Introduction

In order to make decisions across areas such as personal relationships, finances, education, and the workplace, individuals need to be able to make frequent critical judgments and to negotiate through a host of decision points. Some judgments and decisions require the application of specific knowledge or complex calculations in order to solve problems or maximise outcomes. Other judgments and decisions occur within a context of immediacy, surprise or under social pressure or concurrent workload. Further to these difficulties, people often come across situations where their 'gut feelings' seem at odds with their logic in making a decision. These conflicts are often described in lay terms as 'head versus heart' or 'being in two minds'(Epstein, Pacini, Denes-Raj, & Heier, 1996). Dual-process theories of cognition explain that these internal conflicts can arise because we have two distinct modes or types of information processing, and when the output of one mode of processing is incongruent with the output of the other, a sensation of conflict can result (Epstein, et al., 1996).

Competing Views of Human Reasoning

Across the past several decades there has been much debate over the nature of human reasoning and whether it is essentially rational or irrational (Cohen, 1983; Evans & Over, 1996; Gigerenzer, 1996; Kahneman, 1981; Kahneman & Tversky, 1983; Koelher, 1996; Stein, 1996). Several theorists are well known for championing one or the other point of view. Gigerenzer and others propose that human reasoning is essentially rational, that individuals are equipped with an '*adaptive toolkit*' from which they are able to solve problems with a great degree of efficiency and efficacy (2009). Gigerenzer uses the term 'heuristics' to explain the types of reasoning that enable individuals to negotiate problem solving with a high degree of efficiency without

greatly affecting the probability of success. This efficiency is primarily due to the ability to ignore some of the available information. This '*less is more*' effect occurs when the processing of more information can decrease accuracy, and has been demonstrated experimentally. For example, in some instances simple tallying was more effective than complex computations such as linear regression analysis (Czerlinski, Gigerenzer, & Goldstein, 1999).

The phrase 'heuristics and biases' on the other hand, is used in a more negative sense by others such as Kahneman and Tversky to refer to shortcuts in people's reasoning (e.g. Tversky & Kahneman, 1973, 1983). Their viewpoint emphasises the fallibility of human reasoning and the notion that heuristics are accompanied by an accuracy-effort trade-off. That is, if less effort is invested in problem solving, there will be a cost of lower accuracy. Kahneman and others' experiments found that using many of the common heuristics including the so-called '*availability*', '*representativeness*' and '*anchoring and adjustment*' heuristics resulted in violations of rational norms (Bartels, 2006; Epstein, Donovan, & Denes-Raj, 1999; Klaczynski, 2001; Tversky & Kahneman, 1973).

Other theorists have emphasised that heuristics often lead to errors particularly when there is an emotional component (Finucane, Alhakami, Slovic, & Johnson, 2000; Finucane & Holup, 2006; Finucane, Peters, & Slovic, 2003; Slovic, Peters, Finucane, & MacGregor, 2005). A vast body of experimental evidence suggests that in response to environmental stimuli individuals develop an automatic affective response and that this affective reaction subsequently influences the way that they process information (Bechara, Damasio, Tranel, & Damasio, 1997; Druckman & McDermott, 2008; Hine, Marks, Nachriener, Gifford, & Heath, 2007; Hine, Summers, Tilleczek, & Lewko,

1997; King, Burton, Hicks, & Drigotas, 2007; Slovic, et al., 2005). Across these studies this '*affect heuristic*' has been demonstrated to affect a wide range of behaviour including lowering risk perceptions, influencing consumer choices, risk-taking behaviours such as smoking and influencing environmental values.

Different theories of reasoning

Dual process theorists explain that affective and rule-based components of information processing represent essentially two distinct types of processing. They propose that humans process information automatically and predominantly subconsciously with the experiential or implicit system/processes, and operate according to rule-based or logical norms with a rational system/processes (for a review of dual process theories, see Evans, 2008). From the dual process perspective, human behaviour results from the interplay of these two systems in their response to environmental stimuli.

However, unified (or single system) theories of cognition challenge the dual process assumptions, suggesting that distinctions between intuitive and rational processes and their presumed characteristics (such as relative speed and resource dependence) are continuous rather than dichotomous (Keren & Schul, 2009; Kruglanski, Dechesne, & Chun, 2004). Kruglanski and Gigerenzer recently suggested that both types of judgments coined '*intuitive*' and '*deliberative*' (by dual process theorists) are based on rules (Kruglanski & Gigerenzer, 2011). Rule selection is determined by the task itself (entailing time and other constraints), the individual's memory of applicable rules, and the perceived ecological suitability of a rule to the task. When more than one rule has perceived ecological suitability to solving the task, there can be rule conflict, sometimes resulting in the application of a rule having interference

from other competing rules. They also assert that rules are based on the individual's capacities such as recognition memory, and that more complex rules are not necessarily more accurate than simple or heuristic rules.

