Reference: Thompson, V. A. (2009). Dual-process theories: A metacognitive perspective. In J. Evans & K. Frankish (Eds.), In two minds: Dual processes and beyond (pp. 171 –195). Oxford: Oxford University Press.

CHAPTER 8

DUAL-PROCESS THEORIES: A METACOGNITIVE PERSPECTIVE

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The core assumption of Dual-Process Theories (DPT) is that reasoning and decision- making are accomplished by the joint action of two types of processes, differing in terms of the degree to which they are characterized as fast and automatic or slow and conscious (e.g., Evans, 2006; Kahneman, 2003; Sloman, 2002; Stanovich, 2004). Automatic System 1 (S1) processes give rise to a highly contextualised representation of the problem and attendant judgments that are seldom analysed extensively by the more deliberate, decontextualised System 2 (S2) processes. Even in cases where analytic processes are engaged, the representations formed by System 1 may omit relevant information that is not salient in the environment, so that the processes engaged by System 2 may focus on a selected subset of relevant information. Together with the assumption that System 2 processes have limited abilities, variously attributed to poor monitoring, limited working memory resources, absence of good normative models, and a tendency to "satisfice", DPT potentially explain so-called biases and errors in a broad range of reasoning tasks.

In terms of predicting the outcome of any given reasoning attempt, the crucial questions for DPT are when and to what extent does S2 intervene? To date, a number of variables have been suggested (see Evans, 2006 for a summary). With few exceptions, these variables deal with global characteristics of the reasoner, such as cognitive capacity (Stanovich, 1999; de Neys 2006) or aspects of the environment including the amount of time allotted to complete the task (Evans & Curtis-Holmes, 2005; Finucane, Alhakami, Slovic, & Johnson, 2000) and the instructions provided to the reasoner (Newstead, Pollard, & Evans, 1992; Evans, Newstead, Allen, & Pollard, 1994; Daniel & Klaczynski, 2006; Vadenoncoeur & Markovits, 1999). Missing from this analysis is a description of the properties of the stimulus that are more or less likely to trigger S2 intervention. That is the goal of the current paper.

1. The theoretical framework

In this chapter, I develop a framework for predicting S2 intervention that is based on metacognitive experiences associated with S1 processes. In particular, I develop the argument that the outcome of a given reasoning attempt is determined not only by the content of the information that is retrieved by S1 and analysed by S2, but also by a second-order judgment. This metacognitive judgment is largely based on the experience associated with the execution of S1 and S2 processes and it is this judgment that determines whether, and how S2 processes are engaged. A diagram of the complete model is presented in Figure 8.1.

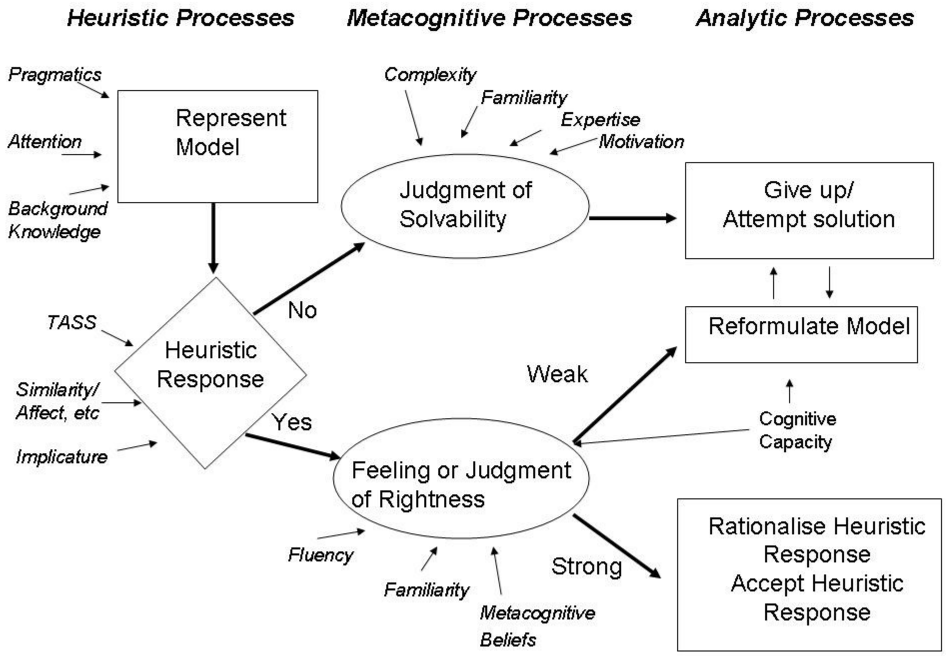

Figure 8.1: *A metacognitive framework of reasoning*

The major difference between the model presented in Figure 8.1 and extant models is the inclusion of metacognitive processes. Other aspects of the model, namely the generation of heuristic responses and that execution of analytic processing have been extensively discussed by others. In the current chapter, I argue that metacognitive processes provide an important link between the heuristic processes represented on the left and the analytic processes described on the right.

To illustrate this approach, consider the following two formulations of a problem. The first is one of the items from Frederick's (2005) Cognitive Reflection Test (CRT). The second is an isomorphic version of the same problem:

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

____ minutes

If it takes 5 machines 2 minutes to make 10 widgets, how long would it take 100 machines to make 100 widgets?

____ minutes

The first problem strongly cues the response “100", which is, in fact, erroneous but often given as an answer (Fredrick, 2005). In the language of DPT, System 1 has produced a heuristic response that is accepted with little, if any, analysis by System 2. In contrast, the second problem does not directly cue a response from S1, and instead invites one to take out a pencil and paper and attempt a solution via algebra.

Put in these terms, the widget example draws attention to several issues. The first concerns the circumstances under which S1 is cued to produce a heuristic response. Second, once such a response is cued, under what circumstances is that response modified? Again, there are at least two facets to this question. The first concerns the properties of the retrieval process that trigger awareness of the need to re-analyse the problem. The second concerns the nature of the analysis that is triggered. Finally, in the absence of a strong heuristic response, what determines S2 intervention? That is, under what circumstances will the reasoner take out the pencil and paper and attempt the algebra needed to solve the widget problem?

