that she is more likely to be one. Of course, the second statement could not possibly be more probable than the first, because it presupposes the first: a conjunction can never be more probable than one of its constituents. Apparently, two mechanisms exist that lead to divergent conclusions: on one hand, an intuitive thought leads to the conclusion that T & F is more probable. On the other hand, a probabilistic argument leads to the conclusion that T is more probable.

Also, on the Wason selection task, the intuitive *matching bias* (Evans, 1998, see Fig. 3), which accounts for typical responding, is found to be increased by use of speeded tasks (Roberts & Newton, 2001) or concurrent working memory loads (De Neys, 2006a).

There are four cards lying on a table. Each has a capital letter on one side and a single digit number on the other side. The exposed sides are shown below:

A	D	3	7

The rule shown below applies to these four cards and may be true or false:

If there is an A on one side of the card,
then there is a 3 on the other side of the card

Your task is to decide those cards, and only those cards, that need to be turned over in order to discover whether the rule is true or false.

Fig. 3. The standard abstract Wason selection task with a conditional statement of the form *if P, then Q*. The generally agreed correct answer is to select A and 7 (P and not-Q), but this is chosen by only around 10% of participants. Typical choices are A (P) alone or A and 3 (P and Q), often attributed to an intuitive *matching bias* as these items are named in the conditional sentence.

Instructions and motivation

It has been known for some years that instructions to reason in a deductive or pragmatic manner can have a big influence. For example, in drawing classical conditional inferences, such as Modus Ponens and Modus Tollens, participants are influenced by the degree to which they believe the conditional statement, often leading them to withhold a valid inference when it is unbelievable (e.g., George, 1995; Stevenson & Over, 1995). However, belief-based responding is clearly attenuated when strong deductive reasoning instructions are used. Belief biases are observed to be less commonly manifest in those of higher cognitive ability (Evans, Handley, Neilens, Bacon, & Over, 2010; Stanovich & West, 1997), who are, by the theory, more likely to engage effective Type 2 thinking. Similarly, De Neys, Schaeken, and d'Ydewalle (2005a, 2005b) have shown that although participants of higher working memory capacity are better able to retrieve counterexamples to all conditional inferences, they use these selectively to block fallacies but not valid inferences when instructed to reason logically. Nevertheless, it has been noted that those of higher ability will reason better only if motivated and disposed to do so (Stanovich, 2011), and that even higher ability participants will suppress belief biases only if specifically instructed to reason logically and draw necessary conclusions (Evans et al., 2010).

Neuroscientific approach

Neural imaging has been increasingly adopted in order to show that different brain areas are active when Type 1 or 2 processing is being observed. Again, belief bias has received particular attention, and studies support the qualitative distinction between belief- and reason-based responding. Goel and others (2000) provided evidence that anatomically distinct parts of the brain were responsible for the two different kinds of reasoning, finding that content-based reasoning caused left temporal hemisphere activation whereas abstract formal problem reasoning activated the parietal system. Neural imaging studies have shown that belief–logic conflict is detected by the brain: in particular, conflict detection is indicated by activation of the anterior cingulate cortex. Moreover, when reason-based responses are observed, different brain areas are activated when responses are belief-based (De Neys, Vartanian, & Goel, 2008; Goel & Dolan, 2003; Tsujii & Watanabee, 2009) than when they are responsive to the logic of the problems: in particular, the override of belief-based responding is signalled by activation of the regions of the right prefrontal cortex known to be associated with executive control. In a study incorporating fMRI during a belief-bias test, Goel and Dolan (2003) found that different mental processes were competing for control of the response to the problems. The prefrontal cortex was critical in detecting and resolving conflicts, which are typical of Type 2 processing. The ventral medial prefrontal cortex, known to be associated with the more intuitive Type 1 responses, was the area in competition with the prefrontal cortex. Tsujii and Watanabe (2009) did a follow-up study to Goel and Dolan's fMRI experiment. They examined the neural correlates on the inferior frontal cortex (IFC) activity in belief-bias reasoning using near-infrared spectroscopy (NIRS). Subjects performed a syllogistic reasoning task, using congruent and incongruent syllogisms, while attending to an attention-demanding secondary task. The interest of the researchers was in how the secondary-tasks changed the activity of the IFC during congruent and incongruent reasoning processes. The results showed that participants performed better in the congruent test than in the incongruent test (evidence for belief bias); the high-demandsecondary test impaired the incongruent reasoning more than it impaired the congruent reasoning. NIRS results showed that the right IFC was activated more during incongruent trials, and participants with enhanced right IFC activity performed better on the incongruent reasoning than those with decreased right IFC activity. This study provided some evidence to enhance the fMRI results that the right IFC, specifically, is critical in resolving conflicting reasoning, but that it is also attention-demanding; its effectiveness decreases with loss of attention. The loss of effectiveness in Type 2 processing following loss of attention makes the autonomous Type 1 take over, which results in belief bias.

Individual differences

It has been already mentioned that differences in working memory capacity and intelligence can influence responsiveness to instructions and resistance to belief biases. More generally, studies of individual differences in reasoning have shown that for many tasks in the heuristics and biases literature, the modal response displays negative correlations with cognitive sophistication. Dual-process theories provide an explanation of this seemingly paradoxical data pattern that recurs in the great rationality debate in cognitive science (Stein, 1996). As is well known, a substantial research literature has established that people's responses sometimes deviate from the performance considered normative on many reasoning tasks (Baron, 2008; Evans, 2007a; Kahneman & Tversky, 2000; Stanovich, 2009b). Demonstrating that descriptive accounts of human behaviour diverged from normative models was a main theme of the heuristics and biases research program inaugurated by Kahneman and Tversky in the early 1970s (Kahneman & Tversky, 1972, 1973; Tversky & Kahneman, 1974). However, over the last two decades, an alternative interpretation of the findings from the heuristics and biases research program has been championed. Contributing to this alternative interpretation have been evolutionary psychologists, adaptationist modelers, and ecological theorists (Anderson, 1990; Cosmides & Tooby, 1996; Gigerenzer, 2007; Oaksford & Chater, 2007). They have reinterpreted the modal response in most of the classic heuristics and biases experiments as indicating an optimal information processing adaptation on the part of the subjects. Stanovich (1999, 2011) has shown, however, that there are other data patterns, concerning individual differences, to be considered. Specifically, although the average person in heuristics and biases experiments might well display several kinds of non-optimal thinking strategies, some people give the standard normative responses. For example, in probabilistic assessment, although the majority of subjects might well ignore the non-causal base rate evidence, a minority of subjects often makes use of this information in exactly the way prescribed by Bayes's theorem. Even if normativity is not a defining feature of Type 2 processing, the dual-process theories predict that it will be a strong correlate in experiments using tasks that are hard to solve directly from previous experience or from previously stored cue validities. In addition, participants are usually motivated by instructions and context to get the right answers. Hence, explicit processing effort and hypothetical thinking (or cognitive decoupling) are generally required for success. It follows that those who are better able or better motivated will be more likely to find the normatively correct answers, and this is generally what the evidence shows. What has been found, more often than not, is that intelligence displays positive correlations with the response traditionally considered normative on the task and negative correlations with the modal response (Stanovich & West, 1998b, 1999; Toplak, West, & Stanovich, 2011; West & Stanovich, 2003; West, Toplak, & Stanovich, 2008). However, dual process theories also predict clear exceptions, occurring when participants are not appropriately motivated or when success can be achieved by Type 1 processing. For example, if pragmatic cues to a correct answer provide a low-effort route to success, as when the Wason selection task is presented with certain realistic contents, the correlation with ability measures largely disappears (Stanovich & West, 1998a). Cognitive ability assists only when a problem requires difficult abstract reasoning that loads heavily on cognitive resources, the same reason that experimental manipulations such as working memory loads and speeded tasks are observed to inhibit the ability to perform the same tasks. The alternative to getting a problem right is not simply to make random errors. Were that the case, then a dual-process account would not have been merited. In a large range of tasks, the modal and "thoughtless" response (Kahneman, 2011) is a systematic intuitive bias of some kind (Stanovich, 2011). Also, when given the opportunity, most participants can explain the reasoning that led to a correct answer, but no participants ever report an established bias like belief bias or matching bias (Evans, 1998) as the basis for a wrong one. On the contrary, participants giving, for instance, a matching response on the Wason selection task, are known to rationalize their answer with reference to the logic of the task (Evans & Wason, 1976; Lucas & Ball, 2005; Wason & Evans, 1975).

Dual process models

Opinions differ across authors regarding mutual influences on human behaviour between intuitive and analytic thinking processes: one question regards the fact that Type 1 and Type 2 processes may interact, rather than operate separately. Analytical thinking can overrule the autonomous processes, like in the case of retrospective reflecting of mistakes (Epstein, Lipson, Holstein, & Huh, 1992), but it has been argued that intuition-related components must be part of each reasoned decision, as they operate faster than any subsequent analytical consideration. The *dual process models* can be distinguished mainly in two categories, called *default-interventionism* and *parallel-competition*. In the following paragraphs I will depict the main characteristics of these two opposite views, concluding then with the description of a more recent model, which attempts to integrate the two perspectives.

Parallel-competitive models

S. A. Sloman (1996; Barbey & Sloman, 2007) proposed an architecture that has a *parallel-competitive* form. This perspective used to distinguish between an *associative processing* (Type 1) mode and a *rule-based processing* (Type 2) mode. The former is based on operations that adopt pattern-completion mechanism: after knowledge has been accumulated from a large number of experiences, memory uses that knowledge to fill in information, quickly and automatically, about the characteristics that previously have been observed or affective reactions that previously have been experienced, in situations that resemble the current one. In contrast, the rule-based processing mode uses symbolically represented and culturally transmitted knowledge as its "program"

(Smolensky, 1988), and rests on human linguistic abilities. Rules may be stored in either processing system, depending on such factors as how frequently they have been encountered (i.e., just one or two times vs. many times) and over what length of time (i.e., whether consolidation has had time to occur).

The main feature of Sloman's theories and other parallel-competitive models of similar structure (e.g., Smith & DeCoster, 2000) is that they assume that Type 1 and 2 processing proceed in parallel, each having their say with conflict resolved if necessary. However, one difficulty with parallel-competitive forms of dual-process theory is that, in general, Type 1 processing is very much quicker than Type 2 processing. Thus, if both types of processing are supposed to have their say, "the fast horse must wait for the slow horse to arrive before any potential conflict can be resolved" (Evans & Stanovich, 2013). A more fundamental problem, perhaps, is that Type 2 processing requires extremely limited and precious working memory resources, that must be selectively allocated to the most important task at hand.

Default-Interventionist models

On the other side, most common dual-process theories, including Kahneman and Frederick (2002) and Evans and Stanovich (2013), are default-interventionist in form. Default-interventionist models describe decision-making as a sequential elaboration in which Type 1 processes start fast and by default to provide an intuitive solution to every problem. These intuitive solutions can be then reconsidered through the intervention of Type 2 processes, that are slower and deliberative in nature, but this does not necessarily happen. So, default-interventionism allows that most of our behaviour is controlled by

Type 1 processes running in the background. Where they lack relevant experience, however, these autonomous intuitions may be inappropriate and fail to meet the goals set: in fact, humans often act as *cognitive misers* by engaging in the substitution of an easy-to-evaluate characteristic for a harder one, even if the easier one is less accurate (this process called *attribute substitution*, as proposed by Kahneman & Frederick, 2002). However, when the decision matters, being a cognitive miser may lead us astray. For example, when we are evaluating important risks, such as the risk of certain activities and environments for our children, we do not want to substitute vividness for careful thought about the situation. In such situations, we want to block the attribute substitution of the cognitive miser. Thus, a key concept in this kind of dual-process theories is that of intervention with reflective (Type 2) reasoning on the default (Type 1) intuition. Since Type 2 processing requires a selective allocation of limited working memory resources, most behaviour will accord with defaults, and intervention will occur only when difficulty, novelty, and motivation combine to command the resources of working memory. In fact, default-interventionism suggests that one of Type 2 processes' functions is to check, and potentially override, those fast thoughts coming as the result of autonomous Type 1 processes.

A three-stage model of analytic engagement

Pennycook, Fugelsang and Koehler (2015) proposed a new model that integrate the parallel functioning of different processes in a first stage, and the sequential form of the default-interventionist models. The model indeed was built to describe the reasoning process for a problem or cue that elicits multiple conflicting outputs. It formalizes and combines distinctions made by previous theorists (e.g., De Neys, 2012; Epstein, 1994;

Evans & Stanovich, 2013a; Sloman, 1996, 2014; Smith & DeCoster, 2000; Stanovich, 2004; Thompson, 2009) by dividing an individual reasoning event into stages and components. According to this model, multiple Type 1 processes may be cued by a stimulus (Stage 1), leading to the potential for *conflict detection* (Stage 2). If successful, conflict detection leads to Type 2 processing (Stage 3), which may take the form of rationalization (i.e., the Type 1 output is verified *post hoc*) or *decoupling* (i.e., the Type 1 output is falsified).

Specifically, in the first stage, autonomous Type 1 processes generate so-called "intuitive" responses. These Type 1 processes are cued by features of the stimulus, do not require working memory or executive functioning, and operate in parallel (Evans, 2008; Sloman, 1996; Stanovich, 2004). A second dimension of the initial stage in this model relates to the idea that some initial responses come to mind more quickly and fluently than others (Thompson, 2009; Thompson et al., 2011, 2013). In the case of base-rate problems, for example, stereotypes are often used as *intuitive lures* because of the phenomenology of their fluent generation (see Fig. 4). However, this does not rule out the possibility that alternative sources of information can cue an alternative Type 1 output in parallel.

In a study 1000 people were tested. Among the participants there were 995 nurses and 5 doctors. Paul is a randomly chosen participant of this study. Paul is 34 years old. He lives in a beautiful home in a posh suburb. He is well spoken and very interested in politics. He invests a lot of time in his career.

What is most likely?

(a) Paul is a nurse.
(b) Paul is a doctor.

Fig. 4. This base-rate problem includes two pieces of information that point to alternative responses. The base-rate probability (995 nurses versus 5 doctors) indicates that there is a 99.5% chance that Paul is a nurse. In contrast, the personality description contains stereotypes that are strongly diagnostic of a doctor. A great deal of research has demonstrated that participants tend to strongly favor the stereotypical information over the base-rate probability because the stereotype is the more intuitive source of information. Thus, the base-rate problem is thought to engender an initial response based on the salient stereotypical information.

Extreme base-rates presented in simple frequency formats influence response time, confidence, and probability estimates in ways diagnostic of Type 1 processing (Pennycook, Trippas, et al., 2014). Thus, base-rate problems serve as an example of a case where two competing sources of information (the stereotype and the base-rate) embedded in a problem can elicit competing initial responses. For other types of problems or cues, it is possible that multiple additional initial responses are elicited.

According to the model, the role of the second stage is to monitor for conflict between Type 1 outputs (De Neys, 2012, 2014). If no conflict is detected (either because no conflict existed or because of a conflict detection failure), the first initial response will continue to the third stage where it is accepted with cursory analytic (Type 2) analysis. This is the prototypical way in which bias is thought to arise: unimpeded and with little effort. If a conflict is successfully detected, however, more substantive Type 2 reasoning will be engaged.

The three-stage model finally distinguishes between two very different forms of Type 2 processing, each with different implications for the degree of bias ultimately displayed. *Rationalization* is a form of Type 2 processing where, despite successful conflict detection, the reasoner focuses on justifying or elaborating the first initial response without seriously considering the other Type 1 output that was cued by the stimulus, but that did not come to mind as quickly and fluently as the first initial response. This leads to a response in line with what would typically be considered bias, but that has been bolstered by analytic reasoning (an "effortful" belief-based response; see Handley & Trippas, 2015). This process is traditionally referred to as "rationalization" in the reasoning literature (e.g., Wason & Evans, 1975), to highlight the idea that the additional consideration is focused on verifying, and not falsifying, the Type 1 output. For example, participants typically spend much of their time looking at the card they ultimately select on the Wason card selection task, indicating that they are likely focused on rationalizing their default response (Ball, Lucas, Miles, & Gale, 2003; Evans, 1996).

The second class of Type 2 processes that could result from conflict detection is *cognitive decoupling* (Stanovich, 2004, 2009a). This is perhaps the most prototypical "analytic" process and, as such, has dominated the literature on reasoning. Decoupling refers to the additional processing necessary to inhibit and override an intuitive response (primarily, IR_1, see Fig. 5). There are three obvious possibilities given a decoupling process: (1) IR_1 is suppressed in lieu of IR_2 which, upon reflection, emerges as a stronger alternative, (2) IR_1 is suppressed in lieu of some other initial response (IR_n), and (3) an alternative response (AR) is generated that represents a novel amalgamation of initial responses.

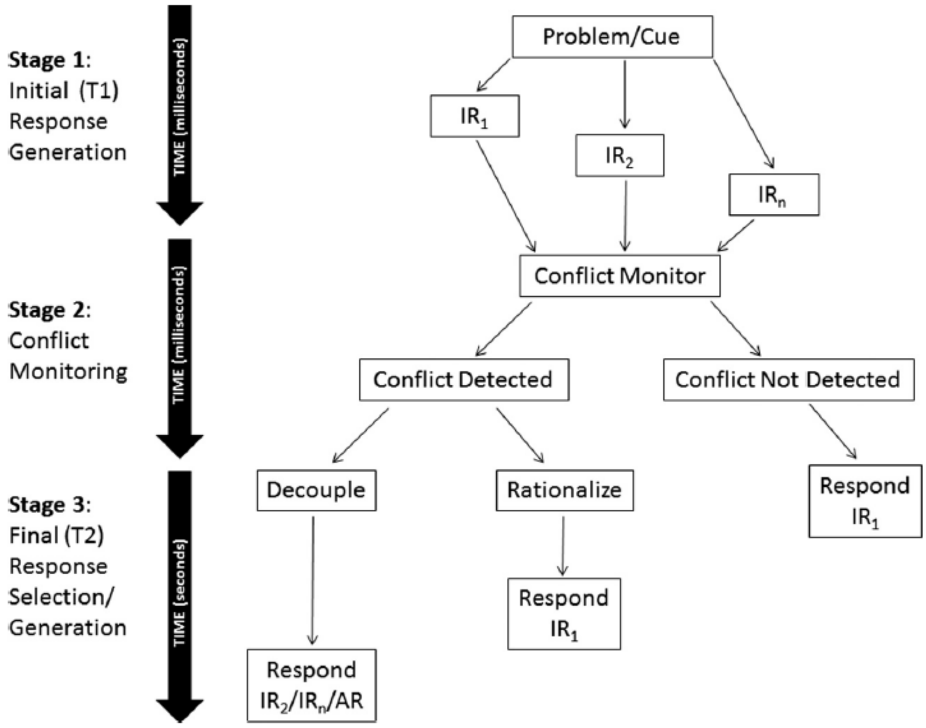

Fig. 5. The three-stage model outlined (Pennycook, Fugelsang and Koehler, 2015)

CHAPTER 2

Meta-cognition and meta-reasoning

Metacognition refers to the processes that monitor our ongoing thought processes and control the allocation of mental resources. While the original framework for studying the metacognitive components in reasoning (Thompson, 2009) was developed inside the default-interventionist forms of dual-process theories (aiming to identify when and how Type 2 processing manage to override Type 1 default responses, see Chapter 1), the logic at the base of this approach can be extended to theories that posit multiple parallel processes rather than sequential ones, and even to single-process theories that do not propose two types of processing: considering that the debate between the different models on the architecture of the mind has not reached a point yet, and given that comprehending when and how people engage in effortful analysis is important, it has been emphasized that the issue of monitoring rapid, initial answers is relevant regardless of the type of reasoning mechanisms that are proposed to underlie them.