Another alternative to dual process theories of cognition are theories of modularity. The proponents essentially propose that the mind is composed of many separate innate structures that each have specific functional purposes, and that the environment provides information to which these modular systems automatically and mandatorily respond (Carruthers, 2006; Sperber, 2005). It is posited that modules (for example, *'face recognition'* and *'theory of mind'* modules) need not refer to other systems to operate, and they produce simple output. Some proponents of modularity, endorsing a *'massive modularity hypothesis'*, believe that the mind is entirely modular with no central processes (Carruthers, 2006) but others allow that some central processing or general reasoning must occur (Roberts, 2007).

One recent attempt to further account for the complexities of human reasoning is the integration of modular components into an essentially dual process theory. Stanovich's recent 'Type 1 processes' included modular components (Stanovich, West, & Toplak, 2011; Toplak, Liu, Macpherson, Toneatto, & Stanovich, 2007). Modularity is also integrated into another recent theoretical account of reasoning by Wastell (submitted for publication). It is based on an integration of modular components with complexity theory. Within complexity theory, processing is carried out by networks of elements (in this theory, 'modules') with no central control and only simple rules of operation, and these can give rise to more complex collective behaviour (Mitchell, 2009).

Dual Process Theories of Cognition

Dual process theories of cognition comprise a range of conceptually related models which, despite differences in terminology, all share the basic premise that human behaviour is governed by two distinct systems or types of processing (for a review of dual process accounts of cognition see Evans, 2008). One type of processing is believed to be the primary and default mode of processing. It is continuously applied in response to environmental stimuli and involves the seemingly pre-conscious or automatic activation of memories, stereotypes, beliefs and routine operations. It generally relies on cursory analyses of situations, often giving the sensation of rapid and effortless thought. The other type of processing relies on context-independent rules and the application of logical justification. By comparison, it can seem slower, deliberative and effortful (Evans, 2008; Stanovich, et al., 2011).

Across the various dual process theories, there has been a wide array of terminology used for the two types of processing. Such terms include "experiential and rational" (Epstein, 2003), "heuristic and analytic" (Evans, 2006), "associative and rule-based" (Sloman, 1996; Smith & DeCoster, 2000), "holistic and analytic" (Nisbett, Peng, Choi, & Norenzayan, 2001), "implicit and explicit" (Reber, 1993). In addition, some more generic terms have been adopted such as "System 1 and System 2" (Stanovich & West, 2003) and more recently, "Type 1 and Type 2 processes" (Evans, 2008; Stanovich, et al., 2011). For the current thesis we have adopted the terms 'experiential' and 'rational'. In accord with Epstein's convention (Epstein, 2003), the term 'rational' is used in this thesis to refer to a set of logical and analytical principles and is not used to imply reasonableness of behaviour.

Neuropsychological evidence indicates that these distinct, but interrelated types of processing map onto separate neurological networks (Lieberman, 2003; Lieberman, Gaunt, Gilbert, & Trope, 2002; Lieberman, Jarcho, & Satpute, 2004). Rational processing is believed to involve the lateral pre-frontal cortex, posterior parietal cortex and hippocampus along with the surrounding medial temporal lobe (Lieberman, et al., 2004). These structures have also been identified in working memory and episodic memory processes (e.g. Cabeza & Nyberg, 2000). Experiential processing involves the prefrontal cortex, basal ganglia, amygdala and lateral temporal cortex (Lieberman, et al., 2004). These structures have also been identified in the preconscious associations of environmental features with affect (e.g. Bechara, Damasio, Tranel, & Damasio, 1997). Extensive work by Damasio has shown that the ventromedial prefrontal cortex is an important brain region in the processing of emotional information that is necessary for learning and reasoning. For example, individuals with lesions to this area of the brain were unsuccessful in performing the Iowa Gambling Task, for which emotion-based learning was required (a complex task with reward and punishment that requires anticipatory emotional responses in order to make gains)(Bechara, Damasio, Damasio, & Anderson, 1994) . Participants with no damage were demonstrated to be using this region of the brain as well as areas identified for working memory processing when successfully carrying out the same type of task (Li, Lu, D'Argembeau, Ng, & Bechara, 2010).

Dual process accounts of cognition emphasize the importance of pre-conscious processes in making judgments and decisions, especially those that are related to the association of affect (positive or negative feelings), or behaviours that have become routine through repetition or learning, or heuristics (cognitive short-cuts) (e.g. Epstein,

2003; Slovic, Finucane, Peters, & MacGregor, 2002). These pre-conscious processes have great practical value because they allow people to negotiate day-to-day activities without having to consciously attend to and analyse the vast amounts of information at their disposal (Epstein, 2003).

Cognitive-Experiential Self Theory

Epstein's Cognitive experiential self theory (CEST; Epstein, 2003) is a global theory of personality which shares the assumptions of other dual process theories in its emphasis on two independent types of thought processes that interact to guide behaviour. According to this theory, *experiential* processing is largely influenced by affect, and guides an individual's behaviour in order to achieve pleasurable outcomes and avoid non-pleasurable consequences.

Experiential processing inevitably results from interaction with the environment. It is fundamental to survival because it filters out a great deal of information, so that the remaining is manageable by the individual. It does not require volition because it operates predominantly outside of awareness, giving it a feeling of effortlessness. Decisions that are made as a result of experiential processing often are also associated with a feeling of '*rightness*', even though the reason behind the decision cannot be sourced (Thompson, 2009). People sometimes try to attribute behaviour that is a consequence of this mode to rational processes. This justification is referred to as '*rationalisation*' and is considered by CEST as an irrational process, and a source of judgment errors (Epstein, 2003).