2. What triggers a strong heuristic response?

Although this is a important question, I will address it only briefly, given that it has been extensively analysed by others. Indeed, three recent approaches to explaining heuristic responding have been proposed; although they differ in terms of specifics, they share the basic assumption that heuristic responses are cued automatically by perceptual or cognitive input and that these responses form the basis of subsequent judgments and decisions.

Kahneman (2003) proposed that heuristic responses consist of impressions formed about the objects of perception and thought. These impressions, which he called *natural assessments*, are formed automatically, in that they are not subject to voluntary control; further, the origins of these impressions are not available to introspection. The accessibility of these natural assessments is thought to be determined by the skill of the reasoner, properties of the stimulus, physical salience, framing, and priming. For example, framing an outcome in terms of survival rates promotes a more positive evaluation than does a framing in terms of mortality rates, presumably because the former primes positive thoughts whereas the latter primes negative ones. Reasoners then form an impression or a natural assessment based on the emotional valence of the primed thoughts and this natural assessment subsequently forms the basis of a judgment.

According to Kahneman, the domain of natural assessments includes physical properties such as size, distance, and loudness, as well as more abstract properties such as similarity, surprisingness, affective valence, etc. These assessments become judgments by a process of attribute substitution in which an individual makes a judgment about one attribute (i.e., probability) by substituting a judgment about a different attribute (such as affective valence) that is more accessible. In this view, the role of S2 is to monitor this process; analytic processes are engaged when the substitution is detected.

Stanovich (2004) offers a somewhat different view of heuristic processes. He argues that what is referred to as “System 1" is really a multiplicity of systems that function automatically in response to triggering stimuli; these he collectively refers to as The Autonomous Set of Systems (TASS). These systems include domain-specific processes, such as those involved in language and perception, domain-general processes, such as those involved in associative and implicit learning, and skills that have been learned to the point of automaticity. These processes, while constrained to operate within the strict limits of their triggering stimuli, are fast, efficient and can operate in parallel. S2, in this view, is responsible for monitoring the outputs of the TASS subsystems and to intervene when TASS produces responses that conflict with the reasoner’s goals.

Alternatively, S1 processes can be viewed as the processes that construct a model of the problem (Evans, 2006); this model may contain only a subset of relevant information, include irrelevant information, and may be contaminated by prior beliefs and expectations. In this view, S1 processes are those used to contextualise input, that is, they are the processes by which relevant background knowledge and beliefs are recruited (Evans, 2006; Evans et al., 2003; Stanovich, 1999). These processes give rise to belief-bias and other related effects. For example, listeners often rely on conversational implicatures to embellish and interpret a reasoner’s speech. In the context of deductive reasoning, for example, a reasoner’s interpretation of logical quantifiers may be guided by conversational principles that gives them a different meaning than intended by logicians (Begg & Harris, 1982; Feeney, Scrafton, Duckworth, & Handley, 2004; Newstead, 1989) and this interpretation plays a functional role in the inferences that they draw (Roberts, Newstead, & Griggs, 2001; Schmidt & Thompson, in press). For instance, the meaning of “some” is logically consistent with “all”even though most listeners would find such usage infelicitous. In other cases, pragmatic and linguistic processes highlight the relevance of some information, and omit others from the representation (Evans, 1998; 2006). In this view, S2 operates on potentially biassed or incomplete representation, and decisions are usually based on the information that is heuristically cued (Evans, 2006). Although the analytic system may scrutinise those choices, it will not do so unless there is a compelling reason.

In sum, all three views suggest that heuristic judgments are strongly cued, automatic and largely implicit (i.e., their origins are not available to introspection). For a variety of reasons, these judgments are often accepted with little further analysis by the analytic system. In the following sections, I turn to the question of why these heuristic judgments are readily accepted, and propose criteria by which S2 is triggered to intervene with those heuristic judgments.

3. Properties of the retrieval process that trigger awareness of the need to re-analyse the problem

Do you feel the need to reread the forgoing paragraphs? The answer to this question is guided by a metacognitive judgment of the degree to which you have adequately understood the text. Metacognitive judgments are routinely used to assess the workings of our cognitive processes, and in particular, the degree to which such processes have functioned or will function correctly. Just as importantly, these judgments are causally relevant in the decision to stay with the current output or seek another (e.g., Mazzoni & Cornoldi, 1993; Son & Metcalfe, 2000; Nelson, 1993; Son, 2004). If you are confident that you have understood the text, you will not re-read it. If you are confident that you have correctly remembered the name of a person you have just run into, you will address that person by name; if not, you may choose a more generic greeting. If you are not confident that you will remember the milk on the way home, you might arrange a cue or trigger to jog your memory. In all cases, the accuracy of performance depends not only on the accuracy of one's memory but also on metamemory, that is, one's ability to monitor one's mental processes and take appropriate actions on that basis (Koriat & Levy-Sadot, 1999).

3.1 The Feeling of Rightness.

Although studied extensively in other domains, the role of metacognitive processes in reasoning have been relatively neglected. However, it is almost certain that they play the same kind of role as they do in other judgments; namely, to provide a means to assess the output of one's cognitive processes and determine whether further action should be taken. Under this view, the explanation for the compellingness of many cognitive illusions is that the heuristic response is generated with a strong intuition that the answer is correct. It is this intuition, or Feeling of Rightness (FOR), that is the reasoner's cue to look no further afield for the answer.

During the preparation of this paper, I asked several of my colleagues to solve the misleading version of the widget problem above. A typical response was something like "Well the answer has to be 100, doesn't it? What else can it be?" The answer "100" is cued with a very strong FOR, so that even when told the answer was incorrect, people suspected me of pulling their leg. Sloman (2002) has made a similar point about the famous "Linda" problem. Even knowing that it is impossible for the probability of being a feminist bank-teller to be less than the probability of being a bank-teller, one is left with the feeling that Linda *has* to be a feminist. That is, one has a strong FOR that Linda is a feminist and this feeling persists, even after the logical contradiction is understood.