As reminded by Ackerman and Thompson (2017) in a recent review, in fact, understanding metacognitive processes requires one to think in terms of two levels. Consider the following example presented by the authors: as you plan your first visit to Eiffel Tower in Paris, you study the Metro map. You see that you need to begin on one Metro line and then switch to another. Before leaving the hotel, you memorize the name of the station where you need to switch and plan a route from your hotel to the nearest station. Map reading, identifying Metro lines, and planning your route are *object-level processes*. These processes, in fact, carry out the basic cognitive work of perceiving, remembering, classifying, deciding, etc; differently, *meta-level processes* monitor the object-level processes and control behavioural responses to these monitoring cues. Monitoring processes operate in the background and represent states of certainty or uncertainty about how well a set of processes has unfolded, or how likely they are to be successful. Following the example, these processes let you know how confident you are that you can find your way to the station. If you are not certain of finding your way, you may take your map with you. Similarly, as you ride the train, you may see that there are two stations with similar names. You may experience doubt that you correctly memorized the station in which you are going to switch trains, which might prompt you to ask another rider for directions. Meta-level processes, thus, monitor those object level processes to assess their functioning (*meta-cognitive monitoring*) and to allocate resources as needed (*meta-cognitive control*). The study of metacognition aims to understand the basis of these states of certainty as well as the role they play in allocating and regulating mental resources to a task.

Most of the extant research on metacognition has examined the processes involved in learning, remembering, and comprehension, and has been motivated mostly from an educational perspective. Despite a recent increase in research in other domains, research about metacognitive processes with respect to complex processes such as reasoning and problem-solving is still in its infancy.

Monitoring and Control in Reasoning and Problem Solving

The Meta-Reasoning framework proposed by Ackerman and Thompson (2017) reflects Nelson and Narens' (1990) model for the study of meta-memory, which is still used today, but, while retaining the basic architecture proposed by Nelson and Narens, it also reflects the complexity of the object-level processes unique to reasoning.

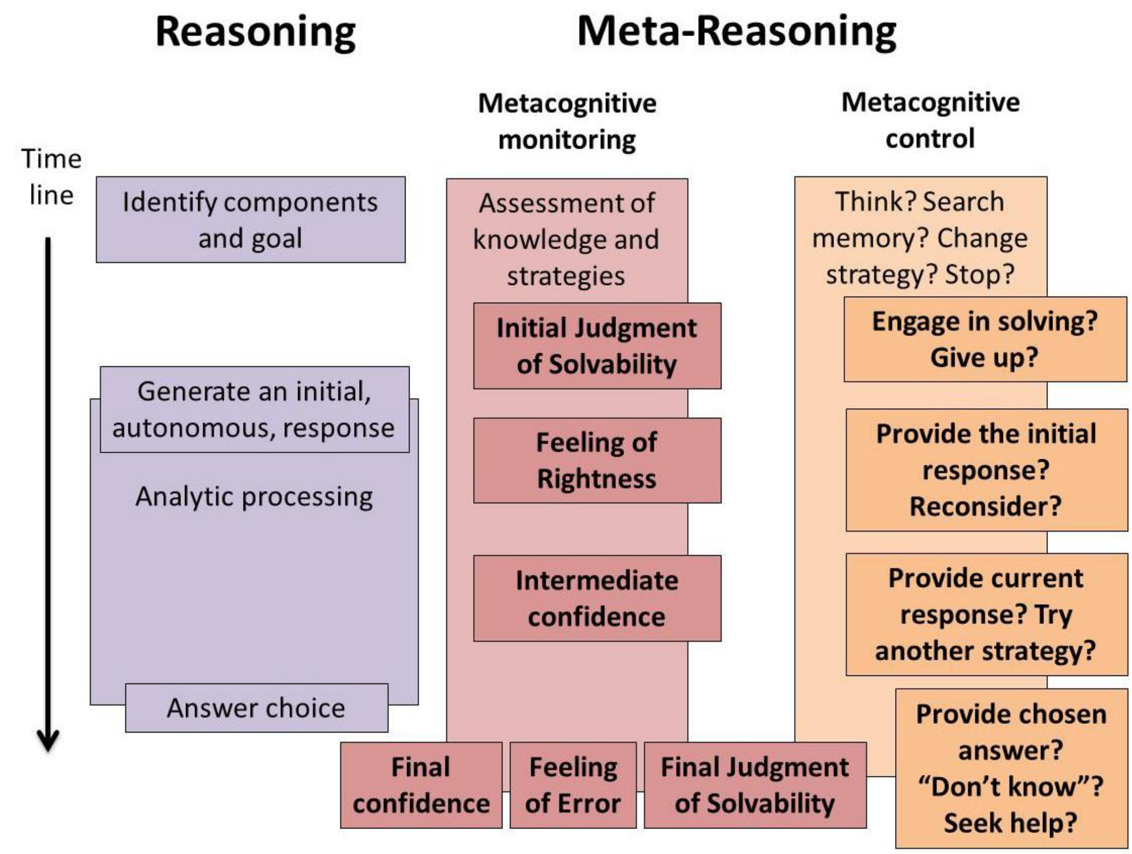

Fig. 6. Different components of reasoning and meta-reasoning in Ackerman and Thompson's framework (2017).

The left column in Figure 6 represents the object-level processes involved in reasoning, with the understanding that various reasoning theories make different assumptions about the timing and nature of those processes (see Chapter 1). The middle column details the monitoring processes that have been identified as relevant for reasoning, while the right column enumerates the associated control functions. All monitoring processes reflect a subjective assessment of the probability of success or failure on a given task, before, during, or after engaging in the task. These assessments are mostly spontaneous (Koriat, 2000; Reder & Schunn, 1996), and are hypothesized to trigger a variety of control decisions including taking action, the allocation of time and effort to a task, and choice of strategy to complete the task. For instance, before embarking on a solving attempt, reasoners are posited to make an initial *Judgment of Solvability* (Thompson, 2009;

Topolinski et al., 2016), which reflects the reasoner's assessment that the problem is solvable, and that it is solvable by her. This initial Judgment of Solvability is posited to control whether to attempt a solution, give up, seek external help, etc. There are cases in which reasoners can quickly and accurately identify whether the problem is solvable (Topolinski & Strack, 2009). However, in many cases identifying unsolvable problems is not trivial (Ackerman & Beller, 2017), which can lead people to waste time trying to solve them (Payne and Duggan, 2011).

So far, there are only two extant models that explain the relationship between monitoring and control of reasoning. The first is the Metacognitive Reasoning Theory (Thompson, 2009). This model deals with cases in which the context of the problem cues an immediate, initial answer to a problem, like in the most popular Cognitive Reflection Test (see Fig. 7).

1. A bat and a ball cost $1.10 in total. The bat costs $1.00 more than the ball. How much does the ball cost? _______ cents

2. If it takes 5 machines 5 minutes to make 5 widgets, how long would it take 100 machines to make 100 widgets? _______ minutes

3. In a lake, there is a patch of lily pads. Every day, the patch doubles in size. If it takes 48 days for the patch to cover the entire lake, how long would it take for the patch to cover half of the lake? _______ days

Fig. 7. The Cognitive Reflection Test (Frederick, 2005) is a set of three math problems, having simple computational requirements, but all require overcoming an initial, misleading response. In the "Bat and ball" example, "5 cents" is the correct answer, but the majority of participant tend to give the misleading wrong answer, "10 cents". In a similar manner, even cultured people commonly give "100 minutes" as a response for the second problem (while the correct answer is "5 minutes") and "24 days" for the third question (while the correct answer would be "47").

This initial answer is proposed to have two dimensions: the answer itself, and a *Feeling of Rightness* (FoR) that accompanies that answer**.** The Feeling of Rightness has been studied using a two-response paradigm in which reasoners give quick, intuitive answers

(Type 1 processing) to problems, rate their Feeling of Rightness, and then reconsider (Type 2 processing) their answers (Thompson et al, 2011; 2013; Thompson and Johnson, 2014; Bago and De Neys, 2017). When the Feeling of Rightness is strong, it is a signal that further reconsideration is not required; consequently, reasoners spend little time rethinking their answer and are unlikely to change their minds. In contrast, a weak Feeling of Rightness is accompanied by longer periods of reconsideration and a higher probability of changing answers. Importantly, because Feelings of Rightness are derived from cues that may be poorly correlated with accuracy, reasoners may be led to wrongly accept their initial intuitions with little reconsideration.

The second extant model is called Diminishing Criterion Model, and addresses the relationship between thinking time, Intermediate Confidence, and Final Confidence (Ackerman, 2014)**.** Because reasoning and problem solving take place over an extended period of time, participants' assessment of their performance and the possibility of success is constantly updated. To study this process, reasoners are asked to give Intermediate Confidence ratings every few seconds until they decide on an answer, at which point they rate their Final Confidence. As with the Feeling of Rightness, the first such judgment in the series is a good predictor of the amount of time that reasoners spend on problems and intermediate confidence tends to increase over time (Thompson, 2011; Ackerman, 2014; Metcalfe and Wiebe, 2017). However, according to the Diminishing Criterion Model, as time passes, participants become more and more willing to give less confidently held answers: early on, participants usually only provide answers when confidence is high; as time passes, they appear to compromise their standards and give answers in which they are less confident. Their degree of Final Confidence can be as low as 20%, even when participants are given the option to opt out of answering, by responding “I don’t know”. Thus, people are willing to give low confidence solutions even when they could give up. In conclusion, it has been argued that an important direction for future research is to investigate the control functions of the monitoring judgements described above (Ackerman & Thompson, 2017).

Bases of metacognitive judgments

As already specified, Meta-reasoning monitoring processes give rise to states of certainty and uncertainty. It is widely accepted that metacognitive judgments are based on heuristic cues, which are informed by beliefs and experiences associated with problem solving, and do not necessarily reflect actual performance. As such, the degree to which our monitoring processes are reliable is determined by the validity of the cues on which they are based (Koriat, 1997). For instance, a robust finding in meta-reasoning is that *fluency,* the perceived ease of responding, is a pervasive cue to certainty. For example, answers that come to mind quickly, engender a strong Feeling of Rightness and Final Confidence, regardless of answer’s accuracy (Thompson et al., 2013; Ackerman & Zalpanov, 2012; Thompson & Morsanyi, 2012). While the ease with which answers come to mind can be a proxy for problem difficulty, it may also be misleading. Consequently, judgments such as the Feeling of Rightness and Final Confidence may be poorly correlated with accuracy, because they are based on cues that are only partially correlated with accuracy (Thompson et al.; 2011, Ackerman & Zalmanov, 2012; 22, Shynkaruk & Thompson, 2006). Examining how these judgments dissociate from accuracy provides researchers a tool for discovering the heuristic cues that give rise to feelings of certainty. We note that it is widely assumed that reliance on heuristic cues is *implicit*, in that reasoners may sense a state of certainty or uncertainty, but not understand the origins of this feeling (Koriat & Adiv, 2016). Despite the broad acceptance of this assumption, recent discussions highlight interactions between implicit and explicit monitoring processes. These discussions are important both theoretically and practically. For example, a potentially important step to improving reasoning is to understand how people's beliefs about the bases of their confidence affect their monitoring (Undorf & Erdfelder, 2015), as well as the degree to which those beliefs can be experimentally manipulated (e.g., Mueller & Dunlosky, 2017; Smith & Oyserman, 2015).

Relations between Meta-level Processes and Object-level Processes

Understanding the processes that give rise to confidence (or undermine it) are important in their own right, given the role that certainty plays in initiating action. But the Meta-Reasoning framework has also an important role to play in elucidating the nature of object-level reasoning processes. For example, one of the most surprising findings that has come to light using the two-response paradigm is that reasoners often do not change their answers during a period of reconsideration, which means that when the answer is correct, it was correct from the start (Thompson & Johnson, 2014; Newman et al., 2017). This finding has profound implications for theories of reasoning that rely on deliberate, analytic thinking to correct erroneous intuitions (Evans & Stanovich, 2013; Kahneman, 2011; Stanovich, 2011). Equally, the absence of deliberate thinking plays an important role in the explanation of many so-called reasoning biases. For example, the Cognitive Reflection Test is a case where most people have the ability to find the correct answer, but fail to do so nonetheless. That is, they fail to take the time to reconsider their initial response. This is essentially a metacognitive phenomenon which could stem from several sources:

1. the reasoner might have a strong Feeling of Rightness, which signals that further reconsideration is not necessary, and moves on (Thompson et al., 2011; 2013);
2. the Feeling of Rightness is weak, but nonetheless sufficient to meet the reasoners' current aspirational level (Ackerman, 2014);
3. the reasoner may not prioritize getting the answer correct, possibly because of time constraints, or because getting it right might require them to invest more time or effort than they are willing to (Ackerman, 2014; Thompson et al., 2013).

In addition to understanding why people terminate processing prematurely, a metacognitive analysis may help to understand cases where processing continues for too long. Many of the strategies posited to underlie reasoning processes are fast and frugal, in that people make decisions with relatively little information (Gigerenzer et al., 2011). However, the evidence shows that reasoners frequently continue to gather more information than needed (Newell & Shanks, 2013), even when they have to pay for the information and even when it is objectively useless. Why does this happen? One explanation might be that reasoners set an aspirational level of confidence and continue to gather information until they reach that level (Ackerman, 2014). Similar findings have been reported in other domains, such as perceptual decision making, where people have been shown to continue to accrue evidence that will inform confidence after they have made their decision (Moran et al., 2015).

Individual Differences in Meta-Reasoning

One of the overarching research question in meta-reasoning regards how individuals do differ in their ability to assess their performance. It has been shown that individuals' performance on one cognitive task correlates with how they do on other tasks, and that this association may be due to the contribution of general cognitive ability (Stanovich, 2011). Recently, evidence has emerged showing that there is a similar positive manifold in both confidence and overconfidence people have in their performance across reasoning tasks (Stankov et al., 2014; Jackson & Kleitman, 2014). In contrast, measures of resolution (i.e., the ability to discriminate right from wrong answers) show less consistency across measures (Jackson et al., 2016), although reasoners who show good resolution tend to show better performance (Jackson & Kleitman, 2014). Confidence has been found connected to decision-making styles, observing that confident reasoners take actions that are congruent with the decision they made, regardless of whether it was accurate (Jackson & Kleitman, 2014; Jackson et al., 2017). In particular, people who are overconfident act when they should not (making so-called errors of commission), whereas those who are underconfident fail to act when they are correct (making errors of omission). A related phenomenon is that those who do poorly at a task tend to overestimate their performance, while those who do well tend to underestimate it (Dunning et al., 2004). This finding has been recently generalized to reasoning tasks: people who scored poorly on a standardized battery of critical thinking problems (Toplak et al, 2011) were also more likely to overestimate their performance on the Cognitive Reflection Test, and to over-estimate their disposition for analytic thinking on self-report measures. An open question is the extent to which gender and cultural variability in reasoning are associated with variability in meta-reasoning processes (Blaise et al., 2005):

for instance, we know that men tend to be more confident than women when solving mathematics problems, even when there is no difference in performance (Morony et al., 2013), and that decision-making styles vary across cultures (Haidt, 2012; Henrich et al., 2010). Even within a given culture, decision-making styles differ between those who are politically liberal vs. conservative and those who are more or less religious (Pennycook et al., 2014; Shanhav et al., 2012; Gervais & Norenzayan, 2012).

Improving meta-reasoning to improve reasoning

Given that people's monitoring judgments (and the subsequent allocation of time and effort) are mediated by cues that are not always well calibrated with accuracy, clearly, having well-calibrated monitoring processes that reliably inform us when we need to rethink a situation is a critical aspect of successful reasoning. Data from educational contexts, for instance, suggest that feedback about the accuracy of learners' confidence may both increase test performance and reduce overconfidence (de Bruin et al., 2017; Kleitman & Costa, 2014; Dunlosky et al., 2011). Similarly, training university students how to solve syllogisms that were particularly challenging reduced overconfidence, even if that did not improve their ability to discriminate right and wrong answers (Prowse Turner & Thompson, 2009). Some evidence show that solving logic problems under free time, rather than under time pressure, can also reduce overconfidence (Sidi et al., 2017), as well as framing the task as the primary task, rather than a training phase. Clearly, despite different kinds of preliminary evidence that monitoring accuracy can be improved, much work is still needed in order to determine which interventions are likely to be effective and in what circumstances.

Thesis overview

The aim of the current thesis is to investigate the mechanisms underlying the formation of states of certainty or uncertainty in reasoning. The research presented here can be subdivided into two main parts. The first part (Study 1 and 2) will focus on the contextual features of a reasoning or decision-making situation, with particular attention to the role of feedback information, which has not been widely taken into consideration in these fields. Indeed, while some attempts to examine feedback effect have been performed on reasoning processes (e.g. Ball, 2013), to our knowledge, this is the first study aiming to identify feedback effect on metareasoning. In study 1, different patterns of responses styles were found between participants receiving information about their incorrect answers, participants receiving information about their correctness and a control condition. Moreover, some post-hoc interpretations provided reason to examine the role of feedback anticipation, or expectation, on the engagement in Type 2 processing, which has been taken into account in Study 2. Despite little evidence that such external manipulations might affect thinking processes and confidence levels, meta-reasoning components showed to be quite independent from these external sources of information.

Thus, the second part of the research (Study 3 and 4) focus on the individual characteristics of a reasoner. While the study of individual differences is quite rich in most sub-fields of psychology, in fact, relatively little is known with regard to metacognition in reasoning. This might be due to the fact that a meta-cognitive approach in reasoning and decision-making is itself quite recent, but, on the other hand, the lack of studies contrasts with the observation that a broad range of researches has already focused on individual differences in reasoning (on an *object*-level). In Study 3, we began our investigation considering a major distinction between so-called rational thinking disposition and intuitive thinking disposition, finding some interesting relation between these individual features and reasoning and meta-reasoning components. In Study 4, we examined in more depth the role of specific features, related to people's proneness to experience regret and their satisficing and maximizing tendencies. The latter, in particular, showed to be predictive of people metacognitive confidence. Overall, this thesis adds to debate in the psychology of higher cognition, bringing new evidence that a metacognitive approach in the field would be useful for reaching new insights.

Two-response paradigm

In order to examine how participants monitor and regulate their performance over a series of problems, in this research, we adapted a procedure commonly used in the meta-reasoning literature, defined as the two-response paradigm (see Fig. 8). In the experiments following this method, participants provide two responses to each of a series of reasoning problems. For the first response, participants are told that the final interest is in studying reasoners' intuitions, thus they get instructed to give the first answer that come to mind. Considering psychological models of dual process in higher cognition, this initial response presumably reflects the outcome of Type 1 processing, with minimal Type 2 analysis. This assumption is based on the findings of several studies indicating that fast responses are more likely than slow responses to reflect the output of intuitive Type 1 processes (De Neys, 2006b; Evans & Curtis-Holmes, 2005; Finucane et al., 2000; Roberts & Newton, 2001; Tsujii & Watanabe, 2010). For example, when forced to respond quickly, reasoners are more likely to respond on the basis of conclusion believability than when allowed additional time to consider their responses (Evans & Curtis-Holmes, 2005;

Tsujii & Watanabe, 2010); they are also more likely to show matching-bias on Wason's selection task (Roberts & Newton, 2001) and to make choices guided by affect (Finucane et al., 2000). Similarly, intuitive, Type 1 responses require less time to produce than their reflected counterparts (De Neys, 2006b). Thus, requiring a fast response from participants should produce responses that are based largely on the output of Type 1 processes. They are told anyway to give the answer that was their first instinct or gut feeling and, as a manipulation check, they are asked to indicate whether or not they had, indeed, done so for each trial. Following this initial response, a subjective measure of confidence (*Feeling of Rightness, FoR*) is taken using a likert scale. The format of the scale varies somewhat through the different experiments, so that in some cases participants are asked to evaluate their sense of certainty on a 5- or 7-points-scale, in others from 1 to 100.

In the two-response paradigm, to measure Type 2 engagement, participants are allowed as much time as needed to produce their second and final answer to the problems. Although the instructions are tailored to the specific tasks that participants complete, they all indicate that participants should be sure at this point that they had taken their time and thought about the problem carefully. From this, three measures of Type 2 engagement are delivered. The first measure is the degree or probability of change from the first answer to the second answer. A change of answer would indicate that some additional analysis have taken place and should therefore be a reliable index of Type 2 thinking. Nevertheless, while a change of answer should reliably indicate Type 2 engagement, failure to do so is not evidence for the absence of Type 2 engagement. That is, there is reason to believe that at least some Type 2 thinking is directed at rationalising the initial response (e.g., Evans, 1996; Shynkaruk & Thompson, 2006; Stanovich, 2004, 2009; Wilson and Dunn, 2004). Thus, it is also measured the amount of time spent re-thinking each problem, because, given that Type 2 processes are assumed to be deliberate, time consuming processes, the amount of time spent engaging in a problem should be a reliable index of the extent of Type 2 processing (De Neys, 2006b). A third measure is a traditional measure of analytic engagement, namely whether or not the final answer is correct by a relevant normative standard. Such measures are presumed to reflect successful application of the rules of probability or logic, and success by these standards is typically more likely among those of high cognitive or working memory capacity (De Neys, Schaeken, & d'Ydewalle, 2005a; De Neys & Verschueren, 2006; Stanovich, 1999) and thus thought to be a signature of effortful, deliberate Type 2 processes. We note however that, given that Type 2 processes may also be engaged to produce normatively incorrect responses (Evans, 2007b; Stanovich, 2009) and that normatively correct responses may be produced by non-analytic processes (Gigerenzer, Todd, & the ABC Reasoning Group, 1999; Oaksford & Chater, 2007), this latter measure might be the least reliable indicator of Type 2 engagement. As a final point, a subjective measure of confidence (*Final Judgment of Confidence*, *FJC*) is taken again, using usually the same scale used for the FoR.