Experiential processing is believed to be an innate capacity, and an ability that is shared with non-human animals (Epstein, 2003). It is essential for survival, and therefore an inherently natural and adaptive process, by which individuals form positive

associations with objects, situations and behaviours that aid in their survival and learn to associate negative affect with behaviour that threatens survival. Experiential processing is also cumulative and associative; individuals are able to use limitless positive and negative associations to generalise from their past experiences to guide them in future situations. Within the framework of CEST, these preconscious influences are considered vital and adaptive. However, there are situations when experiential processing can be maladaptive. For example, when a situation is novel or complex, experiential processing is able to cue the rational system that can attend to and analyse the situation in a more detailed way. However, at times the experiential system will not cue the rational system and generalise inappropriately from past experiences, thereby applying heuristics that guide behaviour in a way that is not in the individual's best interests. In this manner, experiential processing can inappropriately bias the input for subsequent rational processing and the results can be negative.

Rational processing applies a person's knowledge and understanding of rules of reasoning to problem solving. Rules of logic, critical analysis of evidence and abstract thinking are often learned through explicit teaching, rather than predominantly learned through associative learning. Rational processing has the potential for dealing with abstract representations in order to create mental models of alternatives. For example, when given a problem, individuals can mentally simulate several different sequences of possible events in order to weigh potential outcomes. This ability to project beyond the concrete (think abstractly) is regarded as a uniquely human facility and is responsible for many of the triumphs of human creativity and thought, including the facility to communicate in complex verbal language (Epstein, 2003). Some rational operations can be rehearsed to the point of being reflexive, and are made accessible by the

experiential mode. It is in this way that people are able to learn through concentrated effort and then maintain those behaviours through reflexive experiential processing. Everyday examples of this include the learning of complex mathematical procedures or learning to drive a car or ride a bike. These procedures are initially complex but become increasingly reflexive. Rational processing can also provide corrective feedback to the experiential mode. For example, an experiential response might be to decide to make a spontaneous purchase of an item because it is on sale for a short period of time. Rational processing can provide corrective advice that can be more constructive - such as inhibiting the purchase by making calculations as to whether the product is something that is needed, the quality of the product, and assessing the current state of the individual's finances and their ability to afford the product. This feedback can counter the more spontaneous affective response of trying to "grab a bargain".

However, rational processing is not infallible; individuals are only able to process as effectively as their knowledge and understanding will allow. Further to this limitation, rational processing is capacity-limited, and can be overloaded. Therefore, rational processing output can be subject to computational errors. Further, the experiential mode can interfere with rational processes by providing conflicting information. It is proposed that when the two modes come into conflict, experiential processing often wins out (Epstein, 2003).

Conflicts Between Rational and Experiential Processing

Over the past several decades, many researchers have been interested in conflicts between the two processing modes, using paradigms of the type that pit the two modes of processing against each other (e.g. Klaczynski, Gordon, & Fauth, 1997; Newstead, Handley, Harley, Wright, & Farelly, 2004; Tversky & Kahneman, 1982;

West, Toplak, & Stanovich, 2008). For example, participants received vignettes describing two protagonists' situations (Tversky & Kahneman, 1982). Both protagonists arrived to catch a plane 30 minutes late due to unexpected heavy traffic: for one person the plane had left on time and for the other, the plane had only just departed. Participants typically reported that the person whose plane had only just departed would feel worse. This is an affect-biased response because both protagonists were equally inconvenienced and neither had any control over when the plane left. However, because the experiential system is an associative system that automatically relates outcomes to preceding situations and behaviour, it treats them as if they are causally related, even when the relation is completely arbitrary.

In an extension of this paradigm, when participants were asked to take three different perspectives – how they themselves would react, how they believed most people would react and how a completely logical person would react – they reported different reactions even though the items were counterbalanced across participants (Epstein, Lipson, Holstein, & Huh, 1992). For the '*self*' and '*most people*' perspectives, participants typically gave the usual response of rating the protagonist whose plane had just departed as being more upset, however from the '*logical person*' perspective, participants more often reported that the two protagonists would be equally upset. The first two perspectives represent typical responses from experiential processing, based on associative reasoning. The logical perspective provides evidence that individuals know that one protagonist being more upset than the other is actually non-rational.

CEST posits that other non-rational phenomena such as religiosity, phobias, superstitions and belief in the paranormal are the result of predominantly experiential processing rather than rational processes (Epstein, 1994). To give an example of how

this might occur, associative processes can lead people to treat events that are temporally close as causally related (as in the above paradigm) leading to superstitions. To illustrate: if a person was hit by a car after walking under a ladder earlier in the day, even though the two are not causally linked, they might remember the incident and attribute it to the folk superstition that walking under a ladder causes bad luck. Or if a person wins a lottery, they might use the numbers in future because they are 'lucky numbers', even though the competition process of generating winning numbers is completely random. Similarly, phobias can develop by people making associations between rare negative events and everyday events. For example, some individuals are unable to leave the house because of a fear of being poisoned with anthrax, or of dying in a terrorist attack. These fears of rare real-life events can become so emotionally charged that consequent irrational behaviour (staying indoors) is not corrected by the rational mode.