3.2 Determinants of the Feeling of Rightness.

What creates a strong FOR? As above, such metacognitive experiences have not been extensively studied in the context of reasoning, but there is a large literature on analogous processes in the domain of memory. That is, retrieving an answer from memory is accompanied by a Feeling of Familiarity (FOF), which is the cue that the retrieved item is the one that was sought. For example, what is the capital city of England? Of Peru? Do these memories arrive with the same feeling of certainty? As illustrated by the case of the person whose name you are uncertain of, the strength of this FOF provides a basis for subsequent action. A number of related concepts have been extensively studied, including the Feeling of Knowing (FOK), that is the judged probability that an unrecalled item will be correctly recognized, and Judgment of Learning (JOL), that is, the judged probability that a recently studied item will be correctly recalled at a later time.

This family of metacognitive experiences provides a good analogy to the FOR because, as above, it is assumed that heuristic attributes and accompanying natural assessments are retrieved from memory. Moreover, the FOF, like the FOR, can produce erroneous judgments. We know, for example, that people can express high degrees of confidence in completely false or inaccurate memories (Roediger & McDermott, 1995; Sporer, Penrod, Read, & Cutler, 1995). The reason for this is that metacognitive experiences are based on properties of the retrieval processes that produce memories, rather than on the contents of memory per se (e.g., Benjamin, Bjork, & Schwartz, 1998; Busey, Tunnicliff, Loftus, & Loftus, 2000 Jacoby, Kelley, & Dywan, 1989; Koriat, 1995; 1997; Koriat & Levy- Sadot, 1999; Schwartz, Benjamin & Bjork, 1997). For example, familiarity of the retrieval cues, as opposed to familiarity of the answer (Reder & Ritter, 1992; Schunn, Reder, Nhouyvanisvong, Richards, & Stroffolino, 1997; Vernon & Usher, 2003) determines FOK, as does the amount of ancillary information that is brought to mind during the retrieval attempt (Koriat, 1993; 1995; Koriat, Levy-Sadot, Edry, & de Marcas, 2003).

Of particular relevance to the current discussion is the determining role played by fluent retrieval in metacognitive experiences (e.g., Benjamin, Bjork, & Schwartz, 1998; Jacoby et al., 1989; Kelly & Jacoby, 1993; 1996; Matvey, Dunlosky, & Guttentag, 2001; Whittlesea & Leboe, 2003). That is, easy or efficient processing of an item gives rise to the attribution that the item has been previously experienced, *even when it has not* (e.g., Jacoby et al., 1989; Whittlesea, Jacoby, & Girard, 1990). Fluency of processing has also been demonstrated to underlie numerous other attributions (see Schwarz, 2004; Whittlesea, 1993 for summaries) including aesthetic pleasure (Reber et al., 2004) and judgments of truth (Reber & Schwarz, 1999).

Evidence that metacognitive experiences are based on the fluency of processing is twofold: First are cases in which the experimenter manipulates fluency, either by degrading the stimulus (Whittlesea & Jacoby, 1990; Reber & Schwarz, 1999), by secretly enhancing fluency, as by masked priming (Jacoby & Whitehouse, 1989; Rajaram, 1993) or by implicit activation of a target stimulus (Dewhurst & Hitch, 1997; Roediger & McDermott, 1995). The second concerns item- or task-specific properties of the stimulus. For example, the longer a participant takes to generate the answer to a question, the more difficult they predict it will be to recall later (Benjamin, Bjork, & Schwartz, 1998; Kelley & Jacoby, 1996; Matvey, et al., 2001). Indeed, the fluency of processing gives rise to a perception of difficulty, regardless of the actual relationship between the speed of initial retrieval and subsequent recall (Benjamin et al., 1998). In sum, there is a great deal of evidence to support the conclusion that metacognitive feelings are mediated by the fluency with which the information is brought to mind (see Whittlesea & Leboe, 2003 for a summary of the evidence).

On this view, the key to understanding the basis of the FOR is to understand that it is produced by a retrieval experience. That is, heuristic outputs are retrieved from memory, and this retrieval is accompanied by metacogntive experience based on properties of that retrieval experience, such as the fluency of processing. Moreover, given that heuristic attributes are highly accessible (Kahneman, 2003), even processed ballistically (Stanovich, 2004), the experience should be very fluent and result in a strong FOR. It is important to note, however, that such experiences exist along a continuum, such that some are perceived to be more fluent than others. Thus, more effortful, less efficient processes should produce a weaker FOR.

3.3 Affect and the Feeling of Rightness.

How is it that fluent processing should produce a sense of rightness? Although the reasons are not well understood, there is ample evidence that fluent processing is associated with positive affect, as the extensive literature on the "mere exposure" effect illustrates (see Zizak & Reber, 2004 for a recent review): Stimuli that have been previously encountered are liked better than unfamiliar stimuli. Moreover, this increase in liking is associated with physiological indicators of positive affect, such as increased activity in the zygomatic cheek muscles associated with smiling (Harmon-Jones & Allen, 2001; Winkielman, Halberstadt, Fazendeiro, & Catty, 2007). Several explanations for this relationship have been offered (see Winkielman, Schwarz, Fazendeiro & Reber, 2003 for a review). For example, as described above, fluency is a cue that a stimulus has previously been encountered; the positive valence may result from a predisposition towards caution when encountering unfamiliar and potentially hazardous objects. Alternatively, fluent processing may be a sign that a target has been successfully recognized and interpreted.

4. How does the FOR trigger S2 intervention?

Thus far, I have made the case that heuristic outputs are delivered into conscious awareness accompanied by a metacognitive experience that is largely, although not exclusively, determined by the fluency with which the output was retrieved. In the next section, I will argue that the strength of the FOR determines the probability that S2 is engaged to analyse or rethink the decision based on the heuristic output. On this account, the explanation for the compellingness of many reasoning so-called reasoning biases and illusions is the strength of the FOR that accompanies the heuristic response. In cases where the FOR is weaker, the probability of S2 intervention should be higher.

This section has three parts. The first consists of a discussion of the types of intervention that can be engaged in by S2. The second concerns the relation between strength of a FOR and the probability and type of S2 intervention. The third concerns factors that may moderate the link between FOR and the probability of S2 intervention.