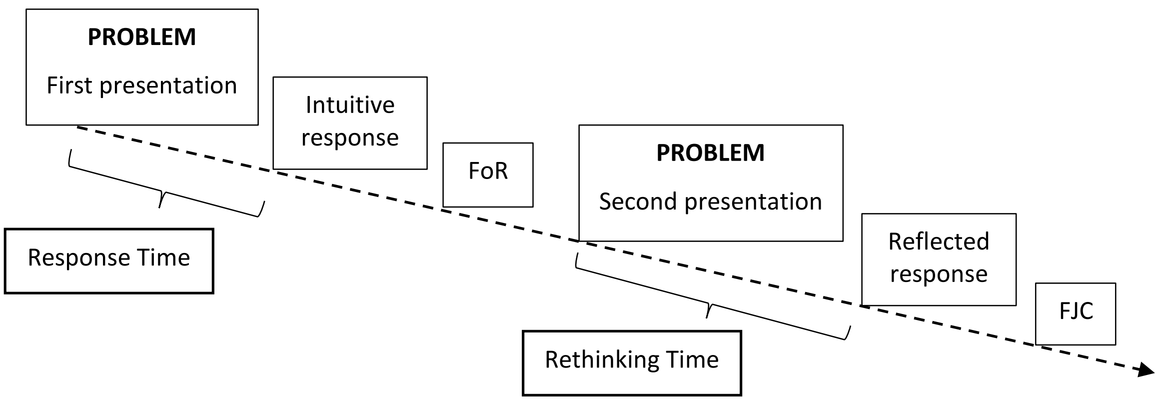

Fig. 8: A basic chart of the two-response paradigm adopted in the study.

CHAPTER 3

Feedback effects on reasoning and meta-reasoning

Researchers have been studying cognitive bias empirically with reasoning problems in which an intuitively cued heuristic response conflicts with elementary logical principles. Although it is well established that our thinking is often biased, the precise nature of this bias is less clear. Numerous factors have been identified and different authors have expressed different views on the importance of each factor to explain the bias (De Neys & Bonnefon, 2013), nevertheless these different views entail subtle processing differences that can be hard to disentangle empirically. In this study, I focus on a simple manipulation, the impact of basic response feedback (i.e., telling participants whether their solutions are right or wrong), in order to verify whether this can take some insight into the research on reasoning and meta-reasoning. This minimal response feedback is a basic correct/incorrect assessment that is presented as outcome to a reasoner after they have provided their solution to a problem. As a matter of fact, in many situations people receive feedback for their decisions in the form of outcomes of actions or observations. Their characteristics might depend on the environment in which decisions are taken, but an optimal decision-making often relies on the ability to improve decisions based on the evaluation of feedback. Indeed, feedback is considered of prime importance in the field of expertise, with several researchers investigating learning processes in educational domains and at workplaces (e.g. Gielen et al., 2010). Moreover, its role was extensively studied in research about decision-making under risk conditions: for example, Brand and colleagues (2009) reported that feedback interact with intelligence and strategy application to improve performance on a gambling task, and, in line with dual process theories (Evans, 2003; Kahneman, 2003; Reyna, 2004), the authors suggested that feedback is processed following either a “cognitive route” or an “emotional route” (Brand, Labudda & Markowitsch, 2006). According to their model, on the cognitive route, information related to feedback is used in controlled cognitive processes, such as rethinking strategies. Executive functions and working memory (Type 2 processing) can integrate the available information and support the development of a decision-making strategy based on this information. Specifically, through Type 2 processing, individuals can check the outcome of a current decision-making strategy, assess the available options, and potentially revise the strategy (Schiebener & Brand, 2015). The emotional route concerns reactions in the periphery of the body, so that, as suggested by the somatic marker hypothesis, feedback affect the limbic system and lead to changes in somatic activity (Bechara & Damasio, 2005; Damasio, Everitt, & Bishop, 1996). When facing a decision situation that had previously led to negative outcomes, for instance, the reactivation of particular somatic reaction can autonomously generate a feeling of liking or disliking a decision option, itself warning the individual and acting as a basis for subsequent intuitions (Bechara et al., 1997).

Even though dual-process theories have been applied to explain two types of feedback processing, like in researches mentioned above (Brand et al., 2006), at present, the relationship between feedback provided in a specific decision situation and the type of processing (i.e. Type 1 or Type 2) on which one later rely is still unclear. Besides, feedback has not been deeply taken into account when considering their possible effect on meta-cognitive processes. Although there are some isolated exceptions (e.g., Ball, 2013; Zizzo, Stolarz-Fantino, Wen, & Fantino, 2000), such feedback is usually not presented in research on reasoning and thinking bias (Ball, 2013; Evans, 2002; Kahneman, 2011). Hence, participants are typically not told whether their response is correct or not. However, in many daily life situations we do find out whether our decisions were correct, and in other fields, such as perception and memory research, presenting performance feedback is a common procedure that has sometimes been shown to boost performance (e.g., Ball, Hoyle, & Towse, 2010; Chun & Wolfe, 1996; Donnelly et al., 2007; Jensen Hays, Kornell, & Bjork, 2010). Similarly, the improvement of reasoning performance is one of the issues called into question by the meta-reasoning approach, where Ackerman and Thompson (2017) suggested to examine how *monitoring* abilities (and hopefully *control* abilities too) might be influenced and by which factors, in order to identify the right circumstances making it possible for mental effort to get effectively managed, reducing overconfidence and cognitive biases. In summary, there are quite a few reasons for why examining the impact of feedback on reasoning characteristics, subsequent performance and confidence might be useful. Some broad questions motivating this study are: what makes people feel sure, or not, about their intuitions? And, how do previous experiences affect the way people make a decision? More specifically, are people able to use relevant feedback information in order to distinguish situations in which following intuitions is a good strategy from those in which one should doubt on them and be more reflective? And how does feedback information affect the type of processing in which people will engage for their future decisions?

Thus, the first aim of this study was to analyze how feedback information might affect the way people tend to rely on their intuitions or decide to reflect more. To illustrate the point, consider the popular view that attributes bias to a so-called *storage failure* (De Neys & Bonnefon, 2013) or *mind gap* (Stanovich, Toplak, & West, 2008). The idea is simply that people are biased and give the biased response on reasoning tasks because they lack the necessary knowledge to solve the problem correctly. That is, the required logical principles would not be stored in their memory, and therefore could not be activated to achieve the correct response. In other words, one gives the incorrect response because one doesn’t know how to reason in order to find the correct response. Based on this view, one would not predict that performance feedback will be helpful. Indeed, simply telling you that a response is correct or not does not give you any explanation or tutoring of the principles that you are not familiar with. Hence, it cannot help you to suddenly acquire them. Consequently, if this minimal feedback allows you to correct yourself and boost performance on subsequent problems, this implies that you must have known the principles all along, and bias would need to be attributed to another factor than a mere mind gap. One such popular alternative factor that has been proposed as a key cause of bias is what De Neys and Bonnefon (2013) have referred to as a *monitoring failure* or *detection failure*. According to this view, the problem is not that people have not stored the relevant knowledge but rather that they do not use or activate it when faced with the reasoning task. Consequently, people will not detect that their intuitive answer is logically questionable and fail to engage in more deliberate reasoning that could allow them to rectify or correct the intuitive response (e.g., see Kahneman, 2011). This view can account for a positive impact of feedback: every time people answer erroneously, the feedback can serve as a simple warning or alarm cue that will signal the need for more deliberate reflection on the subsequent problems. In other words, feedback might help because it gives you a wake-up call and makes you realize you need to start paying closer attention and think harder. Hence, feedback might help because it affects your metacognitive processes. Clearly, in addition to examining whether feedback works it is also important to identify why it works. As sketched above, one possibility is that feedback is effective because it will indirectly boost deliberate thinking, by directly influencing one’s monitoring and control processes. However, an alternative possibility is that feedback works because it allows you to bypass deliberate thinking. For instance, the way feedback (eventually) works, may be related to the number of response options: consider a problem involving open questions, like the CRT. In this scenario, negative feedback does not necessarily give access to the correct answer. Differently, if a problem involves only two alternative responses (e.g. True vs. False, which is the case of our first experiment; see next section), negative feedback might make you immediately move to the correct answer. This does not imply a more careful and analytical thinking. Therefore, in order to understand whether such feedback has been able to activate or not a more analytical thought, only the subsequent performance in similar problems will need to be considered as discriminating.

Study 1

Introduction

In this first study, we observed how people monitor and adapt their decision-strategy over a sequence of problems, during which they receive feedback (set according to the experimental design, see Procedure in the next section). A particular category of classical logic problems was used, more specifically concerning *conditional reasoning*, which is well-studied in the psychological literature (e.g. Klauer, Beller & Hutter, 2010; Schroyens et al., 2001) and present some formal characteristics that allow to define an individual's decision behavior: in these problems, in fact, evaluations of the inferences are substantially affected by both the logic validity of the arguments and the believability of the contents. These two dimensions are linked to the Dual Process Theories, since, as described before, the tendency to evaluate the validity of an argument on the basis of the agreement with the conclusion (i.e. *belief-bias*) is mostly associated to an intuitive solution based on Type 1 processes (Evans & Curtis-Holmes, 2005), while analytical Type 2 processing should be mainly implied in recognizing a possible interference between believability and validity, and with providing solutions that focus on logic validity. Nevertheless, since both a solution based on believability and one based on logic validity can be the result of intuitive as well as analytic processes, we consider responses speed, in addition to accuracy, to evaluate Type 1 and Type 2 extent in this study.

Adopting a two-response paradigm, participants in this study gave two answers to each problem: an intuitive response, based on the first solution that came to mind, and a second response, given after having more accurately reflected. Considering that Type 2 processes are thought to be always at least minimally involved in producing a response (Kahneman, 2003), "if only because the response is made available to working memory prior to its emission" (Thompson et al., 2011, p. 134), and that they are assumed to be time-consuming processes, we considered the amount of time spent to provide the intuitive responses, and the time spent rethinking about those solution, as reliable indexes of the extent of Type 2 processing (De Neys, 2006b). Moreover, since feedback have never been studied in relation to the type of processing (intuitive Type 1 or reflective Type 2) to which they are given, we tested the effect of feedback information, specifically provided in response to Type 1 decisions, hypothesizing that:

Hy1) the availability of feedback information may affect the mental processes involved in a decision situation. Receiving feedback would cause a different activation of monitoring processes and a different deliberate engagement in analytical thinking in the subsequent decision-making. In comparison to decision situations where no feedback is given, the speed of intuitive decisions, the confidence accompanying such decisions, and the time spent rethinking on a solution might change, according to the valence of feedback. In particular,

Hy2) different kinds of feedback information, such as positive feedback that confirm one's intuition correctness, or negative feedback that underline a mistake, should produce different effects on the tendency to rely on intuitive thinking in a sequence of problems. Positive feedback ("You are right") given to correct intuitions should bring about faster decisions, higher confidence levels and shorter time spent rethinking about one's intuitive solution; at the opposite, negative feedback ("You are wrong") given in response to wrong intuitions should produce slower decisions, lower confidence levels and longer times spent rethinking about such intuitive solutions.

Method

Participants

The research has been publicized via alerts in message boards and social networks, and a total of 106 university students (46% females, age ranging from 21 to 33 years old, *M* = 26.38, *SD* = 3.00) were recruited for the study. All participants signed a written consent form before the study began, and their participation was voluntary. The study was approved by the Ethics Committee of the University of Bologna.

Materials

Each trial was composed of a conditional statement in the form "If *p*, then *q*" (e.g. "If Mark steals, then he breaks the law"), accompanied by an inference that had to be assessed valid or invalid as a logic consequence of the presented rule and information. Twelve conditional sentences were prepared, all of them including common contents or describing everyday events. Each of these sentences was used to create four trials, referring to the four inferences that are commonly used in research on reasoning: Modus Ponens (MP), Modus Tollens (MT), Affirmation of the Consequent (AC) and Denial of the Antecedent (DA). Thus, we obtained a total of 48 tasks, whose validity precisely depended on the type of inference that was accompanied and had to be evaluated: as well-known, MP ($p \rightarrow q$, e.g., "Mark stole. So he broke the law") and MT (not-q → not-p, e.g., "Mark did not break the law. So he did not steal") are valid inferences, while AC ($q \rightarrow p$, e.g., "Mark broke the law. So he stole") and DA (not-p → not-q, "Mark did not break the law. So he did not steal") are invalid ones. At the same time, like Thompson and colleagues (2011), we manipulated the believability of the inferences, so that half of them included believable content, while the other half not. Believability and logic validity varied orthogonally in the whole group of trials (see Fig. 9).

Sufficient conditions (MP and MT sound correct, while AC and DA not)

1. If the car is out of gas, then it stalls.

   Examples:

   MP) The car is out of gas. Thus, it stalls.
   MT) The car did not stall. Thus, it is not out of gas.
   AC) The car stalled. Thus, it is out of gas.
   DA) The car is not out of gas. Thus, it does not stall.

2. If the dog tracks mud on the floor, then the floor is dirty.
3. If a crystal glass falls, then it breaks.
4. If a person has the flu, then she's ill.
5. If an animal is a robin, then it is a bird.
6. If a vehicle is a bicycle, then it has two wheels.

Necessary conditions (MP and MT sound incorrect, while AC and DA sound correct)

7. If a cell phone has a charged battery, then it works.

   Examples:

   MP) The cell phone has a charged battery. Thus, it works.
   MT) The cell phone does not work. Thus, it has not a charged battery.
   AC) The cell phone works. Thus, it has a charged battery.
   DA) The cell phone does not have a charged battery. Thus, it does not work.

8. If a fruit is a citrus, then it is a lemon.
9. If a person is 18, then she can drive.
10. If it's night, then the sky is starry.
11. If a figure has four sides, then it is a square.
12. If an animal has spines, then it is a hedgehog.

Fig. 9. The list of conditional statement used in the experiment. For each of them, the four inferences used in the classic reasoning research were created. As shown by the examples, sufficient conditions produce inferences for which believability and logical correctness are consistent. Differently, necessary conditions produce inferences for which believability and logical correctness conflict with each other.

Procedure

The experiment was programmed and run using E-Prime (Schneider, Eschman, & Zuccolotto, 2002) and presented on a high-resolution computer monitor. Participants were tested, in presence of the experimenter, through individual laboratory sessions lasting approximately 35 min. Before beginning, some general instructions illustrated the reasoning task, giving an example and explaining how to give the responses. Participants selected between two response options that appeared below each problem: if they judged that the presented inference followed logically from the given information, they had to choose "true", otherwise they had to select "false".

A two-response paradigm (Thompson et al., 2011; see previous section, pag. 43) was adopted. After reading the instructions, the participants completed five practice problems and before starting the test trials, the instructions were summarized and presented again.

The participants were randomly divided into three Groups (PFC: Positive Feedback Condition, NFC: Negative Feedback Condition, CC: Control Condition), representing the *between*-variable. All participants in the two Feedback Conditions had been previously instructed that, once in a while, after their Intuitive Response, they would have seen a screen telling if it was correct or mistaken, that this information was always reliable, and that just when this screen appeared they would have not been allowed to give another answer, but passed directly to the next problem. The 48 problems were actually presented in a sequence of three blocks (Step 1. Pre Feedback, Step 2. Feedback Administration, Step 3. Post Feedback), representing the *within*-variable. Every block was composed of 16 trials that were presented one at a time in a random order, and balanced for type, logic validity and believability of the inferences. In Step 1, participants did not receive any feedback, a feedback administration took place (only for the two Feedback Conditions) in Step 2, and in Step 3 feedback was not given anymore. Thus, the experimental design was 3 × 3 mixed (Fig. 10). While, in the Control Condition, participants were never given any feedback, participants in the PFC, in Step 2, received a positive feedback (a screen telling "You're right"), only when their Intuitive Responses corresponded to the normatively accurate answer. Similarly, in this phase participants in the NFC received a negative feedback (a screen telling "You're wrong"), only when their Intuitive Responses corresponded to the normatively inaccurate answer (Fig. 11).

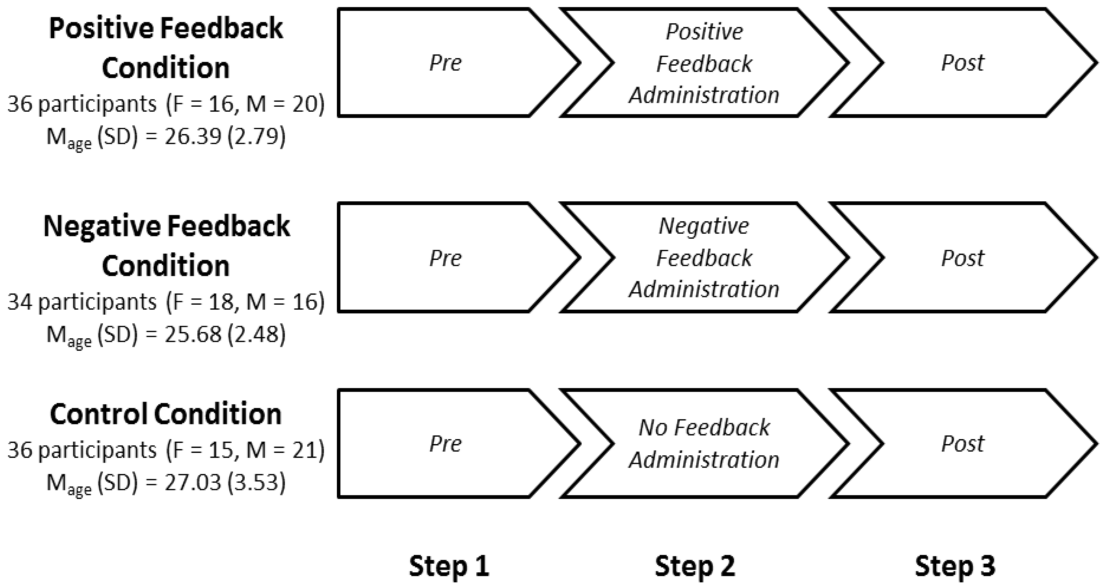

Fig. 10: The experimental design. Descriptives of the participants in each Condition are presented.

In order to verify the effect of feedback administration in the proposed decision situation, we collected data about Confidence (on a 7-point-scale: "At the time I provided my answer I felt: 1 = guessing; 7 = certain I'm right"), Reflected Responses Accuracy and Rethinking Times in Step 1 and 3, namely before and after the Feedback Administration, when every participant had to solve the tasks always providing a second response, independently from the accuracy of the intuitive one. Data about Intuitive Responses Times and Intuitive Responses Accuracy, instead, were collected in all three Steps, which also allowed to examine participants' decision behavior in Step 2.