So, in addition to both types of processing being adaptive and productive, each can be the source of maladaptive behaviour. The experiential mode can bias the input for the rational mode. Conversely, the rational mode can make computational errors and can learn bad habits that become routine and are then used by the experiential mode. These habits can then affect future processing of both modes. As referred to earlier, CEST predicts that in cases where the two modes are in conflict, the experiential system usually wins out. However, there are differences in the extent to which individuals are guided by one type of processing or the other (Pacini & Epstein, 1999).

Individual Differences in Dual Process Thinking Styles

Individuals have been shown to differ in their dispositions toward the use of the two types of processing (Pacini & Epstein, 1999) across different age groups (Sladek,

Bond, & Phillips, 2010) and different cultures (Witteman, van den Bercken, Claes, & Godoy, 2009). Some prefer to rely on intuition and feel confident in following gut feelings and instincts. Others are confident in their ability to analyse effectively and enjoy applying logical rules to everyday situations. Others are either confident (or uncomfortable) with both modes of thinking, indicating that preferences for the two modes are independent of each other (e.g. Wolfradt, Oubaid, Straube, Bischoff, & Mischo, 1999).

These preferences are believed to affect a range of behaviour in individuals (Pacini & Epstein, 1999). In line with expectations of CEST, higher scores in rationality have been significantly associated with low susceptibility to cognitive biases and superior reasoning skills, in both adult and adolescents. In addition, rationality has also been positively associated with personality traits such as openness to experience, conscientiousness and a lack of neuroticism (Epstein, Denes-Raj, & Pacini, 1995; Epstein, et al., 1999; Marks, Hine, Blore, & Phillips, 2008; Pacini & Epstein, 1999; Shiloh, Salton, & Sharabi, 2002; Stanovich & West, 1998). In contrast, these studies found overall, that higher scores in experientiality were associated with emotional expressivity, superstitiousness, susceptibility to cognitive biases and poorer reasoning skills.

Individual differences in thinking styles have been studied in a range of different domains to explain behaviour. For example, individual differences in preferences for rational and/or experiential processing have been invoked to explain behaviour in consumer and economic decision-making (Godek & Murray, 2008; Kawpong & Alden, 2005), industry and the workplace (Lodato, Highhouse, & Brooks, 2011; Sladek, Bond, Luan, Chew, & Phillips, 2008; Wastell, Etheridge, McMahon, Lucas, & Hartley, 2011),

mate-selection difficulties (Shiloh & Shenhav-Sheffer, 2004), ethical and moral judgments (Bartels, 2008; Boyle, Dahlstrom, & Kellaris, 1998), legal/ juror decisions (Gunnell & Ceci, 2010; Mancini, 2011), susceptibility to mental health disorders (Wolfradt, et al., 1999), health practices (Lindeman, 2011; Peters, Diefenbach, Hess, & Västfjäll, 2008), and gambling ideation and behaviour (Amsel, Close, Sadler, & Klaczynski, 2009; Emond & Marmurek, 2010).

The Role of Working Memory Capacity

It is believed that the ability to engage in rational processing is constrained by working memory capacity (WMC) (Barrett, Tugade, & Engle, 2004). This emerging consensus is clear in various dual process theories of cognition that link rational processing to controlled attention or a 'central working memory resource' (for recent discussions see Evans, 2011; Stanovich, et al., 2011). Working memory processes involve simultaneous storage (maintaining information in an active state for later recall) and processing (manipulating information for current computation), as well as active inhibition of irrelevant stimuli both in the external environment and from internally generated thoughts and feelings (Daneman & Merikle, 1996).

WMC is particularly important in situations of distraction, interference, in novel contexts and under time pressure where attentional control is most taxed (Barrett, et al., 2004). People with high WMC are able to retrieve information more quickly and accurately (Rosen & Engle, 1997), are more able to resist distraction and better able to resist unwanted information from being expressed (Conway & Engle, 1994). They are also better able to inhibit automatic or habitual responses such as stereotypes (Barrett, et al., 2004). People with lower WMC are less able to control attention, and therefore are likely to be less successful completing tasks requiring rational processing (Barrett, et

al., 2004). Therefore, it is proposed that a type of negative chain reaction can occur: having a low WMC can lead to errors in rational processing, and because of unsuccessful attempts at rational processing, people with low WMC are eventually disinclined to operate in the rational mode. This, in turn, means that these individuals are less likely than those of high WMC to be open to learning new information or to acquire new critical thinking skills, which exacerbates their difficulties in decision-making and judgment tasks.