4.1 Types of S2 intervention

There are many different responses that could be classified as S2 intervention. I will consider four here, acknowledging that further options are possible. The first is that the heuristic judgment might be considered with little or no further analysis (Kahneman, 2003). This entails the most minimal commitment of analytic resources, and amounts to little more than an explicit acceptance of the answer generated by implicit processes. A related option, requiring a minimally larger degree of S2 engagement, involves an explicit attempt to consider whether the heuristic judgment seems reasonable. Assuming that it satisfies the current goal state and is otherwise plausible, again, it is likely to be accepted without further analysis (Evans, 2006; Roberts, 2004). If it is not, it may be rejected with little further analysis, or may be subject to re-evaluation (see option three below).

A second alternative is that analytic processes may be engaged to rationalise or justify the heuristic judgment. That is, S2 process might be engaged to explain why the heuristic judgment is correct. There is ample evidence that such processes occur. For example, not all reasoners give more normatively correct responses when allowed ample time to respond than when forced to answer quickly; many participants in the free-time condition produce the same answer as those in the forced-time condition (Evans & Curtis-Holmes, 2005; Roberts & Newton, 2001; Shynkaruk & Thompson, 2006). In other words, for many reasoners, the answer that would be given when allowed extra time to think is the same answer that would be given under time pressure, even if the original answer was incorrect.

What, then, do people do with the extra time if they are not rethinking their answer? Evans (1996) suggests that they are engaged in justifying their initial responses. In support of this hypothesis, he found that on Wason's four-card selection task, people spent the majority of their time attending to the cards they were going to select, rather than to the cards they were going to reject (see also Ball, Lucas, Miles, & Gale, 2003; Lucas & Ball, 2005). In other words, people appeared to spend time deliberating about options already identified by heuristic processes, presumably to rationalise them, rather than considering the potential relevance of the items not identified. Similarly, when presented with hypothetical solutions to Wason's four-card problem, participants are just as confident in their explanations for why the not-*q* card is a correct choice as for why it is an incorrect one (Evans & Wason, 1976). Wason and Evans (1975; Evans & Wason, 1976) speculated that the decision about which card to choose in the selection task was generated by a non-conscious matching bias, so that when asked to justify an answer, they were forced to rely on rationalizations. Indeed, there is evidence to suggest that the processes underlying many choices, judgments, and attitudes are implicit and not easily available to conscious introspection, such that the role of consciousness might be limited to trying to create explanations for why such choices, judgments, and attitudes have been made (see Stanovich, 2004, Chapter 2; Wilson & Dunn, 2004 for review).

A third way in which S2 might intervene is to attempt to reformulate the initial model or representation of the premises, with the goal of deriving a different solution (Evans, 2006; Johnson-Laird & Byrne, 1991; Torrens, Thompson, & Cramer, 1999). For example, a reasoner given the first version of the widget problem above may distrust the initial response, and so instead try to reason out how long it takes each machine to produce a widget. This is clearly the most effortful option, and success at this stage is tied to traditional measures of cognitive capacity such as IQ (see Stanovich, 1999 for review) and WM (e.g., de Neys, 2006 a, b; Gilhooly, Wynn, Philips, Llogie, & Della Sala, 2002). For this reason, it is possible for a reasoner to acknowledge the need to rethink the problem, but judge that he/she lacks the wherewithal or motivation to do so (see the section on Judgments of Solvability, below).

A fourth possibility is that there is an attempt at S2 intervention that fails, such that the heuristic response generated by S1 determines much of the response (see Bargh, 2007 for an extensive discussion of this phenomena in social psychology). For example, S2 processes might be engaged and produce an alternative answer that is less compelling than the S1 output, so that the heuristic response is generated. Similarly, the S1 output may be generated with a sufficiently strong FOR that it casts doubt on the answer generated by S2, undermining the confidence with which it is held. Another mechanism by which the S1 output might contaminate S2 judgments is by anchoring. That is, the S1 output might provide a reference point or a starting point for any simulation attempted by S2; thus, the final value of the answer generated by S2 may be shaded towards the initial value generated by S1 (see Chapman & Johnson, 2002; Epley, 2004 for recent reviews of anchoring and adjustment phenomena).

4.2 Link between S2 and FOR.

Under this proposal, one should be able to predict the type and degree of S2 intervention based on the strength of the FOR. At the extremes, very strong FOR's should be correlated with the inclination to accept the heuristic judgment, and weak FOR's with the inclination to reject the heuristic judgment or to reformulate the problem.

It is less clear what the relationship between the FOR and the probability of S2 rationalisation should be, although in the absence of evidence to the contrary, it seems reasonable to hypothesise that such rationalisation is engaged for a purpose. That is, the attempt at explanation should be made when there is a perceived need for one, either because the experimenter has requested one, because the instructions suggest a need for certainty, or because the FOR is not high enough to accept the heuristic judgment without additional warrant.

4.3 Factors that may moderate the link between S2 and FOR.

Although a weak FOR should be a sufficient basis to engage S2, and a strong FOR a sufficient basis to retain S1, there are several factors that may mediate this relationship. Specifically, reasoners' theories about the origins of the FOR should moderate the relationship between that intuition and the probability of S2 intervention. For example, if one believes that the experimenter is trying to be deceptive or tricky, one might engage analytic thinking even if the heuristic judgment cues a strong FOR. Thinking dispositions, such as those measured by the Actively Openminded Thinking questionnaire (AOT; Stanovich, 1999, this volume) might also moderate this relationship: reasoners who enjoy analytic thinking or believe that good thinking requires analysis of more than one option might be more inclined to engage S2 even with strong FOR. Additionally, an internal metric such as the difference between the state of confidence produced by the FOR and a reasoner's desired level of confidence, may also determine how and when reasoners act on a weak FOR (Chen & Chaiken, 1999).

Finally, reliance on the FOR as a cue may vary as a function of individual differences in monitoring and control (Hertzog & Robinson, 2005 for review, Stanovich this volume for a related view). That is, individuals differ with respect to how good they are at monitoring their cogintive processes for errors. Did you catch the typo in last sentence? If so, that is an example of successful monitoring. Generally speaking, individual differences in monitoring skills are linked to successful task performance in a variety of domains, such as reading (e.g., Lin, Moore, & Zabrucky, 2001; Pressley, 2003), learning optical principles (Prins, Veenman, & Elshout, 2006), and mathematical problem solving (Desoete & Roeyers, 2006; Lucangeli, Tressoldi, & Centron, 1998).