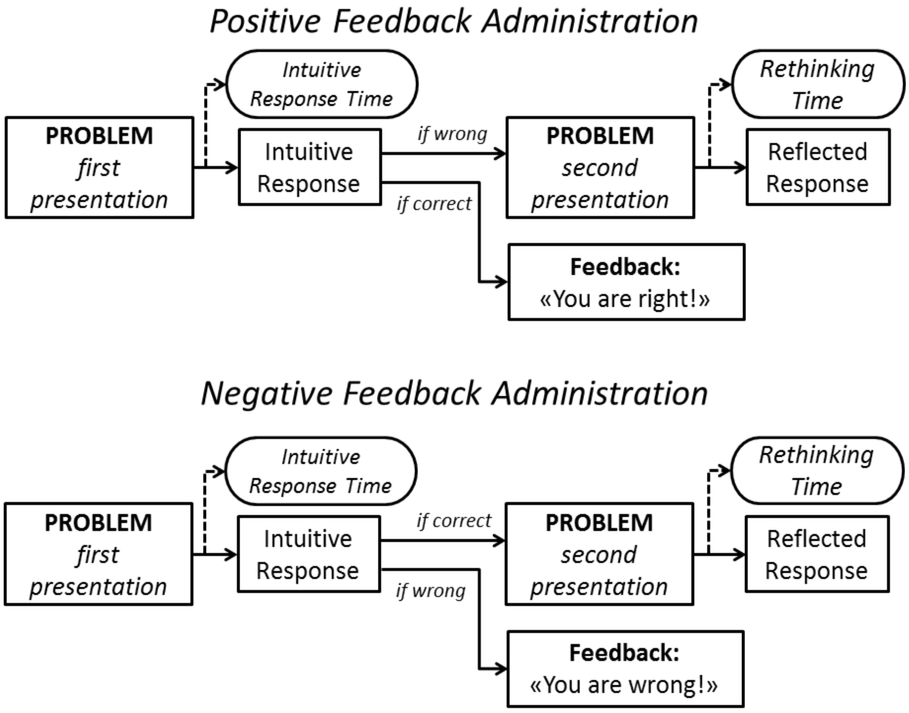

Fig.11: The procedures adopted to provide feedback information in Step 2.

Results

Coding

Gender has been coded assigning +1 to females and -1 to males. All RT were measured in milliseconds, and converted to $\log_{10}$ before proceeding with analyses.

Descriptives and demographic variables

In the following Table, data about the performance of the different groups of participants in the three phases of the experiment are shown:

		Step 1 M(SD)	Step 2 M(SD)	Step 3 M(SD)
Intuitive Response Time	PFC	3.774 (.148)	3.688 (.134)	3.672 (.150)
	NFC	3.791 (.111)	3.780 (.123)	3.741 (.131)
	CC	3.696 (.132)	3.673 (.141)	3.656 (.139)
	All	3.753 (.137)	3.712 (.140)	3.688 (.144)
Rethinking Time	PFC	3.815 (.235)		3.625 (.299)
	NFC	3.803 (.291)		3.562 (.395)
	CC	3.878 (.234)		3.749 (.286)
	All	3.832 (.254)		3.647 (.335)
Intuitive Response Accuracy	PFC	.55 (.12)	.55 (.09)	.54 (.10)
	NFC	.52 (.10)	.49 (.12)	.54 (.11)
	CC	.57 (.15)	.61 (.15)	.61 (.16)
	All	.55 (.12)	.55 (.13)	.57 (.13)
Reflected Response Accuracy	PFC	.57 (.10)		.57 (.11)
	NFC	.55 (.11)		.56 (.13)
	CC	.62 (.15)		.66 (.18)
	All	.5820 (.12)		.5973 (.15)
Feeling of Rightness (Type 1 confidence)	PFC	5.24 (1.14)		5.44 (1.14)
	NFC	5.56 (1.08)		5.67 (1.00)
	CC	5.28 (.91)		5.28 (1.11)
	All	5.36 (1.05)		5.46 (1.09)
Final Judment of Confidence (Type 2 confidence)	PFC	5.97 (.91)		5.99 (.87)
	NFC	6.20 (.89)		6.22 (.76)
	CC	6.20 (.68)		6.25 (.71)
	All	6.12 (.83)		6.15 (.79)
Response Consistence	PFC	.85 (.12)		.88 (.08)
	NFC	.86 (.10)		.90 (.08)
	CC	.84 (.14)		.86 (.10)
	All	.85 (.12)		.88 (.09)

In order to assess how age and gender might have affected participants' responses speed, accuracies and levels of confidence, we performed a series of regression analyses: Age did not show significant effects on Intuitive Responses Times in any phase of the experiment, *p*s varying from .74 to .99. Age did neither affect Rethinking Times, *p*s varying from .58 to .61. Also, it did not affect participants' accuracy for the intuitive responses, *p*s varying from .25 to .99, nor the accuracy of the reflected responses, ps varying from .35 to .66. Analyses on the effects of Age on metacognitive component, specifically the Feeling of Rightness (confidence after the intuitive, Type 1 responses) and the Final Judgment of Confidence (after the second, Type 2 responses in each task) showed that FoR was not affected by the age of participants, *p*s varying from .61 to .68. It did not show significant effects on FJC, *p*s varying from .20 to .12.

Gender showed a significant effect on the Intuitive Responses Times only in Step 1, F (1,105) = 4.12, adj. R^2 = .03, $p < .05$, showing that males provided faster responses in this part of the experiment. But this difference was not found significant in Step 2 and 3, *p*s varying from .06 to .09. Gender did not affect Rethinking Times in any phase of the experiment, *p*s varying from .53 to .16. It did not show significant effects on accuracies of the intuitive responses in Step 1, $p = .20$, but it showed significant effects on Intuitive Responses Accuracy in Step 2, F (1,105) = 11.81, adj. R^2 = .09, $p < .001$, and in Step 3, F (1,105) = 6.15, adj. R^2 = .05, $p < .05$, showing that males were more accurate than females in these phases of the experiment. Similarly, Accuracy of the reflected responses showed to be affected by Gender in Step 3, F (1,105) = 5.64, adj. R^2 = .04, $p < .05$, with males providing more accurate Type 2 responses, but not in Step 1, $p = .09$. Analyses on the effects on metacognitive component showed that FoR was not affected by Gender in any Step, *p*s varying from .06 to .15. Differently, FJC was affected by Gender both in Step 1, F (1,105) = 12.09, adj. R^2 = .10, $p < .001$, and in Step 3, F (1,105) = 8.74, adj. R^2 = .07, $p < .01$, showing higher levels of Final Confidence reported by males rather than by females.

Considering these results, Gender has been used as a covariate in the subsequent analyses regarding Intuitive Responses Times, both Intuitive and Reflected responses' Accuracy, and Final Judgment of Confidence.

Preliminary analyses on Feedback amount

Considering the feedback administration part, the amount of feedback received by each participant in a Feedback Condition varied according to their performance, and they could be given up to 16 feedback. Significant differences on the amount of feedback received were not found between participants in the PFC (M = 8.72, SD = 1.45), and participants in the NFC (M = 8.15, SD = 1.99), F (1, 69) = 3.53, p = .07. Finally, in order to verify if feedback amount affected participants' decision behavior, we performed a regression analyses considering the number of received feedback as independent variable and the differences between Step 3 and Step 1, regarding both Intuitive Responses Times and Rethinking Times, as dependent variables. The results neither showed a significant effect of feedback amount on Intuitive Responses Times, p = .93, nor on Rethinking Times, p = .17. The amount of feedback did not determine any significant variation of Accuracy from Step 1 to Step 3, for Intuitive Responses, p = .55, nor for Reflected Responses, p = .48. Finally, not FoR nor FJC variations from Step 1 to Step 3 were found significantly related to the amount of feedback received by participants (FoR: p = .91; FJC: p = .59). Thus, we concluded that the amount of feedback that participants received (which could not be controlled by the experimenter, as it depended on participants' performance) did not affect any of our dependent variables.

Feedback Effects on reasoning (object-level)

Response Times: In order to analyze the effect of feedback on Intuitive Responses Times, we performed a 3 × 3 repeated measure ANOVA, using the three Steps as within-subject factor, the three Groups as between-variable and Gender as covariate. A main effect of

Step emerged from the analysis, F (2, 101) = 13.62, $p < .001$, partial-η^2 = .21. As shown in Figure 12, participants' Intuitive Responses Times gradually decreased over the experiment: Bonferroni post-hoc analysis showed they were significantly shorter in Step 2 than in Step 1, $p < .001$, and got even shorter in Step 3, $p < .05$. Moreover, a Step × Group interaction emerged, F (4, 204) = 5.82, $p < .001$, partial-η^2 = .10, showing that the Intuitive Responses Times' drop was different between the three groups. A Bonferroni post-hoc analysis revealed significant drops from Step 1 to Step 2 for participants in the PFC, $p < .001$, and in the CC, $p < .05$, but not for participants in the NFC, $p = .48$; significant drops from Step 2 to Step 3 emerged for participants in the NFC, $p < .01$, and in the CC, $p < .05$, but not for those in the PFC, $p = .26$. Moreover, significant differences between the Groups were found in Step 1, where both the Positive and the Negative Feedback Condition showed longer Intuitive Responses Times than Control, respectively $p < .05$, and $p < .01$; in Step 2, where participants in the NFC provided slower responses than both participants in the PFC, $p < .05$, and CC, $p < .01$; in Step 3, where participants in the NFC showed longer Intuitive Responses Times than CC, $p < .05$.

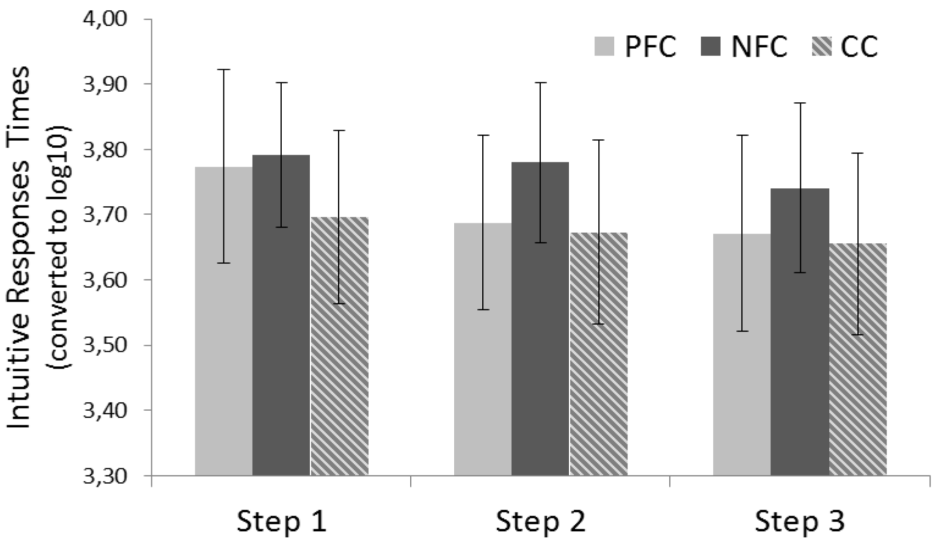

Fig. 12: Feedback effect on Intuitive Responses Times

In order to analyze the effect of Feedback on Rethinking Times, we performed a 2 × 3 repeated measure ANOVA, using Step 1 and Step 3 (where no feedback was provided) as within-subject factor, and the three Conditions as between variable. A main effect of Step emerged, F (1, 103) = 104.25, p < .001, partial-η^2 = .50, showing that Rethinking Times were significantly shorter in Step 3 rather than in Step 1, p < .001 (Fig. 13), and this effect was confirmed for all the three Groups in a Bonferroni post-hoc analysis, ps < .001. Moreover, a Step × Group interaction emerged, F (2, 103) = 3.13, p < .06, partial-η^2 = .05, showing that Rethinking Times' drop was different between the three groups, but post-hoc analyses did not show significant differences between the Groups neither in Step 1, p = .41, nor in Step 3, p = .056.

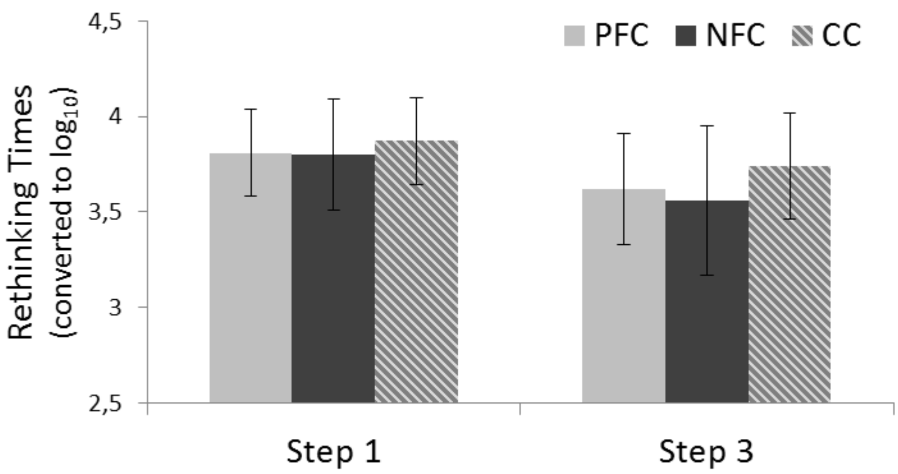

Fig. 13: Feedback effect on Rethinking Times

Accuracy: in order to analyze the effect of feedback on the Intuitive Responses Accuracy, we performed a 3 × 3 repeated measure ANOVA, using the three Steps as within-subject factor, the three Groups as between-variable and Gender as covariate. No effects of Step emerged from the analysis, p = .21. A significant difference was found between the

Control Condition and both the Feedback Conditions, *F* (1,102) = 6.27, *p* < .01, partial-η^2 = .11, showing that, opposite to what one might expect, participants who received feedback information (both about correctness or mistakes) were less accurate than the Controls. In detail, participants in the NFC performed worse than CC in Step 2, *F* (2,105) = 9.07, *p* < .001, partial-η^2 = .15, participants in the PFC peformed worse than CC in Step, *F* (2,105) = 4.00, *p* < .05, partial-η^2 = .07.

In order to analyze the effect of Feedback on Reflected Responses Accuracy, we performed a 2 × 3 repeated measure ANOVA, using Step 1 and Step 3 (where no feedback was provided) as *within*-subject factor, and the three Groups as *between* variable. Again, no effects of Step emerged from the analysis, *p* = .21.

Feedback Effect on monitoring processes (meta-level)

FoR: In order to analyze the effect of feedback on the Feeling of Rightness, we performed a 2 × 3 repeated measure ANOVA, using Step 1 and Step 3 as within-subject factor and the three Groups as between-variable. No effects of Step emerged from the analysis, *p* = .12.

FJC: similarly, in order to analyze the effect of Feedback on the Final Judgment of Confidence, we performed a 2 × 3 repeated measure ANOVA, using Step 1 and Step 3 as within-subject factor, the three Groups as between variable, and Gender as covariate. Again, no effects of Step emerged from the analysis, *p* = .77.

Feedback Effect on control processes (meta-level)

In order to analyze the effect of feedback on the control processes, we performed a 2 × 3 repeated measure ANOVA, using Step 1 and Step 3 as within-subject factor and the three Groups as between-variable. The dependent variable is an index that represents participants' tendency to provide consistent responses in intuitive (first response) and deliberate (final response) manner. Specifically, this valor could go from 0 to 1, where 0 represents a participant who changed answer for every task after her rethinking time, and 1 a participant who always confirmed her intuitive answer. A significant effect of Step emerged from the analysis, $F(1,103) = 8.387$, $p < .01$, partial-$\eta^2 = .08$, showing that participants' tendency to change answer after a period of reflection decreased in the final part of the experiment. Nevertheless, no significant differences were found between the three groups of participants, showing that such a change could not be explained by the influence of feedback administration.

Discussion

In the present work, we applied the definitions of intuitive and analytical thinking adopted by Dual Process Theories (Evans & Stanovich, 2013, Thompson, 2013), in order to examine a specific feature of a decision situation, the presence and the valence of feedback about one's intuitive decision. We analyzed the speed of decisions during the execution of a sequence of deductive reasoning tasks, aiming to examine how external information might mediate the way people rely on their intuitive thinking, rather than being more reflective. Examining participants' resolution processes, we gave emphasis to the time spent by participants to provide their intuitive responses, and to the time spent rethinking about these given answers, both measures considered directly correlated to the intervention of analytic processes and the engagement in deliberate reasoning (Type 2 processing). An initial set of considerations is made focusing on the specificity of the task we used in our study: in the experiment, in fact, we followed a two-response paradigm (Thompson et al., 2011) to present different classes of conditional reasoning tasks to participants. This procedure allowed to distinguish intuitive responses, that were given with the instruction to be fast and spontaneous (Type 1 processing), from analytic responses, for which participants could deliberately spend as much time as needed to rethink and be sure of their answer (Type 2 processing). Results showed that the time spent by participants to provide their intuitive responses progressively decreased throughout the different parts of the experiment: thus, in line with Default-Interventionist models (e.g. Kahneman, 2003; Evans, 2010a; Stanovich, 2011), Type 2 reasoning show to be more likely to intervene for decision situations characterized by novelty or difficulty. The experimental setting itself should fall inside this definition, while getting more used with the tasks seems to have produced a repetition-effect, gradually leading participants to hasten their decisions. At the same time, the results of this research showed some interesting relations between the availability of external information and the resolution processes involved in the tasks. First of all, we could infer that the presence of feedback information affected the way participants approached the tasks: in the present study, in fact, the most evident difference between Feedback Groups and Control, regarding Intuitive Responses Times, appeared at the beginning of the experiment, when those who knew they would have got information about their performance, needed longer times to provide the first solutions that came to their mind. This observation leads us to the conclusion that even before receiving specific feedback information, just knowing that one’s performance will be evaluated might favor the intervention of monitoring Type 2 processes, at least when facing reasoning tasks, for which a certain degree of reflection is supposed to be needed. Moreover, the results regarding Intuitive Responses Times also showed an important difference that is related to the valence of feedback. As soon as positive feedback administration started, intuitive responses took less time to be provided; differently, Intuitive Responses Times in the negative feedback condition decreased only after participants had finished the feedback administration. Hence, we suggest that positive feedback information, provided to intuitive decisions, might act as a positive reinforcement on individuals’ tendency to rely on intuitive thinking, speeding up their decisions. At the opposite, the results about negative feedback administration suggest that this external information might support a strategy monitoring and facilitate the engagement in Type 2 processing. A similar theme has been presented by Egan (2002), who distinguished between “confirmatory” and “corrective” feedback, arguing that through the former, individuals get informed whether they are effective in the way they are applying their reasoning skill, while the latter signal whether they have to improve. Nonetheless, our results showed that when people stop being told they are wrong, they seem to trust more their intuitions and haste their decisions. Thus, in a different way from positive ones, also negative feedback can act as a reinforcement on the tendency to rely on intuitive thinking (even if as a “negative reinforcement”, in its classical meaning of producing an effect from the avoidance, or the end, of a negative stimulus; Skinner, 1938). Previous researches (e.g. Shanks et al., 2002; Brand, 2008) found that providing feedback about decisions’ consequences can lead people to make more advantageous decisions in risky situations. The role of feedback has been considered particularly important in ambiguous situations, where a reasoner has no information about the consequences of a decision, and is seen as an important component for on-going decision making even in tasks with explicit rules, since feedback processing should support strategy developing or initialize a revision of the current strategy (Brand et al., 2006). Differently from these researches, we put attention to the type of decisions (intuitive vs. analytical) to which feedback is given, providing information limited to intuitively-taken decisions, and, in this study, participants' reasoned answers had quite a substantial consistence with their already-given intuitive ones, showing that Type 2 processes did not manage to override the Type 1 responses and confirming that, even if reflection can be induced through instructions (e.g. Markovits et al., 1996; Daniel & Klaczynski, 2006; Beatty & Thompson, 2012), both erroneous and correct reasoning can be the result of Type 1 and 2 processing (Pennycook & Thompson, 2012; Evans & Stanovich, 2013). These observations provide additional evidence to the idea that individuals might often engage in Type 2 deliberation with the aim to generate support for their intuitions (Evans & Over, 1996; Wilson & Dunn, 2004; Shynkaruk & Thompson, 2006; Stanovich, 2009). Thus, we find important to emphasize that Type 2 processes are engaged for more than only checking that intuitive outputs are acceptable, or override them when they are not: for instance, according to different authors (e.g. Pennycook et al., 2015), the engagement in Type 2 thinking (for example when reasoning hypothetically) cannot prevent the reasoner to focus on a faster intuitive output, and such an operation can activate a rationalization process that aim to justify that rapid response.