Age and Thinking Styles

Thinking styles are believed to be relatively stable over time and across different situations, although it is not known whether they change due to other cognitive developments. Recently there has been interest in extending dual-process theories of cognition to account for the development of experiential and rational thinking across the individual life-span (e.g. Barrouillet, 2011; Klaczynski & Cottrell, 2004; Sladek, et al., 2010). Evidence indicates that adolescents' physiology of the brain differs to adults in areas that are essential for rational processing. For example, adolescent frontal lobe activity is much weaker than that of adults during information processing and decision-making (Blakemore, den Ouden, Choudhury, & Frith, 2007), and attentional control is poorer in adolescents compared to adults (Kramer, Gonzalez de Sather, & Cassavaugh, 2005). Also, there is evidence indicating a decline in attentional control in adults aged over sixty (Burke, White, & Diaz, 1987; Coubard et al., 2011).

Dual-process theories suggest that because ageing from childhood to adulthood is accompanied by increasing cognitive ability and attentional control, individuals should become less reliant on heuristic processing as they age (Barrett, et al., 2004; Epstein, 2003; Evans, 2011; Stanovich, et al., 2011). Research into the capabilities of

children and adolescents indicates that the ability to 'meta-cognitively intercede' (i.e., to reflect on arguments and inhibit experiential processing) tends to emerge during middle-adolescence (Klaczynski & Cottrell, 2004). However, in some decision-making tasks, both adolescents and adults tend to use heuristics, except when significant contextual cues are available to trigger rational responding (Klaczynski & Cottrell, 2004). CEST also takes into account that as people are increasingly educated and develop more expertise in everyday tasks and specialty areas, they may begin to favour the wider use of gist information, and therefore the balance could also shift towards experiential preference (Epstein, 2003; Reyna & Brainerd, 2011). So, although individual adults may possess a greater capacity to use logic and rational processing, they might also have developed a strong preference for experiential thinking.

Contrary to these expectations, Sladek, Bond and Phillips (2010) found evidence of a small *negative* association between age and both rational and experiential thinking styles, across five different samples consisting of 20-75 year olds. These propositions and findings produce an uncertain pattern, giving rise to the question of whether different age groups are more likely to have particular thinking styles and whether those thinking styles in turn, affect decision-making.

Sources of Individual Differences in Thinking Styles

Rationality has been linked to WMC and the ability to control attention (Barrett, et al., 2004). Rationality and experientiality have been differentially linked to normative decision-making (Shiloh, et al., 2002) and to variables such as personality traits (neuroticism, openness to experience, extraversion) and beliefs, superstitions, and religiousness (Lindeman & Aarnio, 2007; Pacini & Epstein, 1999). However, the underlying sources of individual variability in thinking styles remain unknown. It is

well acknowledged that both nature and nurture are responsible in varying degrees for all our behaviour (Plomin, DeFries, McClearn, & McGuffin, 2008). What remains of interest is the relative roles of genetic and environmental factors in individual preference for rational and experiential cognition. Also of interest is whether related variables, such as WMC, share genetic or environmental factors with either of the thinking styles. Research into sources of variability could assist in maximising the genetic potential of individuals' thinking styles.

The Current Research

The point of view presented so far in this chapter purports that there are dual processes of thinking and that individuals differ in preferences for their use. Some people prefer to rely on experientiality, others prefer rationality, and some like to rely on both or neither. According to dual process theories, having either an aversion to rational processing or a strong reliance on experientiality may lead to biases that are responsible for non-normative decision-making. In broader terms, these thinking styles could be partly responsible for poor decisions such as the initiation of unhealthy behaviours like smoking, alcohol consumption and other drug use, as well as risky sexual practices and financial choices, and poor relationship decisions.

Knowledge of the individual differences in rationality and experientiality could help us to understand why individuals make poor decisions, even though there are better alternatives readily available. For given situations and contexts, individuals may be able to be trained to process in the optimal mode, even if it is not their preferred thinking style. Already research is targeting areas that might lead to improvements in decision-making, including strategies that can prime individuals to operate in either thinking mode (e.g. Horstmannn, Hausmann, & Ryf, 2010) or train individuals to

override experiential thinking when rational processing is optimal, and vice versa (e.g. Wastell, 2010).

In the current thesis, three studies examined the individual differences in rationality and experientiality. The first study was a mediation analysis to test whether rationality mediated the effects of WMC on a standard range of reasoning tasks. We expected that those individuals higher in WMC would have higher preference for rationality, and in turn, higher rationality would predict more normative reasoning. We also tested the same mediation model with experientiality, with the expectation that experientiality would be independent of the effects of WMC on reasoning, and that experientiality would be negatively associated with normative reasoning.

The second study also focused on the relationship between WMC and rationality, and the absence of such a relationship with experientiality. Its objective was to produce a typology that could help in the identification of different individual thinking styles in an adult sample using the combination of the related variables, WMC, rationality, and experientiality. As dual process theories differ in their predictions of the developmental course of preferences for rational and experiential thinking, a latent profile analysis was also conducted on an adolescent sample to establish whether similar thinking styles were present in both adult and adolescent groups. These typologies were then tested for their predictive power on a range of tasks.

The third study used a behavioural genetics approach to investigate the sources of individual variation in experientiality, rationality and WMC. The first objective was to estimate the heritability of rationality and experientiality. The second objective was to gain a further understanding of the relationship between rationality and WMC, by

estimating whether their shared variability was due to genetic, shared environmental or unique environmental factors.