5. Metacognition and the quality vs quantity of S2 intervention.

The link between monitoring skills and task performance may provide an answer to another contentious question, namely, whether cognitive capacity predicts the probability that S2 is engaged to overturn a heuristic output or whether cognitive capacity predicts the success of S2 intervention once it has occurred (e.g., De Neys, 2006; Klaczyski & Robinson, 2000; Stanovich, Torrens et al, 1999). Evans (in press) refers to these possibilities as the quantity and the quality hypotheses respectively. In the metacognitive framework outlined here, evidence that demonstrated a link between cognitive capacity and monitoring skill would favour the quantity hypothesis. That is, the quantity hypothesis suggests that high capacity reasoners should have better monitoring skill; this, in turn, means that they are more likely to initiate S2 analysis of a heuristic response.

There is good reason to suppose that such monitoring and inhibitory abilities are linked to IQ (e.g., Prins, Veenman, & Elshout, 2006; Veenman, Kok, & Blote, 2005). For example, Necka and Orzechowski (2005) documented evidence that IQ is linked to the ability to suppress automatic responses on tasks such as the Stroop. On this task, participants need to inhibit a highly automatic response in favour of a less available one, such as naming the ink colour of a printed word (e.g., the word blue printed in red ink). Similarly, the probability of suppressing the modal response on the widget and other problems is likewise linked to measures of cognitive capacity (Frederick ,2005) as is the ability to suppress irrelevant counter-examples in conditional reasoning (de Neys, Schaeken, & d'Ydewalle, 2005; Markovits & Doyon, 2004).

Based on these findings, one might proffer the hypothesis that cognitive capacity and IQ have both direct and indirect links to S2. The direct link reflects the fact that high capacity reasoners are more likely to correctly solve a problem once a heuristic response has been suppressed. The second link may be mediated by monitoring skill, in that high ability reasoners have better metacognitive skill (and are thus more likely to inhibit a heuristic response) than low ability reasoners.

Nonetheless, it is important to note that cognitive capacity may explain only a small part of the relationship between monitoring skill and propensity to engage S2 processes. Indeed, the available evidence suggests that the ability to inhibit heuristic responses (Markovits & Doyon, 2004; Handley, Capon, Beveridge, Dennie, & Evans, 2004) and skill at monitoring cognitive processes (Prins et al., 2006; Veenman et al., 2005) predict an independent portion of the variance in problem solving skills after accounting for the effects of IQ. Moreover, the data suggest that many biases, such as belief-bias and my-side bias may be independent of IQ (Klaczynski & Robinson, 2000; Torrens et al., 1999; Stanovich & West, 2007). Thus, while IQ might explain part of the relationship between monitoring and S2 processes, much of the variance is yet to be explained.

Stanovich (this volume) proposes that the remaining variance can be accounted for by what he calls the "reflective" mind. The reflective mind encapsulates an intentional level of behaviour, such as goal- and belief-states. The reflective mind shares many properties with System 2, such as limited-capacity serial processing. Nonetheless, he proposes that intentional states occupy a different level of analysis in cognitive theory than do algorithmic processes (i.e., those processes associated with the execution of S2 analyses). This proposal shares many assumptions with the metacogntive framework advance here, namely, that the regulation of S2 intervention requires a third type of process that is not captured by the S1/ S2 distinction. The key difference lies in the notion of intentionality. Stanovich's description of the reflective mind emphasises conscious processes that are available to introspection; these processes can therefore be adequately indexed using self-report measures of thinking dispositions that tap reasoners' epistemic values and goals. In contrast, the proposal outlined above emphasises the role of implicit processes in monitoring, allowing a relatively smaller role for intentional processes.

Finally, it is assumed that the answer endorsed by S2 is endorsed with a final estimate of confidence. This final judgment should reflect both the initial FOR as well as the influence of the moderating factors described above. For example, in cases where the answer is based on the heuristic output, confidence should vary positively with the strength of the initial FOR. One might speculate that when S2 is engaged to rationalise the heuristic judgment, that the final confidence judgment is stronger than the initial FOR. In cases where the reasoner has an alternative theory for the source of the FOR, there might be no relationship between the strength of that initial response and the final judgment of confidence. Similarly, in cases where S2 is engaged to reformulate the problem, one would expect relatively little relationship between the initial FOR and the final confidence judgment; confidence in this latter case should be determined by the factors discussed in the section dealing with Judgments of Solvability.

6. Metacognitive Judgments and the Feeling of Rightness.

In the forgoing discussion, I have been careful to refer to metacognitive experiences when discussing the FOR, as opposed to metacognitive judgments. As described above, the FOR is assumed to be an affective response that carries little cognitive content and that is generated by implicit processes whose origins are not likely available to conscious processes (Koriat & Levy-Sadot, 1999). It is the interpretation of that feeling or affective response that produces a judgment.

I will use the term *Judgment of Rightness* (JOR) to differentiate the interpretation of the FOR from the affective response itself. Note that use of the term judgment does not imply extensive analysis. Indeed, in most cases, it is assumed that the FOR will be a sufficient basis for judgment, such that one's JOR is completely determined by the strength of the FOR with little, if any, conscious effort. Thus, like many other metacognitive judgments, the JOR may be little more than the awareness of a feeling of confidence that carries little or no information about the basis of that confidence.

6.1 The interpretive basis of the JOR.

Although in most cases, the strength of the FOR should be a sufficient basis for judgment, there will be circumstances in which the FOR may be explicitly discounted. For example, if participants are given an alternative explanation for the basis of their metacognitive experience, they are less likely to rely on fluency of retrieval as a cue (e.g., Jacoby & Whitehouse,1989; Kelley & Jacoby, 1996; Schwarz & Vaughn, 2002; Whittlesea & Jacoby, 1990; Willems, S., van der Linden, M., & Bastin, C., 2007). Schwarz and his colleagues have provided many demonstrations of this phenomena (Rothman & Schwarz, 1998; Sanna & Schwarz, 2003; Schwarz, Bless, Strack, Klumpp, Rittenauer-Schatka, & Simons, 1991). In these studies, participants are asked to generate either short or long lists of exemplars, for example, of instances in which they have recently been assertive. They are then asked to make a judgment about a quality relevant to those instances (i.e., their assertiveness). A typical finding is that those who generate short lists provide more extreme ratings than those who generate long lists. For example, participants who are asked to generate six instances of assertive behaviour rate themselves as more assertive than participants who are asked to generate 12 instances, even though they have less objective evidence to support their judgment (Schwarz et al., 1991). This relationship presumably represents a metacognitive judgment regarding the ease with which instances are generated: Six instances are more fluently generated than 12. Participants who generated many instances presumably found in difficult, and inferred the cause of that difficulty to be the absence of the quality under judgment rather than the properties of the task. However, this trend reverses if they are given a different explanation about why it is relatively difficult to generate instances, such as the background music or unfamiliarity with the task (Schwartz & Vaugh, 2002).