In this study, we were not able to identify any significant feedback effect showing it able to improve metacognitive monitoring processes (e.g. enhancing the ability to discriminate between an adequate intuition and the necessity to apply in deeper reflection) or to increase accuracy. Thus, as argued by Hogarth, Lejarraga and Soyer (2015), we highlight the importance of learning environments characteristics, as they can help identifying sources of bias as well as suggesting corrective procedures. Negative feedback in our experiment, for instance, provided information about inaccuracy, but gave no further explanation that could permit a better comprehension of one's mistake. These information, that do not really represent a "correction", but just a "warning", might themselves make the engagement in Type 2 thinking less likely, or more directed to rationalization and justification of one's intuition. Thus, we share previous suggestions (deBeer & Martensson, 2015) underlining that positive feedback, like compliments, might leave reasoners to their own devices, making them not know how to improve (Boehler et al., 2006), and that negative feedback and corrections on reasoning should be always accompanied by explanations about the nature of an error, and suggestions on how to improve, which should result more effective (McKimm, 2009).

In conclusion, this study provides further evidence for the idea that the characteristics of the context in which reasoning and decision-making take place (in particular, the availability of instructions that one's performance will be evaluated, as well as the specific properties of feedback information, like their confirmatory vs. corrective nature, and their capacity to switch from performance evaluation to the tutoring of reasoning principles), can significantly affect the use of Type 1 and Type 2 processes.

Study 2

Introduction

In Study 1, we started from wondering whether people can use feedback, for instance, to learn that their intuitive answers may not be appropriate. The stimuli that we adopted were conditional statements in various difficulty levels manipulated by inference type and believability, and the observed data pointed on overall reduction in time spent on each item in the course of the task, recognizing some differences between the conditions in the patterns of time reduction. Unfortunately, it was not clear that the experiment provided clear answers to the main question: on one side, as said above, it is difficult to tell, on the basis of a given response to conditional reasoning problems, whether it was produced by intuitive or deliberate processes. For that reason, a different kind of task will be used to continue our investigation. Specifically, the Cognitive Reflection Test (CRT) should be more suitable for this research, as it is known to arouse compellingly wrong intuitive answers. According to Frederick (2005), cognitive reflection can be conceptualized as "the ability or disposition to resist reporting the response that first comes to mind". This approach of reflectivity has been promoted by, among others, Toplak et al. (2011) who considered the CRT as a measure of *miserly processing*, referring to people's tendency to rely on heuristics instead of using more cognitively expensive analytical processes. The explanation of both of these research groups builds on the assumption that the key property of the CRT is that first an incorrect intuitive answer comes to the mind, and then late suppression mechanisms need to intervene and override the heuristic answer to be able to reach a normative solution by further deliberation. Hence, according to the most common understanding of the CRT, suppression of a first answer is a necessary step for good performance. These steps of the reasoning process make the CRT a paradigmatic demonstration of the fallibility of human thinking. Since its publication, the original paper introducing the CRT (Frederick, 2005) has been cited over 1900 times. The cause of its popularity is multifaceted: it possesses high face validity, it is easy to administer, it predicts decision performance in many different situations, and it correlates with a great number of other measures. Just to highlight a few examples, individuals with higher CRT scores are more disposed to avoid decision biases (Toplak, West, & Stanovich, 2011, 2014) and perform better on general ability measures (Liberali, Reyna, Furlan, Stein, & Pardo, 2012; Stupple, Ball, & Ellis, 2013). The CRT also predicts intertemporal behaviour (Frederick, 2005), risky choice (Cokely & Kelley, 2009; Frederick, 2005), conservatism (Pennycook, Cheyne, Seli, Koehler, & Fugelsang, 2012), and belief in the supernatural (Gervais & Norenzayan, 2012). In sum, CRT seems the most suitable measure for studying meta-reasoning processes in a dual process account.

Another relevant point, in Study 1 we observed that feedback manipulation had an impact on the initial, intuitive response times, and interpret this as an increase of the intervention of Type 2 processing: that is, what we found is that when they know they will get feedback, people reflect more, and this results in longer initial response times. However, while the results from the first study showed that the prospect of receiving feedback slows people down, this was found to affect only the intuitive responses, while no evident effects were found on rethinking times or on answer changes. Thus, feedback might have not affected traditional measures of deliberation, but instead prompted people to think longer before giving their first response, counteracting the instructions to respond intuitively. Starting from this observation, the focus of the second study will be on the verification of such “feedback anticipation” effect, examined in a new experimental set that includes a manipulation of the instructions.

Method

Participants

The research has been publicized through the Crowdflower platform, and a total of 122 responses were collected from English-speaking adults. Of 122 total responses collected, 85 (42 females, M_{age}= 39.35, SD = 13.5) were kept as valid, while 37 participants were excluded because they did not complete the experiment, or English was not the first language, or they reported a diagnosis of dyslexia, or gave a wrong answer to a validation test, or reported that they double-checked their answer instead of providing the first intuitive response that came to mind. Participants education level was high, with 1,2% participants having completed the secondary school, 28,2% having finished the High school, and 70,6% having finished the College or with a higher education level. All participants signed a written consent form before the study began, and the completion of the experiment was rewarded with 0.70$ per participant. The study was approved by the Ethics Committee of the University of Bologna.

Materials

Each trial was composed of a cognitive reflection problem, similar to the three included in the original CRT proposed by Frederick (2005). In the decades-long aim of psychological research to understand errors in human thinking, the CRT has become a pivotal tool to measure one type of cognitive ability or disposition: the capacity to suppress the “incorrect intuitive” answer and substitute it with the correct one. As anticipated in the introduction, in fact, CRT tasks trigger a misleading solution that the participants need to overcome before engaging in further reflection to arrive at the correct solution. Recently, extended versions of the CRT have been created (e.g., Baron, Scott, Fincher, & Metz, 2014; Primi, Morsanyi, Chiesi, Donati, & Hamilton, 2015; Thomson & Oppenheimer, 2016; Toplak et al., 2014), as the original three items of the CRT became increasingly well known to the public. Gathered from these new versions, the following nine problems were used in this study:

1) *A mountain-bike and a helmet together cost 550 dollars. The mountain-bike costs 500 dollars more than the helmet. How much does the helmet cost?*

   (heuristic response: *50$*; correct response: *25$*)

2) *If it takes 2 cats 2 minutes to eat 2 mice, how long would it take 20 cats to eat 20 mice?*

   (heuristic response: *20 minutes*; correct response: *2 minutes*)

3) *An autumn tree started losing its leaves. Every day, the number of leaves falling down doubles. If it takes 24 days for the tree to lose all the leaves, how long would it take for it to lose half of the leaves?*

   (heuristic response: *12 days*; correct response: *23 days*)

4) *If John can drink one barrel of water in 6 days, and Mary can drink one barrel of water in 12 days, how long would it take them to drink one barrel of water together?*

   (heuristic response: *9 days*; correct response: *4 days*)

5) *How many cubic feet of dirt are there in a hole that is 3' deep × 3' wide × 3' long?*

   (heuristic response: *27 cubic feet*; correct response: *none*)

6) *A man buys a pig for $60, sells it for $70, buys it back for $80, and sells it finally for $90. How much has he made?*

(heuristic response: *10$*; correct response: *20$*)

7) *If you're running a race and you pass the person in second place, what place are you in?*

   (heuristic response: *first*; correct response: *second*)

8) *A farmer had 15 sheep and all but 8 died. How many are left?*

   (heuristic response: *7*; correct response: *8*)

9) *Emily's father has three daughters. The first two are named April and May. What is the third daughter's name?*

   (heuristic response: *June*; correct response: *Emily*)

Procedure

The experiment was programmed on Qualtrics (Qualtrics, Provo, UT) and made accessible to participants gathered through the Crowdflower platform. Thus, every participant took part in the experiment from their own personal computer: all of them were instructed to perform the experiment individually, and they were asked to proceed only if they were in a situation that could permit them not to have any interruption, and to put the maximum attention to the questions. Completing the experiment required about 15-20 minutes. Before beginning, some general instructions illustrated the reasoning task, giving an example and explaining how to give the responses. Participants were shown the problems one at a time, and they had to type-in their solution. As for Study 1, a two-response paradigm (Thompson et al., 2011) was adopted. After reading the instructions, the participants completed one practice problems and before starting the test trials, the instructions were summarized and presented again.

The participants were randomly divided into four Groups. Specifically, two *between*-variables on two levels were set in this study: on one hand, participants could or could not be instructed about the presence of feedback information in the experiment (*feedback anticipation*); that is, half of them received instructions about the fact that they would sometimes be told if their responses were accurate, during the resolution of the problems, while the others were not revealed any information in advance, specifically regarding the presence or the characteristics of the feedback. On the other hand, and orthogonally to this first distinction, half of participants were actually given feedback information in the experiment (*feedback administration*), while the other half not. To sum up:

1) In the first condition, participants got instructed about the presence of feedback and actually received feedback information during the resolution of the problems (*feedback anticipation* and *feedback administration*)
2) In the second condition, participants got instructed about the presence of feedback, but never received feedback information during the experiment (*feedback anticipation* only).
3) In the third condition, participants were not given any instruction about the presence of feedback, but still, they received feedback information during the experiment (*feedback administration* only)
4) In the fourth condition, participants were not given any instruction about the feedback, and they were never told if their responses were correct or incorrect (control condition)

The nine problems were actually presented in a sequence of three blocks (Step 1. Pre Feedback, Step 2. Feedback Administration, Step 3. Post Feedback), representing the *within*-variable, and adopting the same experimental structure of Study 1. Hence, every block was composed of three trials that were presented one at a time in a random order. In Step 1, participants did not receive any feedback, a feedback administration could take place in Step 2, and in Step 3 feedback was not given anymore. Thus, the experimental design was 2 × 2 × 3 mixed.

Differently to Study 1, in this second study we did not examine different effects of confirmatory or corrective feedback. That is, in order to prevent potential differences due to the amount of feedback received, those who received feedback information in Step 2 were provided with reliable information about both the accuracy or the inaccuracy of their responses.

In order to verify the effects of feedback anticipation and administration in the proposed experiment, in each Step we collected data about participants' performance in the cognitive reflection tasks, examining the following dependent variables: Intuitive Responses Times and Intuitive Responses Accuracy, Rethinking Times and Reflected Responses Accuracy, Feeling of Rightness and Final Judgments of Confidence (FoR and FJC; in this study were measured on a scale from 1 = feeling guessing when giving one's response, to 100 = feeling absolutely certain of one's solution), and an index of Response Change, as done in Study 1.

In sum, in this study we hypothesized to observe indicators of a stronger engagement of Type 2 processes (longer response times and higher accuracy) for participants that get instructed about the presence of feedback information, during the resolution of CRT problems in the first part of the experiment, even before eventually receiving any kind of feedback. Differently, the effect of feedback administration on the dependent variables considered would be observed through comparisons of participants' performance in the final part of the experiment, after feedback administration has taken place. In particular, given that accuracy in CRT when providing an intuitive response should be quite limited, thus bringing to the administration mainly of negative feedback that underline one's solution incorrectness, in Step 3 we expect observe a higher engagement of Type 2 processes from participants belonging to the *feedback administration* conditions.

Results

In the following Table, performance of participants in the resolution of the different problems are shown:

	Intuitive Response Time	Intuitive Response Accuracy	Feeling of Rightness (FoR)	Rethinking Time	Reflected Response Accuracy	Final Judgment of Confidence (FJC)	Response Change
	M (SD)	Correct %	M (SD)	M (SD)	Correct %	M (SD)	Changed %
CRT1 *(bike and helmet)*	31.97 (120.85)	9.41%	69.62 (29.3)	20.16 (27.28)	35.3%	84.45 (21.06)	30.6%
CRT2 *(autumn tree)*	18.65 (20.58)	36.5%	68.0588 (27.31)	15.71 (18.25)	45.9%	80.40 (21.02)	36.5%
CRT3 *(cats and mice)*	25.89 (37.38)	28.2%	68.0706 (26.10)	22.31 (37.63)	35.3%	70.83 (27.84)	34.1%
CRT4 *(drink a barrel)*	34.89 (61.6)	18.8%	52.8824 (28.43)	31.65 (34.03)	40%	70.29 (25.46)	55.3%
CRT5 *(dirt in a hole)*	20.66 (40.59)	8.2%	68.5529 (30.15)	13.65 (23.5)	15.3%	78.16 (24.71)	35.3%
CRT6 *(buy a pig)*	19.68 (17.55)	31.7%	64.6 (26.15)	42.73 (180.43)	47.1%	81.25 (18.27)	34.1%
CRT7 *(running a race)*	16.14 (13.23)	56.4%	85.1294 (21.51)	7.35 (6.26)	75.3%	92.02 (12.77)	20%
CRT8 *(sheep)*	13.58 (18.23)	65.8%	86.9294 (19.25)	8.73 (14.34)	77.6%	91.80 (15.88)	14.1%
CRT9 *(Emily's father)*	14.50 (12.04)	48.2%	83.6941 (24.95)	9.71 (15.62)	56.5%	90.91 (16.86)	12.9%

Since the nine problems were presented to each participant in a random order, the following table reports data about the CRT problems considering their order of presentation.

	Intuitive Response Time	Intuitive Response Accuracy	Feeling of Rightness (FoR)	Rethinking Time	Reflected Response Accuracy	Final Judgment of Confidence (FJC)	Response Change
	M (SD)	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**	**Changed %**
1st task	19.40 (37.13)	.24 (.43)	71.24 (23.4)	36.12 (180.21)	.42 (.49)	83.57 (17.87)	35.3%
2nd task	23.44 (31.68)	.34 (.47)	69.84 (29.9)	19.44 (30.97)	.41 (.49)	80.61 (22.33)	29.4%
3rd task	21.77 (58.01)	.28 (.45)	73.41 (28.22)	15.65 (16.96)	.42 (.49)	84.31 (19.18)	27%
4th task	31.36 (120.6)	.34 (.47)	69.88 (30.41)	18.55 (27.14)	.54 (.50)	79.18 (26.25)	37.6%
5th task	22.61 (27.95)	.32 (.47)	72.78 (28.4)	18.98 (35.15)	.48 (.50)	80.41 (25.04)	31.7%
6th task	18.23 (19.70)	.36 (.48)	71.04 (30.71)	19.19 (30.20)	.57 (.49)	84.45 (21.94)	42.3%
7th task	18.71 (21.36)	.42 (.49)	77.43 (23.25)	16.67 (23.45)	.44 (.50)	82.78 (20.04)	25.8%
8th task	20.14 (24.98)	.34 (.47)	72.12 (27.37)	13.83 (16.00)	.48 (.50)	84.31 (20.99)	23.5%
9th task	20.29 (24.90)	.36 (.48)	69.75 (30.0)	13.58 (24.06)	.49 (.50)	80.48 (25.65)	20%

Finally, derived from the aggregation of these previous data, the following data refer to participants' performance in the three parts of the experiment (Step), and will be used as dependent variables in the subsequent analyses.

	Intuitive Response Time	Intuitive Response Accuracy	Feeling of Rightness (FoR)	Rethinking Time	Reflected Response Accuracy	Final Judgment of Confidence (FJC)	Response Change
	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	Changed %
STEP 1	21.54 (26.48)	.29 (.27)	71.50 (18.68)	23.74 (61.02)	.41 (.30)	82.83 (14.23)	30.5%
STEP 2	24.07 (42.96)	.34 (.32)	71.23 (20.78)	18.91 (19.84)	.53 (.35)	81.35 (16.71)	37.2%
STEP 3	19.71 (17.12)	.37 (.31)	73.10 (19.43)	14.69 (14.18)	.47 (.35)	82.52 (16.08)	23.1%

Demographic variables.

In order to assess how age and gender might have affected participants' responses speed, accuracies and levels of confidence, we performed a series of regression analyses:

Age did not affect Accuracy, neither of Intuitive Responses nor Reflected Responses, in any Step, *p*s varying from .42 to .98. It did not show significant effects on Intuitive Responses Times, either, in any phase of the experiment, *p*s varying from .16 to .89. Age did not affect Rethinking Times in Step 1 and 2, *p*s varying from .58 to .61, but it showed a significant effect in Step 3, F (1,83) = 7.487, Adj. $R^2 = .07$, $p < .01$, with older people taking more time for reflection in this final part of the experiment, $t = 2.736$, $p < .01$. Similarly, it did not affect participants' FoR assessments in Step 1 and 2, *p*s varying from .08 to .19, but a significant effect was found in Step 3, F (1,83) = 4.42, Adj. $R^2 = .04$, $p < .05$, with younger people feeling more confident with their Intuitive Responses, $t = -2.10$, $p < .05$. Age did not show to influence FJC in any Step, ps varying from .22 to .84, and it also did not show significant effects on Response Change, *p*s varying from .051 to .76. Hence, Age was used as a covariate in the subsequent analyses on Reflected Response Time and Feeling of Rightness.

Gender did not affect Accuracy, neither of Intuitive Responses nor Reflected Responses, in any Step, *p*s varying from .31 to .95. It did not show significant effects on Intuitive Responses Times in any phase of the experiment, *p*s varying from .21 to .75, and it did not affect Rethinking Times in any phase of the experiment, too, *p*s varying from .17 to .81. The only variable found influenced by Gender was the Feeling of Rightness, specifically in Step 2, F (1,83) = 5.712, Adj. $R^2 = .053$, $p < .05$, and Step 3, F (1,83) = 5.951, Adj. $R^2 = .06$, $p < .05$, with males reporting significantly higher levels of confidence than females in their Intuitive Responses (Step 2: $t = -2.39$, Step 3: $t = -2.44$). Gender did not affect FJC in any Step, ps varying from .27 to .66. Finally, it did not affect Response Change, *p*s varying from .25 to .62. Considering these results, Gender has been used as a covariate in the subsequent analyses only regarding Feeling of Rightness.

Effects on reasoning (object-level)

In order to verify feedback anticipation and feedback administration effects on reasoning, a series of repeated measures Anova were performed. For each analysis, Feedback anticipation (instructions about the feedback shown vs. not shown) and Feedback administration (feedback given vs. not given) were used as independent *between*-variables on two levels, and Step as a *within*-factor on three levels (Step 1, Step 2, Step 3).

Response Times: a 2 × 2 × 3 repeated measure ANOVA was performed on Intuitive Response Times. We did not find any significant effect of Step, $p = .45$, nor of feedback anticipation, $p = .28$, or of feedback administration, $p = .20$, on Intuitive Response Times. Similar results emerged from the analysis on Rethinking Times (for which, in addition, we used Age as covariate), that were found not to be affected by Step, $p = .11$, or feedback anticipation, $p = .81$, or feedback administration, $p = .26$.

Accuracy: another 2 × 2 × 3 repeated measure ANOVA was performed on Intuitive Responses Accuracy. Again, we did not find any significant effect of Step, $p = .16$, nor of feedback anticipation, $p = .94$, or of feedback administration, $p = .65$. A main effect of Step was found on Reflected Responses Accuracy, $F(2,162) = 3.44$, partial-$\eta^2 = .04$, $p < .05$, but no interactions were found with feedback anticipation, $p = .96$, or feedback administration, $p = .41$, for which we could not observe any differences between the experimental conditions. Thus, independently from the experimental manipulations, a post-hoc analysis showed significant difference in Reflected Responses Accuracy between Step 1 and Step 2, with participants providing more accurate responses during the central phase of the experiment.

Effects on monitoring (meta-level)

In order to verify feedback anticipation and feedback administration effects on metacognitive monitoring processes, a series of repeated measures Anovas were performed. For each analysis, Feedback anticipation (instructions about the feedback shown vs. not shown) and Feedback administration (feedback given vs. not given) were used as independent *between*-variables on two levels, and Step as a *within*-factor on three levels (Step 1, Step 2, Step 3). Both Age and Gender were used as covariate for the analyses on FoR.

FoR: again, a 2 × 2 × 3 repeated measure ANOVA was performed on the Feeling of Rightness. Neither Step, $p = .91$, nor feedback anticipation, $p = .36$, nor feedback administration, p = .84, significantly affected FoR assessments, showing that such monitoring component seems quite resistant to external manipulation.

FJC: another 2 × 2 × 3 repeated measure ANOVA was performed on the Final Judgment of Confidence. Again, no main effects of Step, $p = .69$, feedback anticipation, $p = .63$, or feedback administration, $p = .90$, were found on participants' final confidence, even if an interaction between Step and feedback administration reached significance, F (1,81) = 6.24, partial-η^2 = .07, $p < .05$, with participants in Feedback conditions reporting a decrease in the assessments of confidence from Step 1 to Step 2.