Overall, the current research aimed to achieve the following objectives:

1. To determine whether individual differences in rationality mediate the effects of WMC on normative responding in a set of standard reasoning tasks.
2. To determine whether individual differences in experientiality are independent of the effects of WMC on normative responding in a set of standard reasoning tasks.
3. To create a typology for individuals' thinking styles according to combinations of experientiality, rationality and WMC.
4. To establish whether the thinking styles typology is invariant across adults and adolescents.
5. To test the predictive power of the typology for thinking styles in both adults and adolescents.
6. To use a genetically informative sample to estimate sources of variability for rationality and experientiality along the dimensions of genetic, shared environment and nonshared environment factors.
7. To estimate the shared sources of variability (genetic, shared environmental and nonshared environmental effects) for rationality and WMC.

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Working Memory Capacity and Cognitive Styles in Decision-Making

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Research Progression to Study 2

Study 1 found that rationality mediated the relationship between working memory capacity (WMC) and normative decision-making and unbiased judgment, and that experientiality did not mediate this relationship. This finding supports dual process accounts of cognition, in that there is one mode of thinking that relies heavily on attentional control, and one mode that is more automatic. Taking this into account, in Study 2 we conducted a latent profile analysis to produce a new typology for thinking styles that included a measure of WMC as well as the more traditional self-report measure of preferences for rational and experiential thinking. We also investigated whether there were functional differences between ability (capacity) and engagement (proclivity) in preference for either thinking style. Finally, we aimed to investigate whether the thinking style typology remained invariant across both adolescent and adult age groups, and whether thinking types were predictive of performance on a series of judgment and decision-making tasks.

Latent Profile Analysis of Working Memory Capacity and Thinking Styles in Adults and Adolescents

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Research Progression to Study 3

Across the first two studies, we found evidence that, over a range of judgment and decision-making tasks, those higher in rationality performed more normatively than those lower in rationality, and that those higher in experientiality performed less normatively than those lower in experientiality. We also found that rationality was related to working memory capacity (WMC) and mediated the effects of WMC on judgment biases and normative reasoning. These studies also showed that experientiality was independent of the effects of WMC. In Study 3 we aimed to investigate the sources of individual variation in experientiality, rationality and WMC. We adopted a behavioural genetics approach to estimate sources of variability due to genetic, shared environment and unique environment effects. A second aim of the study was to investigate whether preference for a rational thinking style and WMC have shared genetic origins.

Heritability of Preferred Thinking Styles and the Genetic Link to Working Memory Capacity

Jennifer M. Fletcher, Anthony D. G. Marks, Donald W. Hine and William L. Coventry

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General Discussion

The three studies reported in this thesis investigated the effects of rational preference (rationality) and experiential preference (experientiality) on judgment and decision-making, and examined these relationships in conjunction with working memory capacity (WMC).

The objectives of this research were:

1. To determine whether individual differences in rationality mediate the effects of WMC on normative responding in a set of standard reasoning tasks.
2. To determine whether individual differences in experientiality are independent of the effects of WMC on normative responding in a set of standard reasoning tasks.
3. To determine a typology for individuals' thinking styles according to combinations of experientiality, rationality and WMC.
4. To establish whether the thinking styles typology is invariant across adults and adolescents.
5. To test the predictive power of the typology for thinking styles in both adults and adolescents.
6. To use a genetically informative sample to estimate sources of variability for rationality and experientiality along the dimensions of genetic, shared environment and nonshared environment factors.
7. To estimate the shared sources of variability (genetic, shared environmental and nonshared environmental effects) for rationality and WMC.

The first study addressed objectives 1 and 2. Path analysis provided a well-fitting model confirming that rationality fully mediated the relationship between WMC and gambling biases and superstitiousness and partially mediated the relationship between WMC and deductive reasoning and less categorical thinking. The gambling and deductive reasoning tasks were selected because they were frequently used paradigms throughout the judgment and decision-making literature, and are indicative of the non-rationality of individual judgments where there is conflicting types of information. The results indicate that preference for rational processing is an important contributor to individual differences in cognition and that WMC plays a significant role in governing this relationship. As expected, experientiality did not mediate WMC, but did itself predict poorer performance on reasoning tasks, and was positively related to gambling biases and superstitiousness.

The findings of this study accord with the increasingly reported assumption of dual-process theories that two types of processing exist: one that is reliant on attentional control and the other that is not. Further, it adds that personal preferences for rational and experiential thinking, not just the capacity for attentional control (as indexed by the WMC task), also plays an independent role in normative decision-making and lack of judgment biases. One of the important implications of these findings is that people with lower WMC, who are already disadvantaged by lower attentional control and capacity, might be further disadvantaged by the disinclination toward rational processing. Conversely, those with a higher WMC are more likely to be higher in rationality and therefore have the benefits of both good attentional control and the inclination to use it.