6.2 Explicit cues to the JOR.

Thus far, I have discussed only implicit aspects of the JOR. By analogy to other memory- based judgments, such as the Feeling of Knowing and the Judgment of Learning, it is assumed that the JOR reflects two sources of information (e.g., Kelley & Jacoby, 1996; Koriat & Levy -Sadot, 1999; Koriat, et al., 2004; Schwarz, 2004; Brewer & Sampaio, 2006; Matvey, et al., 2001). The first source is the FOR; it is assumed to be cued automatically and the origins of the response (e.g., as a feeling of fluency) are assumed to be unavailable to introspection (e.g., Brewer & Sampaio, 2006, Koriat, et al., 2004; Matvey, et al., 2001; Schwartz, 2004). The second source consists of a reasoner's metacognitive beliefs. These can be accessed explicitly, although it is not assumed that the reasoner is necessarily aware of their contribution to a judgment. For example, beliefs about how memory deteriorates over time can moderate confidence in memory retrievals (Koriat et al., 2004), although such beliefs may be difficult to access in a particular context and so have limited effect.

Shynkaruk and Thompson (2006) found evidence that confidence in syllogistic reasoning performance may be moderated by these types of metacognitive beliefs. Reasoners were asked to evaluate the conclusions to syllogistic arguments and to provide confidence ratings on two occasions: The first in response to an initial, fast assessment of the conclusion and the second after more deliberation. They observed that confidence increased from first to second response, regardless of whether accuracy increased, decreased or the answer did not change. The authors argued that the increase in confidence was a function of reasoner's metacognitive beliefs that decisions considered over time are superior to those made under pressure.

Other source of metacognitive beliefs may be a reasoner's global assessment of their reasoning ability or thinking style as indexed by measures such as the Rational Experiential Inventory (REI), a 40-item self-report inventory (Pacini & Epstein, 1999). The REI measures self-reported tendency to engage in rational (i.e., reliance on analytic approaches to solving problems) and/or experiential thinking (i.e., reliance on past experiences or intuition). Consistent with this hypothesis, Prowse-Turner and Thompson (2007) observed that those who scored high on the rationality portion of the REI expressed a high degree of confidence in their evaluation of syllogistic arguments, even though they were no more accurate than those who scored low in rationality (see also Dunning, Johnson, Ehrlinger, & Kruger, 2003; Jonsson & Allwood, 2003).

Another basis of metacognitive beliefs concerns the extent of one's domain- specific knowledge about a topic. That is, if one believes that one knows a lot about a particular domain, one may be prone to confidence in judgments associated with that domain (Cowley, 2004; Costermans, Lories, & Ansay, 1992; Gill, Swann, & Sivera, 1998; Morgan & Cleave-Hogg, 2002). Shynkaruk and Thompson (2006) posited that these types of beliefs may also play a role in reasoning judgments: In a syllogistic reasoning task, reasoners expressed more confidence in conclusions to which they could apply pre-existing knowledge (i.e., that were believable or unbelievable) than ones that were neutral, even though they were no more accurate with the believable than the neutral conclusions.

In sum, it is proposed that the JOR, like other memory based metacognitive judgments, is multiply determined by both implicit and explicit cues. Implicit cues are based on properties of the retrieval experience, such as its fluency; explicit cues are derived from beliefs that are accessible to conscious introspection. Note that, as is the case with decisions based on heuristic outputs, metacognitive decisions may be based on implicit cues, even when a more accurate judgment could be derived from explicit sources (Koriat et al. 2004).

6.3 JOR's, FOR's, and the control of cognition.

Figure 8.1 allows for the possibility that S2 intervention may take place either on the basis of a JOR or a FOR. As above, a JOR is more complex than a FOR, at minimum, reflecting an interpretation of the cues giving rise to the FOR; it may include variety of beliefs about the tasks, one's own reasoning ability, etc. That cognitive functions can be controlled by these types of judgments is well documented (see Koriat, 2007 for an excellent summary).

Less clear is whether a judgment per se is required to initiate S2 intervention. That is, can S2 be initiated without conscious intent to do so? Or, put another way, is awareness of the FOR necessary to initiate S2 intervention? Although the term "metacognition" is generally understood to imply conscious awareness, there are those who argue that monitoring and control processes can be initiated without such awareness (again, see Koriat, 2007). This possibility is allowed for in Figure 8.1.

Under this view, S2 analysis could be initiated by a weak FOR without the need for an explicit evaluation of that feeling. This type of direct association was implied by the discussion on rationalisation. This could still be true in those circumstances where the reasoner undertakes a re-analysis of the problem; whilst it is possible for the reasoner to be aware of the particular circumstances that motivated their re-analysis, it might also be prompted by a vague unease about the heuristic output. That is, it is not necessary to assume that the reasoner has any more conscious awareness about why they are analysing the heuristic output than they do about the sources of that output.

7. In the absence of a strong heuristic response, what determines degree of S2 involvement?
In the preceding sections, I addressed the situation in which the content or context of the problem provokes a heuristic judgment and attendant FOR. In this section, I examine the situation in which the combined activities of S1 do not suggest a compelling solution or decision. That is, in many cases there will be little contextualisation provided by the heuristic systems; in other cases, there might be some but not enough on which to base an answer.