Effects on control (meta-level)

Response Change: the 2 × 2 × 3 repeated measure ANOVA that was performed on Response Change showed a main effect of Step, F (2,80) = 5.13, partial-η^2 = .11, $p < .01$, and a significant interaction of Step and Feedback administration, F (2,80) = 8.29, partial-η^2 = .71, $p < .001$. In particular, Bonferroni post-hoc analyses showed that participants gave a Reflected Response that was different from the Intuitive one less frequently in Step 3 than in Step 2, $p < .01$, and a significant difference was found between participants who received feedback information and those who did not, in Step 2, when the former gave a reflected response that was different from the intuitive one more frequently.

Discussion

The main aim of the current study was to explore whether feedback anticipation could affect the way people tend to rely on their intuitions, or put a higher mental effort when solving a problem for which they know they will receive an external assessment about accuracy. The results of this study, however, did not confirm the effects predicted by our hypotheses. The manipulation of the instructions, in fact, did not seem to influence participants, where it was expected to observe differences in performance in the initial phase of the experiment, between those who were aware of the presence of feedback and those who were not. The only significant effect that emerged from our analyses have shown that feedback given to participants' intuitive responses, mainly helped participants to not reconfirm their mistakes in the final responses. Although feedback contributed in increasing participants' accuracy prompting the research of alternative (and correct) solutions, such an effect remained limited to the specific item to which those particular feedback referred. That is, participants did not extend the research for alternatives when facing the other problems in the final part of the experiment, suggesting that cognitive and metacognitive processes involved in reasoning might work mainly in a task-specific way, and quite independently from other external sources of information. We underline, in particular, that participants' confidence was not affected by experimental manipulations, nor the Feeling of Rightness showed systematic variations in the proceeding of the resolution of different tasks.

CHAPTER 4

Individual differences in reasoning and meta-reasoning

There has been increasing attention paid to individual differences in judgment-and-decision-making research over the past decade, including research on developmental differences that can be thought of as a type of individual difference (Weber & Johnson, 2009). Such individual differences have implications for the real world because they imply that some people are likely to make better medical, legal, or policy decisions than others; identifying these individuals has the potential to improve outcomes for the broader society (Nelson, Reyna, Fagerlin, Lipkus, & Peters, 2008; Reyna & Farley, 2006). Further, research on individual differences has been used to adjudicate important theoretical controversies, especially regarding biases and fallacies in judgment and decision making (e.g., Evans, 2007; Milkman, Chugh, & Bazerman, 2009). As already argued, according to most dual-process theories Type 2 reflective processes do not always intervene in reasoning and decision-making, and one of the central issues addressed by research in these field regards the identification of those factors that control the initiation or cessation of mental effort. Regarding the Type 1 versus Type 2 strategies of reasoning, it has been a consensual assumption that factors within the environment influence the selection of a strategy. These include contextual variables such as time pressure, and whether or not reflective thinking is primed (e.g., Godek & Murray, 2008; Kinnunen & Windmann, 2013). For instance, physiological needs are said to usually trigger affect-based strategies, whereas the presence of probabilities inside a problem triggers the use of more analytic strategies (Epstein, 1999). However, in addition to this, individuals tend to select their strategies referring to their past learning experiences: when a reasoning strategy has repeatedly worked out in the past, it might turn into routine. Hence, people can also develop preferences for intuitive or for analytic thinking in a way that makes such preferences chronic and stable factors making the use of Type 1 or Type 2 processes more or less likely. Evidence suggests indeed that individuals are different from each other in their habitual use of intuitive and reflective thinking and that these tendencies are trait-like in stability across time and context (Betsch & Kunz, 2008; Marks, Hine, Blore, & Phillips, 2008; Pacini & Epstein, 1999). Several studies have indicated that high (or low) use of intuition may coexist with high (or low) use of reflection (e.g. Bjorklund & Backstrom, 2008; Shiloh & Shenhav-Sheffer, 2004), but if an individual uses one type more readily than the other, the former will represent their default approach to decision making, and such style will be likely to prevail in the absence of other strong influential factors, such as primes to use a particular type of processing. People's tendency to adopt one or the other reasoning strategy is clearly explained by the concept of *cognitive styles* described by Pacini and Epstein inside the cognitive experiential self-theory (CEST; 1990, 1994, 1998). They can indeed be defined as stable attitudes, preferences, or habitual strategies that determine individuals' modes of perceiving, thinking, and problem-solving (Messick & Fritzky, 1963): people are aware of the two different ways of thinking (Type 1 labelled as *Experiential system*, Type 2 labelled as *Rational system* within the CEST) and reliable individual differences could be measured in the extent to which people process information based on experience (*intuitive thinking style*) or on analysis (*rational thinking style*). For instance, as shown in numerous studies using the Cognitive Reflection Test, people vary in how likely they are to override a strong intuition that is incorrect, and to engage in additional reflection needed to reach a correct solution. Thus, although both types of processing are expected to perform together in an interactive way, the relative dominance of one mode over the other could occur (Pacini & Epstein, 1999, p. 972). In the recent years, the role of metacognitive processes in reasoning has increasingly caught attention, suggesting that the study of meta-reasoning might both help for a better understanding of the processes that underlie reasoning and problem solving, and be useful for improving reasoning performance. Specifically, the role of monitoring processes has been highlighted as they should provide a means to assess the output of one's cognitive processes and determine whether further action should be taken, and high levels of confidence in one's intuition (Feeling of Rightness), in particular, have been shown able to thwart the disposition to put mental effort in the reflection on a problem. Although both the research on individual differences and on metacognition share an interest in the functional characteristic of reasoning and decision-making processes, and despite the concept of thinking style being represented by different preferences and tendencies in the engagement of Type 1 and Type 2 processes, to date, the role of metacognitive components in relation to these features has not yet been investigated. In this part, we aim to examine how such individual differences might predict thinking processes in decisions taken as fast as possible.

Study 3

Introduction

The aim of this study is to explore the different ways in which a more pronounced predisposition to rational thought, or intuitive thought, and the relative dominance of one or the other kind of thought, might predict the functioning of metacognitive monitoring processes in reasoning. For example, Mata and colleagues (2013) observed that "rational" and "intuitive" responders do not have the same metacognitive awareness, that is they make different estimates of their own and others' accuracy in a reasoning task: while rational responders seem aware of both their solutions and the alternative intuitive solutions, intuitive responders are aware only of the intuitive solutions that they give. Thus, when the former are shown the intuitive solutions of the Cognitive Reflection Test, they do not change their estimates about how well they and others perform. Differently, intuitive responders do change their estimates when they are shown the rational solutions, and their estimates become similar to the ones that rational responders make at first. In a similar way, through this study we intend to ascertain whether different *cognitive styles* are linked to different degrees of accuracy and confidence in the solutions provided during the primed intuitive resolution of the CRT. The focus on metacognitive monitoring components is again justified by the above-described framework that have shown how the degree of confidence experienced in providing a solution to a problem is a determining factor for the subsequent use of analytical resources. In this first study on individual differences in meta-reasoning, we examined how individuals that report a preference for rational information processing, or for intuitive information processing, deal with a problem solving setting in which they're asked to provide a solution as fast as possible. We hypothesised that some specific differences in thinking style may determine different tendencies in the adoption of intuitive or analytic reasoning strategies, and in the confidence that accompanies the solutions. More specifically, we expected that individual characteristics related to higher levels of Rational Thinking Style should lead to a higher tendency to adopt analytic solutions, accompanied by higher levels of confidence; at the opposite, we also expected that individual characteristics related to stronger preferences for an Intuitive Thinking Style should lead to a higher tendency to rely on heuristic solutions, with lower levels of confidence. Anyway, since intuition and analysis should not be considered as strictly opposed, we aim to check in detail which of these two dimension might predict specific aspects of reasoning (speed and accuracy), monitoring and control processes.

Method

Participants

The research has been publicized via alerts in message boards and social networks, and a total of 149 university students took part to the experiment. Twenty-seven participants were excluded from the analysis as they reported they had previously seen at least one of the cognitive reflection tasks presented. Thus, the final sample was composed of 122 participants (108 females, age ranging from 18 to 47 years old, M = 23.82, SD = 4.95). They signed a written consent form at the beginning of the study, and their participation was voluntary. The study was approved by the Ethics Committee of the University of Bologna.

Procedure and materials

All participants carried out the experiment online, through the Qualtrics platform (Qualtrics, Provo, UT). Before the beginning of the study they were explained that the aim of the research was to examine whether and how some specific individual characteristics could affect reasoning, and they knew they would have been administered some brief questionnaires and a series of problems to solve. All participants were instructed to perform the experiment individually, and they were asked to proceed only if they were in a situation that could permit them not to have any interruption, and to put the maximum attention to the questions. After providing some basic personal information, regarding Gender and Age, the participants were asked to complete the Rational-Experiential Multimodal Inventory (REIm; Norris & Epstein, 2001; trad. It. Monacis et al., 2016; see Fig. 14), which is designed to assess preferences for information processing and distinguishes between a *rational thinking style* and an *experiential thinking style*. The former emphasizes a logical and analytical approach, while the latter is composed of three subscales, concerning imagination, intuition, and emotionality. To the aim of this study, the *rational thinking style* scale (12 items, α = .82) and the *intuitive thinking style* scale (10 items, α = .72) only were considered, and used as independent variables in the subsequent analyses. After completing the questionnaire, the participants were presented, one at a time and in a random order, five Cognitive Reflection Tasks (CRT), similar to the ones already seen in Study 2. In particular, the following problems were used in this study:

1) *A TV and a DVD together cost 110 dollars. The TV costs 10 dollars more than the DVD. How much does the DVD cost?*

   (heuristic response: *10$*; correct response: *5$*)

2) *If it takes 10 hens 10 days to lay 10 eggs, how long would it take 100 hens to lay 100 eggs?*

   (heuristic response: *100 days*; correct response: *10 days*)

3) *A computer virus is spreading through the system of a computer. Every minute, the number of infected files doubles. If it takes 100 minutes for the virus to infect all of the system, how long would it take for the virus to infect half of the system?*

   (heuristic response: *50 minutes*; correct response: *99 minutes*)

4) *Jerry received both the 15th highest and the 15th lowest mark in the class. How many students are there in the class?*

   (heuristic response: *30 students*; correct response: *29 students*)

5) *In an athletics team, tall members are three times more likely to win a medal than short members. This year the team has won 60 medals so far. How many of these have been won by short athletes?*

   (heuristic response: *20 medals*; correct response: *15 medals*)

In order to examine the role of metacognitive monitoring components of reasoning, participants were instructed to solve these problems as fast as possible, providing the first solution that came to mind, and Response Times were collected as dependent variable: for each task, timing started when the text of the problem appeared, and stopped when participants indicated they were ready to give their solution. The response style, representing the type of solution (Analytic vs. Heuristic) given, and the Confidence associated to each solution (measured through a five-point scale: *At the time I provided*

Rational thinking style

1. I enjoy problems that require hard thinking
2. I am not very good in solving problems that require careful logical analysis *
3. I enjoy intellectual challenges
4. I prefer complex to simple problems
5. I don't like to have to do a lot of thinking *
6. Reasoning things out carefully is not one of my strong points *
7. I am not a very analytical thinker *
8. I try to avoid situations that require thinking in depth about something *
9. I am much better at figuring things out logically than most people
10. I have a logical mind
11. Using logic usually works well for me in figuring out problems in my life
12. Knowing the answer without understanding the reasoning behind it is good enough for me *

Experiential thinking style

Imagination

13. I enjoy reading things that evoke visual images
14. I enjoy imagining things
15. I can clearly picture or remember some sculpture or natural object (not alive) that I think is very beautiful
16. I identify strongly with characters in movies or books I read
17. I tend to describe things by using images or metaphors, or creative comparisons
18. Art is really important to me
19. Sometimes I like to just sit back and watch things happen
20. I have favorite poems and paintings that mean a lot to me
21. When I travel or drive anywhere, I always watch the landscape and scenery
22. I almost never think in visual images *

Emotionality

23. My emotions don't make much difference in my life *
24. Emotions don't really mean much: they come and go *
25. When I have a strong emoziona experience, the effect stays with me for a long time
26. When I'm sad, it's often a very strong feeling
27. Things that make me feel emotional don't seem to affect other people as much
28. Everyday experiences often evoke strong feelings in me
29. I'd rather be upset sometimes and happy sometimes, than always feel calm
30. I don't react emotionally to scary movies or books as much as most people do *
31. My anger is often very intense
32. When I'm happy, the feeling is usually more like contentment than like exhilaration or excitement *

Intuition

33. I like to rely on my intuitive impressions
34. I often go by my instincts when deciding on a course of action
35. I don't think it is a good idea to rely on ones intuition for important decisions *
36. I trust my initial feelings about people
37. I tend to use my heart as a guide for my actions
38. I enjoy learning by doing something, instead of figuring it out first
39. I can often tell how people feel without them having to say anything
40. I generally don't depend on my feelings to help me make decisions *
41. For me, descriptions of actual people's experiences are more convincing than discussions about ''facts''
42. I'm not a very spontaneous person *

Fig. 14. The Rational-Experiential Multimodal Inventory (REIm). Each item has to be assessed on a 5-point scale from completely false to completely true. * Star indicates items with a reverse score.

my answer I felt: 1 = *Guessing*, 3 = *Fairly certain*, 5 = *Absolutely certain I'm right*), were also collected as dependent variables.

Results

Coding

Male gender was coded with -1, female with +1. For each participant, Response Times (RT) was measured as the mean of the time (in seconds) spent to provide the responses in each of the five CRT problems. Participants' Response Styles were used to assign each participant scores for the total number of correct Analytic solutions, representing the Accuracy (ACC: min = 0, max = 5). A general measure of Confidence was computed as the mean of the different judgments of Confidence provided (1 = participant responded feeling only guessing, 5 = participant responded feeling only absolutely certain). As a new measure for Meta-Reasoning Competence (MRC), a score was computed as the mean of the judgments of confidence, in case of correct answers, and the reversed score of the judgment of confidence, in case of incorrect answer. Thus, a higher score in this scale would represent both participants providing correct solutions being sure of them, and participants providing incorrect responses but with low confidence. At the opposite, lower point on this scale would represent both participants providing correct responses while not feeling certain of them and participants providing incorrect responses with high confidence.

Percentage scores on the REIm scales for rational thinking style (*rts*) and the intuitive thinking style (*its*) were used to distinguish participants with a prevalent rational thinking style (RAT) and those with a prevalent intuitive thinking style (INT). That is, a bipolar scale (M = 4.27, SD = 21.47, Mdn = 5.41) describing the relative dominance of rational and intuitive thinking styles was obtained as the difference of *rts* and *its*, the median used as a cut-off to split the sample.

Descriptives and demographic variables

Means and Standard Deviations for each variable, and intercorrelations between all the variables are presented in the following Table, that refers to the whole sample of participants.

	M (SD)	1	2	3	4	5	6
1. Rational Thinking Style (*rts*)	63.15 (14.26)	1	**-.341****	-.074	**.221***	**.353****	**-.188***
2. Intuitive Thinking Style (*its*)	59.51 (13.05)	**-.341****	1	-.030	**-.300****	**-.289****	.153
3. Response Times (RT)	38.13 (20.29)	-.074	-.030	1	.076	-.054	.070
4. Accuracy (ACC)	1.30 (1.30)	**.221***	**-.300****	.076	1	**.286****	.126
5. Confidence (CON)	2.98 (.84)	**.353****	**-.289****	-.054	**.286****	1	**-.645****
6. Meta-reasoning Competence (MRC)	3.34 (.70)	**-.188***	.153	.070	.126	**-.645****	1

** $p < .01$
* $p < .05$

The two sub-scales of the REIm showed opposite patterns in their correlations with Accuracy and Confidence: higher scores on the *rts* were related to a high frequency of correct solution given ($p < .01$) and higher feelings of certainty accompanying those solution ($p < .001$); higher scores on *its*, instead, were accompanied by a lower number of correct solution given by participants and lower feelings of certainty (*p*s < .001).

Indeed, accurate solutions resulted overall associated with a higher confidence ($p < .001$). As the most evident result, *rts* and *its* showed a significant inverse correlation ($p < .001$), accounting for the distinction between the groups of RAT (N = 61, 41 females, M_{age} = 24.79, SD = 4.98) and INT (N = 61, 51 females, M_{age} = 23.93, SD = 5.19).

While not showing significant differences in age, INT presents a higher amount of females than RAT. A series of regression analyses were thus performed in order to check whether Age and Gender affected the other dependent variables: Gender showed a significant effect on Response Times, $t = -2.28$, Adj. $R^2 = .03$, $p < .05$, with males taking more time to provide their solutions. While no differences in Accuracy were found between males and females, $p = .50$, the former showed significantly higher levels of Confidence, t = -3.07, Adj. $R^2 = .07$, $p < .01$, but a lower Meta-Reasoning Competence, t = 2.13, Adj. $R^2 = .03$, $p < .05$. Age showed to significantly affect Response Times, $t = 3.34$, Adj. $R^2 = .08$, $p < .001$, with younger participants being faster with providing their solution. Age did not predict accuracy, $p = .96$, nor Confidence, $p = .208$. Instead, it predicted MRC, $t = -2.81$, Adj. $R^2 = .05$, $p < .01$, with older people showing less consistence between their actual accuracy and confidence in their solutions. Considering these results, Age and Gender were used as covariate in the following analyses.

Preliminary Analysis on Response Times

Considering that participants were instructed to provide a solution to each problem as fast as possible, but they did not have an actual time-constraint, we performed a preliminary analysis aimed to check whether thinking styles affected Response Times. A one-way Anova using RAT and INT as *between*-factor, RT as dependent variable, and Gender and Age as covariate, did not show any significant difference between the two groups in how fast they were in providing a solution, p = .97. A distribution of both groups' participants Response Times is shown in Figure 15. Moreover, in order to check that Response Times did not affect our dependent variables, two regression analyses were performed, using RT as independent variable, and Accuracy and Confidence, respectively, as dependents. Neither the Accuracy (p = .40) nor the Confidence (p = .55) showed to be affected by Response Times.

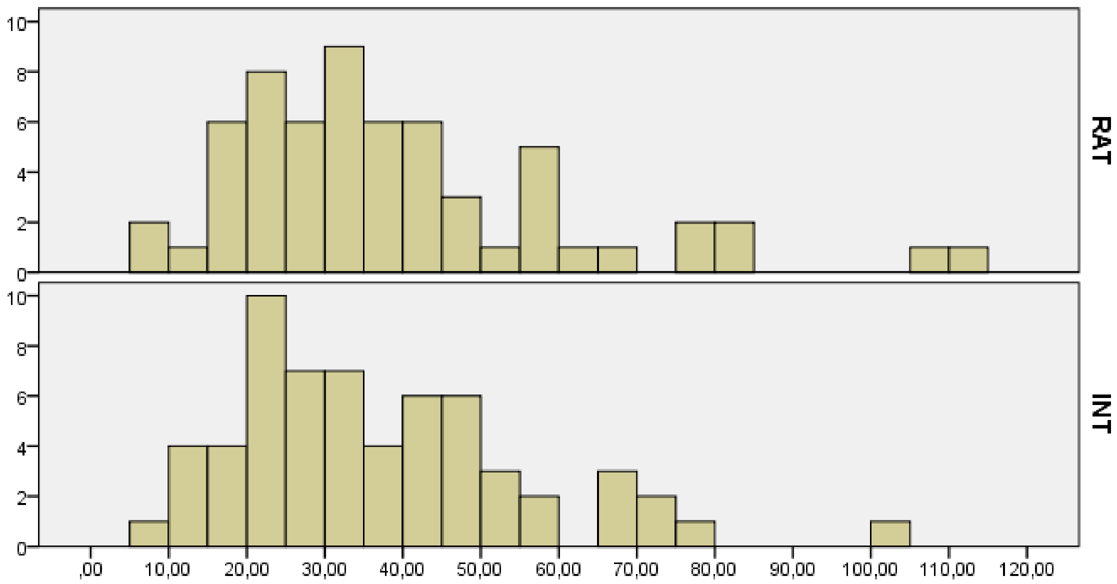

Fig. 15. Distribution of participants' (y-axis) on the basis of Response Times: x-axis represents the mean time taken by each participants to provide their solution to a problem, measured in seconds.