The second study addressed objectives 3 and 4. A latent profile analysis was conducted to produce a typology that was an optimal statistical and theoretical

representation of different thinking types in adults. Given the association between rational preference and WMC reported in Study 1, we included the measure of WMC as well as the Rational Experiential Inventory (Pacini & Epstein, 1999) to measure thinking styles. We used all four sub-scales of the REI (rational ability, rational engagement, experiential ability, and experiential engagement) in case the differences between reported ability and engagement were important for distinguishing thinking types. The resulting typology was a four-profile solution comprising of *rationally dominant*, *experientially dominant*, *dual preference* and *disengaged* groups. We found that within the four profiles, the sub-scales for experientiality, and for rationality, clustered similarly, such that individuals high on the ability sub-scale also reported being high on the engagement subscale, and those low on the ability subscale were low on engagement subscale. This occurred for each of the rationality and experientiality scales.

Importantly, the two profiles that were higher in WMC were also higher in both rational ability and rational engagement (i.e., the rationally dominant and dual preference groups) and the two profiles that were lower in WMC were also lower in both rational ability and rational engagement (i.e., the experientially dominant and disengaged groups). This clustering of WMC and rationality was as expected, and provides further support for the link between these individual difference variables.

The second part of Study 2 involved a latent profile analysis on a sample of adolescents to see whether similar characteristics emerged for thinking styles in their age group. A similar pattern of four profiles emerged, with each exhibiting the same major characteristics as the adult profiles. However, the results showed some

interesting differences between the adolescent and the adult groups in terms of proportions of people in each profile and in their performance on external tasks.

The percentages of adolescents compared to adults for each profile were respectively: for the *disengaged* group 35% - 7%, for the *experientially dominant* group 4% - 47%, for the *dual preference* group 43% - 22% (all significantly different) and for the *rationally dominant* group 18% - 24%. These results can help to predict how thinking styles might change over time. The greatest age difference in group membership was in the experientially dominant group, to which 4% of adolescents and 47% of adults belong. These results favour the proposition that experiential processing is likely to increase with age, presumably due to the acquisition of a wide range of experience and skills (Epstein, 2003; Reyna & Brainerd, 2011). The relatively effortless nature of experiential processing compared to rational processing might encourage the predominance of experientiality in the long run, especially if the individual has difficulty with attentional control. Preference for rational processing over experiential processing (i.e., evidenced in the rationally dominant group) was not significantly different between adolescents and adults, suggesting that this type is more stable.

Another interesting difference between the adolescent and adult groups is that by far the majority of adolescents belonged to the undifferentiated groups (i.e., 43% in dual preference and 35% in disengaged) whereas the majority of adults belonged to groups that were polarised (47% in experientially dominant and 24% in rationally dominant). This infers that the adults tend to feel a preference for one or the other type of processing rather than both (or neither) – and that adolescents have perhaps not yet settled on a habitual preference for thinking style. These cross-sectional data can only give us a general idea of the changes that are likely to develop, but it appears that

changes do occur between adolescence and adulthood, with a large proportion of people possibly becoming more inclined towards experiential processing in their styles of thinking as they age. Longitudinal data would be necessary to test this proposition in future.

The predictive power of the typology was tested for both the adult and adolescent samples, on a set of reasoning tasks: syllogistic reasoning, gambling bias (outcome bias, for adolescents), superstitious thinking and categorical thinking measures. The results showed that the *rational* group performed most normatively across all tasks but the *dual preference* group did not significantly differ, except that they reported more superstitiousness. The *experiential* and the *disengaged* groups performed poorly across all tasks as expected. The adolescent profiles had fewer differences in performance on the external variables, though the differences generally trended in the same direction as the adult results, with the *rational* and *dual preference* groups performing more normatively and the *disengaged* performing the less normatively**.** This could mean that thinking styles have less impact on decision-making for adolescents, who are likely to have less established routines and methods of problem solving than adults. If this is the case, then it also suggests that early intervention is an important consideration. These findings are in accord with studies that have found that adolescents take more risks than adults, even though their risk perceptions do not differ (Quadrel, Fischhoff, & Davis, 1993). That is, adolescents might make more risky choices and decisions overall, even accounting for differences in individual preferences for rational and intuitive thinking, possibly due to the high salience and importance of other factors in their environment such as social pressure.

The third study reported in this thesis aimed to estimate the sources of variability for rationality and experientiality from a behavioural genetics perspective (objective 6). Model fitting analyses of 173 pairs of twins (100 monozygotic; 73 dizygotic) estimated that 44% of the variability in preferences for experiential processing were accounted by genetic factors and there was no shared environmental factor. We obtained estimates for the variability in WMC of additive genetics of 39% and nonshared environment of 61%. For rationality, the univariate models produced ambiguous results about the relative roles of heritability and shared environment, but subsequent bivariate analyses suggested that the genetic effects accounted for 34% of its variability. For both rationality and experientiality, unique environmental effects accounted for large proportions of variability (66% and 56%, respectively). This large proportion attributable to unique environment sources indicates that there are likely to be many different sources that can affect preferences in thinking styles. These could include a range of influences such as peer groups, accidents, health status, and mental health problems such as anxiety or depression. This gives rise to the expectation that these styles might be fairly malleable and able to be changed if it is desirable for the individual. Preferences for both rational and experiential thinking had the same order of magnitude of genetic effects found for many personality variables (Bouchard & McGue, 2002) in line with expectations.