In those cases where the heuristic systems do not deliver a compelling response, I propose that the probability with which reasoners will engage analytic processes varies according to the strength of a prospective metacognitive judgment that I will term the Judgment of Solvability (JOS). Less is understood about these kinds of judgments than about the processes that give rise to the experiential judgments discussed above, although there is evidence that such prospective judgments predict accuracy for some types of problem-solving situations (Metcalfe & Weibe, 1987) but not others (Metcalfe, 1986a). As with the JOR, it is proposed that initial JOS's determine the type and extent of analytic engagement. Initially, the choice is to attempt a solution or not; during the course of problem-solving, the choice is to continue with the current strategy, start anew, or abandon the attempt.

A few obvious candidates suggest themselves as the basis for this JOS. For example, reasoners may undertake an initial estimate of problem difficulty (Elfklides, Samara, & Petropoulou, 1999; Kruger, 1999). Although there is little evidence to indicate how such estimates are derived, variables such as self-assessed ability in a particular domain certainly mediate such estimates (see Hertzog & Robinson, 2005 for a review). One might also speculate that the reasoner's goals and motivation might determine the strength of the JOS, such that problems that might be deemed solvable in some circumstances might not be attempted in others (Elfkides et al., 1999).

Other bases for JOS's can be derived by analogy to prospective memory estimates, such as Judgments of Learning. Such judgments are moderated a quick assessment of solvability (Son & Metcalfe, 2005), fluency of reading (as above), and familiarity with problem components (Reder & Ritter, 1992; Rehder, 1999; Vernon & Usher, 2003). There is also evidence that JOS's are made at several points during a problem solving episode, such that initial estimates of difficulty are continuously revised and updated (Elfkides et al., 1999; Vernon & Usher, 2003).

8. Outstanding issues
In this final section, I attempt to address several questions raised by the preceding analysis: First, given that heuristic processes are associated with processes that comprehend and represent information, the next logical question concerns how that information is represented. In the paragraphs below, I suggest some lines of enquiry that might be fruitful in elucidating this issue. Second, at a fundamental level, one might query the adaptive value of relying on metacognitive processes that so often produce reasoning biasses. Third, I discuss the "levels of representation"

issue with respect to the JOR and FOR. Finally, I offer some suggestions about how these constructs could be operationalised and tested experimentally.

8.1 Comprehension, attention, and representation.

Earlier, it was proposed that heuristic responses are derived from impressions of attributes of the objects of perception and thought such as similarity, suprisingness, affective valence, and so on (Kahneman, 2003) or from the operation of quasi-modular systems that subserve language comprehension, perception, and learning (Stanovich, 2004). Both views make an explicit link between the information that is extracted and represented from a stimulus and a heuristic output. Moreover, even given that the analytic system has been engaged, its operation is largely restricted to the contents of the representation formulated by S1 unless a deliberate effort is made (Evans, 2006; Markovits & Quinn, 2002; Versheuren, Schaeken, & d''Ydewalle, 2005).

Consequently, the next level of theorizing needs to be explicit about the information that is extracted from a stimulus and the processes by which representations are formed (Newstead, 2000; Thompson, 2000). A possibly fruitful line of enquiry would be to frame the issue in terms of basic comprehension processes. That is, one way to look at the problem is to view heuristic processes as the output of processes used to contextualise representations, that is, to make meaning out of input (Evans, 2006; Stanovich, 1999). For example, processes of semantic priming have been used to elucidate the mental representations underlying such diverse phenomena as conditional reasoning (Markovits & Quinn, 2002, Thompson, 1995; 2000), anchoring and adjustment (Chapman & Johnson, 2002) and analogical reasoning (Krendl, Macrae, Kelley, Fugelsang, & Todd, 2006).

In addition to deriving meaning from input, S1 processes also act as a filter for incoming information, so that S2 processes often operate on incomplete information (Arbuthnott, Arbuthnott, & Thompson, 2005; Evans & Over, 1996; Stanovich, this volume). Thus, another potentially fruitful line of enquiry would be to examine the role played by basic attentional processes in constraining and determining the information that is represented. For example, our attentional processes are largely driven by information that is present in the environment; missing or absent information, no matter how relevant to the current goal, is detected only with difficulty (see Hearst, 1991 for a review and Brockmole & Henderson, 2005 for a recent demonstration). Attention can also be driven by pragmatic and linguistic factors, as numerous experiments with Wason's four card selection task demonstrate (e.g., Evans, 1998; Sperber, Cara, & Girotto, 1995, Thompson, 2000).

8.2 The utility of metacognitive judgments.

What is the adaptive value of metacognitive processes, if they so often lead us astray? The fact that metamemory experiences, such as the FOF, give rise to judgments that are based on aspects of the retrieval experience rather than the contents of memory per se, means that people can have high confidence in completely false memories. As above, I have argued that similar properties of the FOR explain why S2 fails to intervene, even when it is appropriate to do so.

A straightforward answer to the adaptiveness question is that these feelings are, in fact, normally accurate. In the case of feelings of familiarity, for example, it is true that recently encountered events will be recalled more fluently than distant ones, that highly frequent events are recalled more fluently than less frequent ones, and so on. Thus, basing judgments of familiarity on processing fluency is usually a reliable cue to the contents of memory.

Moreover, as Gigerenzer and colleagues have argued (e.g., Gigerenzer, Hoffrage, & Kleinbolting, 1991; Todd & Gigerenzer, 2000; 2003) experimenters are very good at designing studies that show people's intuitions in a poor light. They argue that processes that produce dismal performance under laboratory conditions are optimised to take advantage of the structure of the everyday world, and perform well under normal circumstances. Indeed, even in difficult laboratory environments, there is a positive correlation between metacognitive judgments and performance (Burson, Larrick, & Klayman, 2006; Metcalfe, 1986b, Schraw, Dunkle, Bendixen, & Roedel, 1995; Nelson & Dunlosky, 1991) especially when participants are asked to estimate their overall performance rather than make item by item judgments (Dunning et al., 2003, Stankov, 2000; Shynkaruk & Thompson, 2006; Prowse-Turner & Thompson, 2007).