Effects of Thinking styles on Accuracy (object-level)

In order to verify how thinking styles could predict participants' responses, an Anova was performed, using RAT and INT as a *between*-factor, and Accuracy as dependent. Despite, overall, both groups showed quite low degrees of Accuracy, a significant difference emerged from the analysis (see Fig. 16), showing that RAT gave the correct analytic response more frequently than INT, $F(1,121) = 6.61$, $p < .05$, partial-$\eta^2 = .05$.

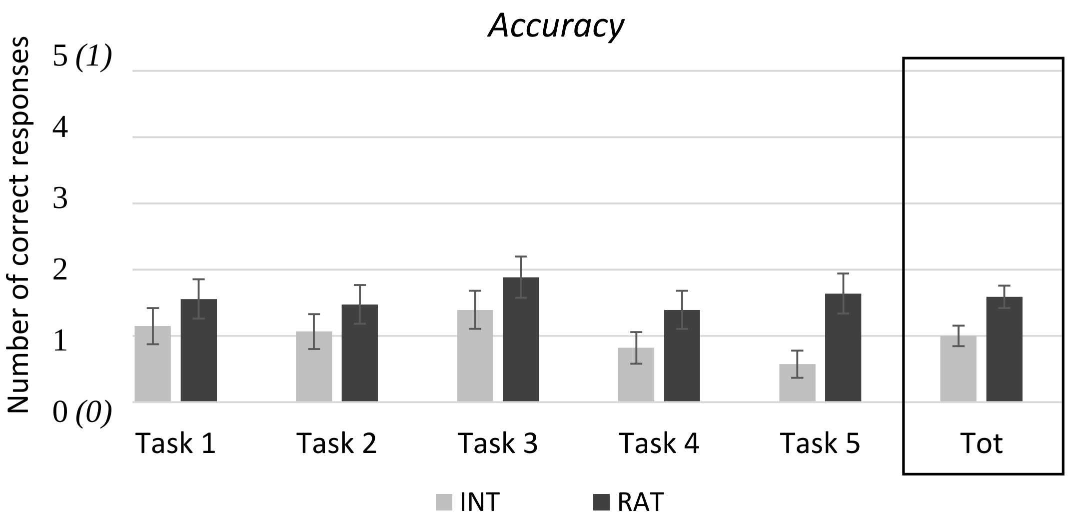

Fig. 16. Differences in accuracy between INT and RAT groups for the CRT problems presented. The total accuracy could go from 0 to 5 points (y-axis). Accuracy means (from 0, incorrect, to 1, correct response) for each problem are shown too.

Two regression analyses were then used to examine the different roles, respectively, of *rts* and *its*: it emerged that only a lower *its*, but not a higher *rts*, could be predictive of Accuracy ($t = -3.45$, $p < .001$, $R^2 = .09$).

Effects of thinking style on Confidence (meta-level)

In order to verify how thinking styles could predict participants Confidence, an Anova was performed, using RAT and INT as a *between*-factor, Confidence as dependent, and Gender as covariate. As shown in Figure 17, a significant difference emerged from the analysis, with RAT reporting higher confidence than INT, $F(1,121) = 7.06$, $p < .01$, partial-$\eta^2 = .06$.

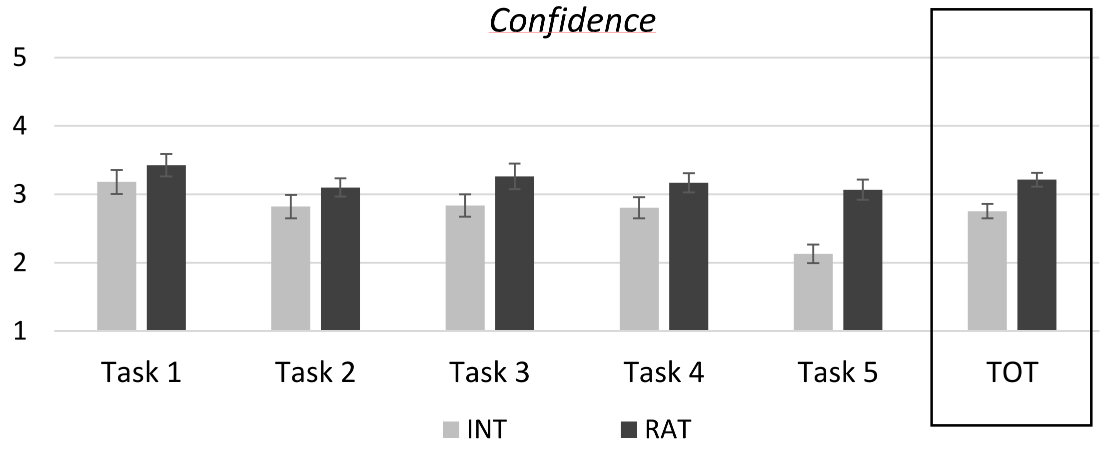

Fig. 17. Differences in Confidence between INT and RAT groups for the CRT problems presented.

Two regression analyses were then used to examine the different roles of *rts* and *its*. Interestingly, and opposite to what seen for Accuracy, this time only a higher *rts*, but not a lower *its*, could be predictive of Confidence ($t = 4.14$, $p < .001$, $R^2 = .12$).

Effects of thinking style on Meta-reasoning Competence

Finally, another Anova was performed, using RAT and INT as a *between*-factor, Meta-Reasoning Competence as dependent, and Gender and Age as covariates. A significant difference emerged from the analysis, $F(1,121) = 4.12$, $p < .05$, partial-$\eta^2 = .03$, with INT reporting feeling of confidence that were more consistent with the accuracy of their solutions, when compared with RAT, that likely felt too much confident even of inaccurate responses (see Fig. 18).

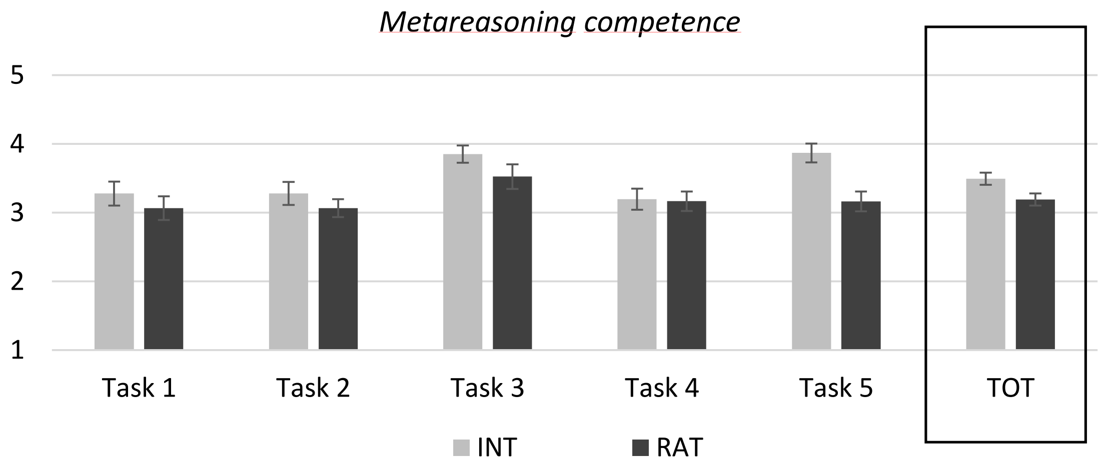

Fig. 18. Differences in Metareasoning competence between INT and RAT groups for the CRT problems presented.

Again, two regression analyses were then used to examine the different roles, respectively, of *rts* and *its.* However, no significant effects on MRC due to *rts,* or *its,* alone, emerged from the analyses, showing that only their relative dominance could explain the difference observed in the first place between RAT and INT.

Undefined inaccurate responses

In each CRT problem, some participants gave responses that did not correspond to the typical heuristic solution, nor to the correct analytical solution. In order to present a more complete picture of the participants' resolution performance, we summarize here these undefined responses. Unexpected answers were given by 15 participants in CRT problem #1, by 35 participants in CRT problem #2, by 25 participants in CRT problem #3, by 42 participants in CRT problem #4, and by 51 participants in CRT problem #5. The Confidence showed a negative correlation with the amount of unexpected answer given by each participants ($r = -.26$, $p < .01$), showing that many of such answers were probably guessed, or randomly given. For instance, considering only undefined answers in CRT problems #1, #3 and #5, modes in the distribution of FoR assessments were on 1, meaning that the majority of these participants felt they were guessing. In CRT problem #5, in particular, 30% of the participants who gave an undefined response, explicitly stated they could not know or infer the answer. More interestingly, in other cases, some specific unexpected responses were found to be given by many participants, them feeling quite certain when responding. As an example, in CRT problem #2, an amount of 26 participants gave "6 elves" as a response, which we conjecture was the result of the simple operation "30 ÷ 5", even if such a calculation wasn't appropriate to solve the problem. As another example, in CRT problem #4, an amount of 24 participants gave "15 scholars" as a response, probably inferring that all scholars had an equal grade, and 6 participants gave "31 scholars" as a response, probably adding together "1 (Miriam) + 15 + 15", instead of "1 (Miriam) + 14 + 14". Thus, we suggest that such unexpected responses could reveal different attempts to reach the solution by applying logical rules that, even if incorrect, should represent a thinking style based on Type 2 processes.

Discussion

The aim of this study was to begin an exploration of those individual characteristics that might predict cognitive and meta-cognitive processes in reasoning. We observed that people's thinking styles relate to metacognitive feelings in different ways, and that it is useful to examine both the individual preferences for reflection and for intuition. Each of these dispositions accounted for different kinds of performances in the CRT: people showing a lower preference for intuition, in fact, may be more prone to inhibit the heuristic response and look for the correct alternative. On the other side, when facing these tasks, a higher preference for reflection can increase the individual confidence, and not only due to better performance. Results regarding meta-reasoning competence, indeed, showed that people with a preference for rational style might be particularly overconfident when providing the erroneous intuitive solution. One main findings, thus, is that while, as expected, people with a preference for intuition are more likely to rely on heuristic solutions although they are wrong, they would be more prone to question their mistakes than "rational" people, which could be less aware when they fall in thinking bias. Collectively, these findings reveal pervasive differences between intuitive and analytic individuals at various levels of cognitive functioning. Our findings are quite unique in the sense that they illustrate consequences of individual preferences for intuitive vs rational thinking style, considering both dimensions separately. One might say that more-intuitive people (but not less-rational) are less effective at inhibiting a compelling heuristic response in a reasoning task, but they may also be as accurate as the more-rational individuals in conflict detection. Indeed, much research has indicated that people are capable of detecting conflict between competing reasoning outputs (see De Neys, 2012, 2014) to the point that conflict detection has been referred to as omnipresent (De

Neys et al., 2008, p. 488), and even particularly biased participants have been shown to have an increased skin conductance response when faced with a conflict-inducing reasoning problem (De Neys et al., 2010). This indicates that even the most biased of reasoners can be sensitive to stimuli that cue conflicting responses. Differently from our findings, previous research (e.g. Pennycook et al., 2017) observed that particularly intuitive individuals greatly overestimated their performance on the CRT, a tendency that diminished and eventually reversed among increasingly analytic individuals. This outcome has become widely known as *Dunning-Krueger effect*, that refers to the observation that the "incompetent" are often ill-suited to recognize their incompetence. In our study, instead, higher preferences for rational-thought (self-report measures) apparently acted as a boost for confidence in CRT, but did not give any kind of metacognitive advantage. Namely, despite results showed slightly better performances in the CRT by people reporting themselves as rational thinkers, when compared to individual self-describing as intuitives, the former still provided several incorrect responses, moreover feeling confident they were right. The latter, at the opposite, even if showing slightly worse performances than "rational" people, showed to be at least more aware they could be wrong. While such conclusion seem to show an opposite direction compared to Pennycook and colleagues (2017), we shall provide an alternative explanation, noting that self-reported analytic thinking disposition, like in our study, has been often found just as strongly correlated with one's estimated CRT performance than with actual CRT performance. That is, relatively intuitive individuals might report that they are more analytic than is justified by their objective performance. This alternative interpretation would indicate that participants who are low in analytic thinking are at least somewhat unaware of (or unresponsive to) their propensity to rely on intuition in lieu of analytic thought during decision making. Such a conclusion is consistent with suggestions that the propensity to think analytically facilitates metacognitive monitoring during reasoning (Pennycook et al., 2015; Thompson & Johnson, 2014): those who are genuinely analytic should be aware of the strengths and weaknesses of their reasoning, whereas those who are genuinely nonanalytic might be described as "happy fools" (De Neys et al., 2013). Clearly, other studies using different methods than self-report measures will be needed, in order to clarify the relation between thinking dispositions and metacognitive functioning. Besides, the contrast between different lines of research is particularly evident when considering the CRT: whereas De Neys et al. (2013) found that even people who gave the intuitive response to the bat-and-ball problem were only around 82% confident of their response (as compared to 97% confidence on a control version of the problem), Pennycook et al. (2017) showed that poor performance on the CRT might be characterised by strong feelings of rightness. This contraposition indicates that the neurological (e.g., De Neys et al., 2008) and physiological (De Neys et al., 2010) conflict detection signals may be relatively effective, but the response to this signal may actually be rather ineffective. De Neys et al. (2013) found a large decrease in confidence for the bat-and-ball problem relative to a control, but 82% confidence is still quite high. In our study, mean confidence was near 3 (on a 5-points scale), representing a relatively low degree, when compared to that observed by the other authors. Thus, given that analytic thinking mostly relies on volitional control, the presence of a signal to think analytically does not guarantee that the individual will engage in more than cursory levels of analytic thought. This line of reasoning is supported by previous work showing that the propensity to think analytically correlates with increases in response time for biased responses to incongruent (conflict) base-rate problems (Pennycook et al., 2014; Pennycook et al., 2015). That is, more-analytic individuals seem to engage in more substantive analytic thinking, even in cases in which they ultimately rationalize their initial biased response.

Study 4

Introduction

Several approaches based on the analysis of individual differences showed that some personality characteristics are significantly related to the prevalent use of one of the two types of thinking processes, which can be revealed by the tendency to accept intuitive solutions, or the opposite tendency to collect more information and revise one's assumptions in the decision-making: high *trait anxiety*, for instance, seems related to a minor research of information while solving simple probabilistic reasoning problems, and there's ample support to the idea that both trait and state anxiety can reduce the inhibition of prepotent autonomous responses, increase distraction, and alter performances in double task situations (Eysenck, 2007); another personality characteristic, *trait impulsivity*, is typically related to low working-memory capacity, and it has been observed that the more impulsive individuals show some cognitive distortion, some of which are related to fast emotional activation (Mobini, 2006), to an increased removal of not-relevant information in the working memory, and to lack of planning that lead to risky and reckless behaviour (Whitney, Jameson, & Hinson, 2004). As another example, the *maximizing tendency*, a feature of the decision-making style, refers to the level of resources that an individual is typically willing to invest to get to the solution of a problem: linked to the adoption of Type 2 reflective processes, it describes the tendency to search for alternative response options in order to reach the "optimal solution", and is in contrast with the *satisfacing tendency*, which leads an individual to accept "good-enough solutions". Inside individual characteristics related to the approach to decision-making, then, the *regret* is described as an emotion involving counterfactual thinking, and it has been observed that people favouring intuitive thinking show less regret than those prone to analytical thinking; at the same time, people showing more regret in decisions show the tendency to put effort in more hypothetical consideration and explore all the possible alternative solutions to a problem; such considerations, in fact, can help a reasoner avoid the option that might lead to experiencing regret. To date, the functioning of metacognitive monitoring and control processes in relation to these features has not yet been investigated. Hence, in order to continue with the investigation of individual differences in meta-reasoning, the aim of this study was to examine individual characteristics related to anxiety, impulsivity, maximizing vs satisficing tendencies, and the propensity to experience regret, in order to see whether they might predict how metacognitive confidence accompanies intuitive decisions and determine the use of analytical reasoning resources.

Pre-test

Considering the manifold of individual features identified for the focus of this research, in order to select the individual characteristics on which to focus our investigation, a preliminary test on a reduced sample was carried out in a first step.

Participants

A total of 81 participants started the experiment, but only 39 (22 females, M_{age} = 29.74, SD = 12.84) were kept valid for the analyses. Regarding this final sample, 22 participants were recruited through Psychological Research on the Net, and 17 through Reddit. The others participants were excluded because they didn’t finish the experiment, were not English native speakers or they had a diagnosis of dyslexia, gave a wrong answer to a validation task, reported that they already knew at least one of the problems presented, or that they did not manage to follow the instruction to provide the very first intuitive response to any problems. All participants signed a written consent form before the study began, and their participation in the experiment was voluntary.

Materials and procedure

At the beginning of this experiment, participants were instructed that this study aimed to examine some specific individual characteristics and their relation to thinking processes. They were informed that in one part of the experiment, they would be asked to complete a series of questionnaires about their personality and thinking style, while in another part they would be asked to solve some reasoning problem. During the "questionnaire part", the following four scales were presented in a random order, each one appearing on a different screen page:

1) The State-Trait Inventory for Cognitive and Somatic Anxiety (STICSA, Gros et al., 2007), which is used as a measure of global anxiety and replicates the State-Trait Anxiety Inventory's (STAI) format of independent State and Trait scales, with better psychometric properties. To the aim of this study, the *trait* scale only was used (see Fig.19). It is composed of 21 items (two subscales distinguish between *cognitive symptoms*, min. score = 10, max = 40, and *somatic symptoms*, min. score = 11, max = 44) asking respondents to assess how often, in general, the statements are true for them. Respondents rate each item on a 4-point Likert scale, ranging from 1 (not at all) to 4 (very much so). Minimum score is 21, maximum is 84.

1) Heart beats fast
2) Muscles are tense
3) Feel agonized over problems
4) Think others won't approve
5) Can't make up mind
6) Feel dizzy
7) Muscles feel weak
8) Feel trembly and shaky
9) Picture future misfortunes
10) Can't get thoughts out of mind
11) Trouble remembering things
12) Face feels hot
13) Think worst will happen
14) Arms and legs feel stiff
15) Throat feels dry
16) Avoid uncomfortable thoughts
17) Irrelevant thoughts intruding
18) Breathing is fast and shallow
19) Cannot control thoughts
20) Butterflies in the stomach
21) Palms feel clammy

Fig. 19. The complete list of symptoms included in the *trait* scale of STICSA (Gros et al., 2007)

2) The Barratt Impulsiveness Scale (BIS-11; Patton et al., 1995; see Fig. 20), which is the most widely used scale for the assessment of personality impulsiveness (Stanford et al., 2009). The current version is composed of 30 items that describe common behaviours related to impulsiveness. Participants are asked to assess the frequency of such behaviours on a 4-point scale (1 = Rarely/Never, 4 = Almost always / Always). Three subscales representing Attentional Impulsiveness (min. score = 8, max = 29), Motor Impulsiveness (min = 11, max = 44) and Non-planning Impulsiveness (min = 11, max = 44) are used to distinguish these different facets;

	Rarely/Never	Occasionally	Often	Almost Always/Always
1 I plan tasks carefully.	□	□	□	□
2 I do things without thinking.	□	□	□	□
3 I make-up my mind quickly.	□	□	□	□
4 I am happy-go-lucky.	□	□	□	□
5 I don't ''pay attention."	□	□	□	□
6 I have ''racing" thoughts.	□	□	□	□
7 I plan trips well ahead of time.	□	□	□	□
8 I am self controlled.	□	□	□	□
9 I concentrate easily.	□	□	□	□
10 I save regularly.	□	□	□	□
11 I ''squirm" at plays or lectures.	□	□	□	□
12 I am a careful thinker.	□	□	□	□
13 I plan for job security.	□	□	□	□
14 I say things without thinking.	□	□	□	□
15 I like to think about complex problems.	□	□	□	□
16 I change jobs.	□	□	□	□
17 I act ''on impulse."	□	□	□	□
18 I get easily bored when solving thought problems.	□	□	□	□
19 I act on the spur of the moment.	□	□	□	□
20 I am a steady thinker.	□	□	□	□
21 I change residences.	□	□	□	□
22 I buy things on impulse.	□	□	□	□
23 I can only think about one thing at a time.	□	□	□	□
24 I change hobbies.	□	□	□	□
25 I spend or charge more than I earn.	□	□	□	□
26 I often have extraneous thoughts when thinking.	□	□	□	□
27 I am more interested in the present than the future.	□	□	□	□
28 I am restless at the theatre or lectures.	□	□	□	□
29 I like puzzles.	□	□	□	□
30 I am future oriented.	□	□	□	□

Fig. 20. Complete list of items in the Barratt Impulsiveness Scale (Patton et al., 1995)

3) The Regret Scale (Schwartz, 2002), which assesses how people deal with decisions after the decisions have been taken, specifically the degree to which an individual is prone to experience regret, or their sensitivity to regret. The scale is composed of five items dealing with counterfactual thoughts about decision-making (see Fig. 21) that respondents are asked to assess on a 7-point scale (1 = completely disagree, 7 = completely agree; min. score = 5, max = 35);

1) Once I make a decision, I don't look back.
2) Whenever I make a choice, I'm curious about what would have happened if I had chosen differently.
3) Whenever I make a choice, I try to get out information about how the other alternatives turned out.
4) If I make a choice and it turns out well, I still feel like something of a failure if I find out that another choice would have turned out better.
5) When I think about how I'm doing in my life, I often assess opportunities I have passed up.