A less optimistic explanation for the unreliability of metacognitive judgments is the one argued in the current paper, namely that metacognitive judgments, like most other cognitive processes are based on implicit inputs. Consequently, one may have access to the outputs of those processes, but seldom to their inputs (Hertzog & Robinson, 2005; Stanovich, 2004). The resulting metacognitive judgments are based on a number of cues that vary in terms of their diagnositicity, but because they are implicit, the diagnosticity of these cues is unknowable (Koriat 1995; 1997). Indeed, several researchers have suggested that training in a domain needs to address not only the skills necessary to solve problems, but also needs to provide information about how to monitor those processes (Hertzog & Robinson, 2005, Dunning, et al., 2003; Prowse-Turner & Thompson, 2007; Pressley, 2003; Desoete, Roeyers, & De Clercq, 2003).

8.3 Theory of mind.

In the opening section to this chapter, I referred to metacognitive judgments as second-order judgments, that is, as judgements about judgments. Specifically, a JOR is a judgment about the heuristic judgment delivered by S1. In that way, it is similar to other metacognitive constructs, which are often viewed as "representations of representations". The judgments themselves have propositional content, and express beliefs about the workings of one's cognitive processes "that answer feels right" or "I should be more confident of this judgment than the first one because I have had more time to think about it".

The same cannot be said about many of the processes that give rise to the JOR. As discussed at length, the FOR likely resembles other metacognitive experiences whose origins are not available to introspection. Koriat (2007, p. 315) refers to them as "sheer subjective feelings, which (although they) lie at the heart of consciousness, may themselves by the product of unconscious processes."

One might be tempted to thereby classify the FOR as a heuristic output that bears more similarity to the automatic, implicit responses generated by S1 than to a true metacognitive judgment. Indeed, Kahneman (2003) argued that the accessibility of a heuristic attribute is, in and of itself, a natural assessment. A metacognitive account shares with Kahneman's the assumption that experience of accessibility, or fluency, gives rise to an attribution that is causally relevant to the outcome of any judgment or decision. However, the metacogntive account assumes that the assessment of fluency (and other cues that give rise to a FOR) is qualitatively different than other types of natural assessments, because the FOR is really an assessment about an assessment. That is, the process of retrieving a heuristic attribute, such as a stereotype, produces two outcomes: The first is the natural assessment of the perceived similarity of the target to that stereotype, and the second is an assessment of the fluency with which this information is retrieved. The former produces a heuristic judgment, the latter, the feeling that this judgment is right (i.e., FOR).

8.4 Methodological considerations.

To wrap up, I will offer suggestions for how the constructs and hypotheses developed in this chapter might be operationalised and tested. The first goal, of course, will be to develop a measure of the FOR. The second will be to establish the link between the FOR and the probability and type of S2 engagement. From there, one has the tools to evaluate the many specific predictions that fall out of the framework I have sketched.

Given its similarity to other metacognitive experiences, it would be reasonable to adapt methods from the metacognitive literature for measuring the FOR. The normal approach for measuring Feelings of Knowing or Judgments of Learning is to ask the reasoner to self-report. The difference between the FOR and these other jugdments is that it pertains to an event that has already occurred, whereas the others pertain to events that will happen in the future (i.e., the probability that an unrecalled item will be recognised or the probability that a just learned item will be subsequently recalled). Thus, the measurement will have to be modified.

Specifically, the FOR is defined as the feeling of certainty associated with the answer produced by S1. Under the assumption that S1 are automatic processes, the first answer (A1) should be produced rapidly, whereas answers generated by S2 require deliberation and should be slower. Thus, measuring the FOR will require reasoners to respond quickly, giving the first answer that comes to mind and then to rate their certainty that this answer is the right one.

Two related predictions can then be tested. The first is that the FOR accompanying A1 responses predicts the probability with which it is given as a final answer. Consequently, participants will need to be asked to produce a second answer (A2) without time constraint.

FOR's should be correlated with the probability that A1 occurs as A2. This method allows for within-individual estimates, but runs the risk that asking reasoners to articulate A1 changes the response that would normally be given at Time 2. Thus, a between-subjects design will also be needed in which one group generates generate fast answers and another works without time pressure. Items that produce high FOR in the fast condition should be answered with A1 in the free time condition.

The second prediction is that low FOR's promote S2 processes. For this, one needs a measure of S2 intervention. Several possibilities offer themselves. For example, low FOR's should be associated with a high probability that A2 is normatively correct. However, given that S2 may not always produce normatively correct answers, converging evidence will be required. For example, under the assumption that S2 processes take time to implement, low FOR's should be associated with longer RT's to produce a final answer. Moreover, given that S2 processes, by definition, involve conscious deliberation, they should therefore be available to introspection. Thus, think aloud protocols and strategy choice paradigms (which of the following strategies did you use to solve the problem?) should be diagnostic of S2 processing. .

9. Summary.

A crucial issue for DPT concerns the circumstances under which analytic processes intervene to alter a heuristic output. I have proposed that the process by which reasoners become aware of the need for such intervention is a metacognitive one. Stimuli that produce a strong Feeling of Rightness are not likely to be further scrutinised, whereas those that produce a weaker feeling are more likely to trigger S2 analysis.

Framed in that way, the next question to be addressed concerns the variables that moderate the strength of a FOR. By analogy to the memory literature, several hypotheses were offered. Specifically, it was proposed that the FOR is mediated by implicit cues that are largely based on experience of retrieving heuristic output; these include variables such as fluency of retrieval and familiarity with the retrieval cues. Judgments based on the FOR may also incorporate cues that are available to introspection, although it is not assumed that the reasoner necessarily applies them in a deliberate manner to a given problem solving episode. These include metacognitive theories, beliefs about one's own competence, attributions about the problem solving environment and so on.

This analysis supplements current theories in several ways. First, it allows for another set of tools for predicting the probability of analytic system engagement by focussing on a different level of analysis than is currently common. That is, rather than global characteristics of the reasoner and the problem solving environment, analysis of both the FOR and JOS invite us to consider the experience of processing a stimulus and interpretations of that experience as causally relevant dimensions.

Finally, a metacognitive framework may also offer a means to explain the relationship between cognitive capacity and reasoning performance. For example, cognitive capacity might determine the efficacy of S2 once it has been triggered. However, the key question concerns whether or not cognitive capacity also determines the likelihood that S2 is engaged in a particular situation. It was argued that S2 intervention is linked to metacognitive processes of monitoring and control, and that these metacognitive processes are in turn linked to cognitive capacity. That is, it is possible that the link between capacity and intervention can be explained by a shared link to metacognitive efficiency.

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