Fig. 21. The five items composing the Regret Scale by Schwartz (2002).

4) The Maximization Scale-short (MS-short, Nenkov et al., 2008; see Fig. 22), which is used to assess how individuals approach decision situations, and distinguish between a Maximizing tendency (characterized by increased information-seeking and social comparison) and an opposite Satisficing tendency (characterized by increased use of shortcuts when making decisions and settle for a “good-enough” solution). The scale is composed of six items using 7-point ratings. Two items contribute to the measurement of *Decision Difficulty*, two concern *High Standards* and two *Alternative Search* (each sub-scale is independent from the others. They have min. score = 2, max = 14).

Alternative Search

1) No matter how satisfied I am with my job, it's only right for me to be on the lookout for better opportunities.
2) When I am in the car listening to the radio, I often check other stations to see if something better is playing, even if I am relatively satisfied with what I'm listening to.

Decision Difficulty

3) I often find it difficult to shop for a gift for a friend.
4) Renting videos is really difficult. I'm always struggling to pick the best one.

High Standards

5) I never settle for second best.
6) No matter what I do, I have the highest standards for myself.

Fig. 22. The complete list of item of the Maximization Scale-short (Nenkov et al., 2008), divided in subscales.

During the "reasoning problems part", six Cognitive Reflection Tasks were presented to participants. Again, like in the previous studies, these tasks are equal to the original CRT measure by Frederick (2005), but have different contents which were preferred, considering that the original measure's items have become extremely well known and widespread. For this study, three problems were taken from Mata, Ferreira and Sherman (2013), and three more problems were taken from Primi and colleagues (2015). In particular, the CRT used here were the same five problems used in Study 2, plus the following:

> *If three elves can wrap three toys in hour, how many elves are needed to wrap six toys in 2 hours?*
>
> (heuristic response: *6*; correct response: *3*)

Differently from Study 3, here participants provided their responses following a two-response paradigm (Thompson et al., 2011; see previous section, pag. 43), and like in

Study 1, Feeling of Rightness and Final Judgments of Confidence were measured on a 7-point scale ("At the time I provided my answer I felt: 1 = Guessing, 7 = Certain I'm right").

Results

In the following Table, participants' means and standard deviations for the self-report measures of personality and thinking style are shown:

		M (SD)
1.	STICSA (cognitive anxiety)	25.15 (8.78)
2.	STICSA (somatic anxiety)	20.19 (6.13)
3.	STICSA (total)	45.35 (13.45)
4.	BIS-11 (attentional)	19.54 (4.84)
5.	BIS-11 (motor)	22.69 (4.67)
6.	BIS-11 (non-planning)	23.69 (4.54)
7.	BIS-11 (total)	65.92 (10.39)
8.	Regret	20.08 (5.23)
9.	MS-short (Decision difficulty)	8.62 (2.97)
10.	MS-short (alternative search)	8.08 (3.07)
11.	MS-short (high standards)	9.62 (2.91)

Here, our measures of participants' performance in the CRT problems are presented:

		M (SD)
1.	**Intuitive Response Times (IRT)**	17.08 (11.46)
2.	**Intuitive Response Accuracy (IRA)**	.37 (.28)
3.	**Feeling of Rightness (FoR)**	3.94 (1.18)
4.	**Reflected Response Times (RRT)**	26.67 (19.17)
5.	**Reflected Response Accuracy (RRA)**	.58 (.32)
6.	**Final Judgment of Confidence (FJC)**	5.50 (1.02)
7.	**Response Change (RC)**	.34 (.23)

In order to pinpoint the individual features that should be chosen for a deeper analysis with a bigger sample of participants as they might be more likely related to meta-reasoning processes, we performed an exploratory correlation analysis between these measures. Correlations are shown in the following Table:

	IRT	IRA	FoR	RRT	RRA	FJC	RC
STICSA (Cognitive anxiety)	.271	- .180	.060	.024	- .174	.104	- .034
STICSA (Somatic Anxiety)	.154	- .191	- .187	- .164	**- .368***	- .033	- .177
STICSA (total)	.240	- .203	- .056	- .067	- .287	.046	- .108
BIS (attentional)	.228	- .200	.169	.089	- .197	.095	- .182
BIS (motor)	.072	- .201	.032	.037	- .026	.191	.259
BIS (non-planning)	- .199	- .135	- .067	.055	- .081	- .084	- .060
BIS (total)	.045	- .250	.061	.085	- .143	.092	.005
Regret	.221	.082	.105	.059	.156	.249	.066
MS-short (Decision Difficulty)	- .087	.106	.172	- .017	.228	**.454****	- .060
MS-short (Alternative Search)	**.331***	- .031	**.348***	- .183	.088	.230	- .046
MS-short (High Standards)	.221	- .122	- .088	.204	.007	.038	.103

* *p* < .05

** *p* < .01

The analyses showed significant correlations with meta-reasoning components, only for what concerns measures included in the Maximization Scale. Namely, higher scores on Decision Difficulty were found positively correlated with higher judgments of final confidence ($p < .01$), while higher scores on Alternative Search were linked to longer times for providing an Intuitive Response, and with a higher Feeling of Rightness (*p*s < .05). Taking into account these results, personality characteristics assessed by BIS-11 and STICSA were excluded from the main experiment. In fact, just one subscale related to STICSA (Somatic Anxiety) showed a negative correlation ($p < .05$) with Reflected Responses Accuracy; thus, considering also the difficulty in administering questionnaires that could be quite long and unsuitable for a research purpose, we decided to focus the main experiment on the individual characteristics assessed by the Maximization Scale. Despite Regret Scale did not show any significant correlation in the exploratory analyses, we kept this measure also in the main experiment. Such decision is justified by the observation that Regret has been traditionally linked, from a theoretical and conceptual perspective, to Maximization and satisficing tendencies. Besides, this 5-items scale would not represent a burden in the questionnaire administration.

Method

Participants

The research has been publicized through the Crowdflower platform, and a total of 125 responses were collected from English native speakers. Ninety-one responses were kept (44 females, M_{age}= 36.19, SD = 11.91) as valid (34 excluded because the experiment was not completed, or English was not the first language, or the subjects reported a diagnosis of dyslexia, or gave a wrong answer to a validation test). Education level was high, 68.1% participants had a college (or higher) level of education, 25.3% had completed the high school and 6.6% the secondary school. All participants signed a written consent form before the study began, and their participation in the experiment was rewarded with 0.70$ per participant. The study was approved by the Ethics Committee of the University of Bologna.

Materials and procedure

As for the pre-test, at the beginning of this experiment participants were instructed that this study aimed to examine some specific individual characteristics and their relation to thinking processes. They were informed that in one part of the experiment, they would be asked to complete a series of questionnaires about their thinking style, while in another part they would be asked to solve some reasoning problem. During the "questionnaire part", the Regret Scale (Schwartz, 2002) and the Maximization Scale-short (Nenkov et al., 2008) described above were presented in a random order, each one appearing on a different screen page. Thus, in order to verify whether scores on the tendency to experience regret, and scores on the subscale of the Maximization/satisficing tendencies (Decision difficulty, Alternative Search, and High Standards) can predict metacognitive processes in reasoning, these measures were used as predictors in the subsequent analyses. Dependent variables were represented by participants' performance in the same six CRT problems adopted in the pre-test, following a two-response paradigm. Hence, again, Intuitive Response Times, Intuitive Response Accuracy, Feeling of Rightness, Rethinking Times, Reflected Response Accuracy, Final Judgments of Confidence and Response Change were collected. RT were measured in seconds. Accuracy means are represented on a scale from 0 (all tasks incorrect) to 1 (all correct), and Judgments of confidence (FoR and FJC) were assessed on a scale from 1 (guessing) to 100 (feeling completely certain).

Results

In the following Table, descriptives for participants' performance in each of the CRT problems given are shown:

	Intuitive Response Time	Intuitive Response Accuracy	Feeling of Rightness (FoR)	Rethinking Time	Reflected Response Accuracy	Final Judgment of Confidence (FJC)	Response Change
	M (SD)	Correct %	M (SD)	M (SD)	Correct %	M (SD)	Changed %
CRT1 *(TV and DVD)*	11.91 (9.00)	14.9%	78 .89 (27 .28)	16.12 (46.4)	29.9%	90 .45 (15 .05)	18.4%
CRT2 *(hens and eggs)*	17.81 (13.57)	48.3%	73 .02 (25 .38)	17.26 (20.11)	48.3%	82 .69 (19 .62)	20.7%
CRT3 *(computer virus)*	21.74 (19.99)	23%	64 .47 (29 .61)	24.49 (59.26)	29.9%	75 .09 (25 .68)	29.9%
CRT4 *(elves and toys)*	20.5 (20.34)	71.3%	70 .80 (28 .96)	12.95 (14.71)	87.4%	88 .70 (14 .17)	19.5%
CRT5 *(student's class)*	14.42 (11.00)	11.5%	67 .49 (28 .27)	16.24 (24.35)	20.7%	76 .21 (24 .16)	28.7%
CRT6 *(athletic team)*	26.23 (32.61)	14.9%	57 .59 (28 .75)	18.51 (19.01)	33.3%	76 .03 (20 .97)	33.3%

Means and Standard Deviations for each variable, and intercorrelations between all the variables are presented in the next Table.

	M	*(SD)*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
1. Regret	47.76	(7.95)	1	**71****	**.49****	**.40****	.08	.02	.11	.03	.04	-.07	.11
2. Decision Difficulty	8.80	(2.88)	**.71****	1	**.30****	.15	.18	-.03	.08	.05	.09	-.07	.08
3. Alternative Search	9.04	(2.70)	**.49****	**.30****	1	**.28****	-.03	.04	**.22***	-.04	-.04	-.07	.07
4. High Standards	9.18	(2.68)	**.40****	.15	**.28****	1	-.20	.15	**.31****	-.16	-.03	-.08	.06
5. Intuitive Response Time	19.28	(12.38)	.08	.18	-.03	-.19	1	.01	.08	-.14	.05	-.12	-.09
6. Intuitive Responses Accuracy	.32	(.23)	.02	-.03	.04	.15	.01	1	**.24***	**-.21***	-.09	**.71****	**.26***
7. Feeling of Rightness	69.87	(20.77)	.11	.08	**.22***	**.31****	.08	**.24***	1	**-.59****	**-.44****	-.15	**.56****
8. Response Change	.25	(.24)	.03	.05	-.03	-.16	-.14	**-.21***	**-.59****	1	**.45****	**.28****	-.07
9. Rethinking Time	17.15	(22.82)	.04	.09	-.04	-.03	.05	-.09	**-.44****	**.45****	1	**.24***	-.09
10. Reflected Responses Accuracy	.42	(.28)	-.07	-.07	-.07	-.08	-.12	**.71****	-.15	**.28****	**.24***	1	**.33****
11. Final Judgment Confidence	82.51	(13.97)	.11	.08	.07	.06	-.09	**.26***	**.56****	-.07	-.09	**.33****	1

As a first consideration, we could observe an elevated consistency between the four individual characteristics assessed through the self-report questionnaires. Regret and Alternative Search tendencies, in fact, positively correlated with each other, and with both Decision Difficulty and High Standards, *p*s $< .01$. Meaningfully, Regret and Decision Difficulty showed a particularly high correlation, $r = .71$. Only Decision Difficulty and High Standards emerged as not significantly correlated with each other, $r = .15$. High Standards and Alternative Search were the only two measures found correlated with a measure of metacognitive monitoring, that is the Feeling of Rightness, respectively $r = .31$, $p < .01$, and $r = .22$, $p < .05$.

For what concerns variables derived by participants' performance in the reasoning tasks, we could see that, as expected, the accuracy of solutions provided as intuitive responses showed a positive correlation with both FoR and FJC, an inverse correlation with Response Change, and a particularly high positive correlation with accuracy of reflected responses, suggesting that, reasonably, correct intuition were likely reconfirmed after reflection, but also that participants were likely to reconfirm their heuristic incorrect solutions too. The FoR was negatively correlated with Rethinking Times, suggesting that, as in previous researches (e.g. Thompson et al., 2011), monitoring processes may act as mediators of mental effort. Indeed, longer times spent to provide a reflected solution were accompanied by a higher final accuracy. Unexpectedly, longer Intuitive Response Times were correlated with higher FoR, suggesting that this judgment of confidence could actually be conceptually different from the monitoring component described by Thompson (e.g. 2011). Thus, a series of regression analyses were performed to verify whether classic effects in meta-reasoning literature were confirmed: indeed, Feeling of Rightness could predict both Rethinking Times, $t = -4.59$, $p < .001$, adj. $R^2 = .18$, and

Response Change, $t = -6.87$, $p < .001$, adj. $R^2 = .34$, confirming that a lower confidence can reveal the need of deeper reflection, and enhancing the possibility to activate the research for alternative solutions to a problem.

Focusing on our main question, we performed a series of regression analyses in order to examine the role of the individual characteristics on meta-reasoning. Using separately Regret, Decision Difficulty, Alternative Search and High Standards as independent variables and the FoR as dependent, only the High Standards measure reached significancy, $t = 3.05$, $p < .01$, adj. $R^2 = .08$, showing that the tendency to aim at the best possible solution might be predictive of higher confidence in one's intuitions, even if it did not enhance their accuracy.

Discussion

In this last study, we examined how individual features related to decision-making style could predict metacognitive feeling of confidence. The most evident result from this individual differences research would be focused on the sub trait of the Maximization tendency regarding High Standards, which has been shown to positively predict the Feeling of Rightness. Schwartz et al. (2002) have suggested that the tendency to optimize when making decisions may manifest as a dispositional variable. Whereas some individuals consistently try to choose the "best," other people tend to "satisfice" and settle for options that are simply good enough. Maximizers tend to pursue the best option, not simply an option that is good enough, and are constantly asking themselves "is this the best outcome?" rather than "is this a good outcome?". Schwartz and his colleagues (2002) suggested that this difference represent a general behavioral tendency, and several psychological correlates, including regret, happiness, depression, optimism, self-esteem, perfectionism, neuroticism, and subjective well-being showed that not only do maximizers exhibit a different style of decision-making from satisficers, but they also appear to experience different emotional concomitants of decisions (Nenkov et al., 2008). They experience higher levels of regret and dissatisfaction than satisficers, and are less happy, more depressed and less optimistic than satisficers (Iyengar et al., 2006; Schwartz et al., 2002). Despite these general correlates, Higher Standards dimension is more strongly related to perfectionism than the relevant correlations involving either Decision Difficulty or Alternative search. Furthermore, this dimension does not have a strong negative correlation with satisfaction with life, subjective happiness, or optimism, as the other dimensions of Maximization, and it does not positively correlate with depression. Therefore, if an individual scores high on this single dimension of the Maximization Scale, s/he is not likely to exhibit several of the various negative affective correlates of the maximization trait. Related to our study, High Standards dimension has also been previously shown positively and significantly related to the Need for Cognition, conceptualized by Cacioppo and Petty (1982) as the relative proclivity to process information and engage in and enjoy thinking in general (Nenkov et al., 2008). Hence, such a relation would make you expect to observe stronger indicators of Type 2 processing together with higher scores on the High Standards. At the opposite, in our study this component was only related to the FoR, and in the direction that would thwart effortful reflection. Not questioning now the unexpectedness of this result, our finding adds to the literature that focus on the different emotional concomitants of decisions and their relation with the decision-making style, and provide new insights to the suggestion that a wide dimension of metacognitive monitoring process might share some trait-like characteristic.

General discussion

The present dissertation aimed at investigating the mechanisms through which we monitor and control our mental resources in order to efficiently solve problems and make decisions, which is a critical aspect of everyday life. Indeed, as humans, we have unique abilities that make us possible to reason hypothetically, logically, and through abstract representations, but such "powers" come at cost of time, working-memory capacity and disposition to engage in mental effort. Metacognitive monitoring and control processes intervene in establishing when such effort is required, and are revealed by feelings, or states, of certainty and confidence. Starting from the recognition that inefficient actions of such metacognitive processes might bring to states of overconfidence or underconfidence that can be seen as general frames for cognitive biases, mounting evidence suggests that rationality inevitably depends on the good functioning of such metacognitive processes: thus, exploring the functions of reasoning and decision-making through a meta-cognitive perspective seems nowadays absolutely useful and promising. One basic idea is that obtaining a stronger understanding of the factors that lead to engage in (or prevent the engagement of…) analytic thought, could lead to more efficient debiasing interventions and, as a consequence, better decision-making. Our theoretical background has been centred on the extant models that try to depict the architecture of the mind with the distinction between intuitive and deliberative thinking processes. Indeed, also the recently-developed meta-reasoning framework was born within this field. The key question of the present thesis is whether and how different features, both underlying a decisional context or characterizing an individual reasoner, might predict different operations of metacognitive monitoring and control processes. In fact, while states and feelings of confidence have been conceptualized in order to explain the intervention of analytic thoughts, the research regarding what cues such feelings is still in its infancy. Thus, the present dissertation contributes to the current debate starting the investigation of both contextual features, like feedback information made available during the reasoning process, or expectations of external assessments of our reasoning process; and individual differences in people's trait-like tendencies to rely on "intuition" or engage in deliberative reflection. The studies described in Chapter 3 mainly addressed this issue examining the role of positive and negative feedback information, and the role of feedback anticipation, focusing on their effects on the engagement in Type 2 reflective thinking. In study 1, in particular, participants' response times during a sequence of conditional reasoning task progressively decreases. Moreover, the confirmative vs. corrective nature of the pieces of information provided to participants, showed that people's reasoning processes reactions are different when they get to know that they are doing right (such information would give a boost to reasoning strategies based on Type 1 processing) or when they get to know that they are doing wrong (this information would temporarily make you keep a higher vigilance on the task). Nevertheless, feedback information did not manage to influence metacognitive monitoring and control processes.

In study 2, we tried to replicate a finding of the previous experiment, with a new set of different reasoning tasks, all them equal to the CRT (Frederick, 2005). However, we could not identify any significant feedback effect on reasoning or metareasoning components. Even with a shortage in recognizing feedback effect on metacognitive components, we claim the originality of our attempt to in the fields of reasoning and metareasoning: such feedback manipulations, in fact, appear not to have been commonly implemented previously in such research, despite its potential to provide insights into reasoning processes and the way in which they can be modulated by external factors arising as part of the task environment.

The studies described in Chapter 4 focused on the role played by individual characteristics of a reasoner. In the Study 3, we began with the major distinction in thinking disposition, or *cognitive style*, that is the preference for a rational or for an intuitive thought. Being these dimension themselves conceptually linked to a dual process perspective, we could observe different patterns in the performance of two groups (rational vs intuitive) of participants in the resolution of the CRT-similar problems. As the most interesting finding, while people with a preference for intuition are, not surprisingly, more likely to rely on heuristic solutions although they are wrong, those with a preference for rationality, that still show they can easily fall in thinking bias, could be less aware then the former, and possibly less prone to question their mistakes. Finally, in Study 4, we took into account several individual features related to personality traits and decision-making styles, and identified in the Maximization Tendency, or, more specifically, in its sub-class labelled as High Standards, a new predictor of the metacognitive Feeling of Rightness.

In conclusion, the present dissertation provides behavioural evidence that supports the utility of performing research in reasoning and decision-making by integrating a metacognitive approach, able to bring attention on a wide range of states and feelings that play their part in the complex dynamics of higher cognition.

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