We also performed a bivariate Cholesky decomposition to estimate the shared sources of variability for WMC and rationality (objective 7). According to the most parsimonious model, shared genetic effects were estimated to account for over half the correlation between WMC and rationality (60%), with the remaining due to nonshared environment (40%). The analyses provide evidence that a major source of the

observable correlation between WMC and preference for rational processing is shared genetics. This shared genetic origin helps to account for the observations by dual process theorists that rational processing is intimately linked with WMC, and also goes a step beyond this to implicate preference for rational processing as an important personality factor that is involved.

Research has demonstrated that individuals with low WMC can improve with training (Turley-Ames & Whitfield, 2003) and that training in working memory tasks can be generalised to other cognitive tasks (Klingberg, et al., 2002). Other studies that are investigating individuals' WMC deficits due to disease, are making ground in understanding the pharmacology of neurotransmitters that are involved in WMC (Ellis & Nathan, 2001). The current studies suggest that if improvements in increasing WMC can be gained, these might also improve other areas of cognition by increasing a preference for rational processing. Although we recognise that rational analysis is not necessarily the optimal processing strategy in all situations, we believe it is preferable to possess this capacity, and apply it when appropriate, rather than to rely exclusively or primarily on the experiential system.

Throughout this thesis, we have referred to WMC in the sense of a capacity-limited, directly accessible working memory. Recent research has proposed there to be another type of working memory, implicit in nature and only measurable by implicit means (Hassin, et al., 2009). This implicit working memory is proposed to operate outside of conscious awareness and is unintentionally activated. The present study provides evidence for processes between explicit WMC and preference for rational deliberation. Future studies might benefit from using implicit measures to detect whether the same relationships exist or whether there might be a different range of

outcomes for implicit working memory (Hassin, et al., 2009). It is a possibility that a preference for experiential processing might be more affected by implicit working memory, and that this has not been explored because of the tendency to use explicit WMC tests.

Similarly, many researchers have used implicit measures that attempt to indirectly (or covertly) detect preconscious processes; including Implicit Associations Tests (Holland & de Vries, 2010), and Mouse-lab and Eye-tracking tools (Norman & Schulte-Mecklenbeck, 2010). Some researchers have pointed out that self-report inventories of experientiality can be problematic, because they attempt to measure a preconscious mode of thought (Glöckner & Witteman, 2010). However, self-report scales of experientiality and rationality have demonstrated generally good internal and test-retest reliability, and it is clear that individuals are able to report that they enjoy "going with" their feelings, affect or intuition – or feel uncomfortable with their gut feelings - without them having direct access to or knowledge of the processes entailed in doing so (Koele & Dietvorst, 2010). Further, the scales for rationality and experientiality across the different dual-process inventories have consistently been found to be independent, indicating that individuals do not experience enjoyment of intuitive thought simply as an absence of enjoyment in rational thought (Koele & Dietvorst, 2010).

The current thesis lends support to the validity of self-report measures for preferences for the two thinking styles, in particular the REI (Pacini & Epstein, 1999), given that the two styles were found to be independent and exert independent effects on normative decision-making. Further, the present studies were able to indicate that WMC is likely to be another possible contributor to the measurement of individual

thinking styles. However, future studies could extend the present results by using implicit measures to test genetic and environmental effects.

Throughout the current thesis, our emphasis has been directed towards the judgment biases and non-normative decision-making that can result from the conflict between rational and experiential processes. In the types of reasoning and judgment tasks that were the focus of our studies, reliance on experiential processing can be particularly detrimental. However, CEST and other dual process theories do not view experiential processing as an inferior mode of processing. Preference for experiential processing has been linked to superior performance in many domains such as in emergency situations where previously learned routines have to be carried out immediately (Hogarth, 2008), and in problem solving tasks with limited, high-quality information available (Kardes, 2006). Also, intuitive, rather than analytic thinking, was found to be positively related to entrepreneurship and drive (Armstrong & Hird, 2009) and to performance measures of humour, creativity, aesthetic judgment and to self-report measures of empathy and popularity (Norris & Epstein, 2011).

Future research

Future behavioural genetic research could provide more certainty for the current genetic and environmental estimates, and could also investigate the causal pathway between WMC and rationality. Importantly, we were able to provide preliminary evidence that one plausible pathway is that genes influence WMC which, in turn, influences preference for rational processing. Also, longitudinal studies of genetically informative data would help to elucidate factors affecting the development of thinking styles and their related rational and experiential processes, an area that has recently come to the forefront in dual process accounts of cognition.

Preference for rational and/or experiential cognition has previously been linked to a number of personality traits and psychological interests including, the Big Five (Pacini & Epstein, 1999), superstitious thinking (Fletcher, et al., 2011) and beliefs in the paranormal, astrology, feng shui and religiousness (Lindeman & Aarnio, 2007). Many of these variables are known to be highly heritable (Bouchard, 2004). Future studies may be able to assess shared genetic and environmental sources of variation with variables such as these in order to give a better understanding of preferences for rational and/or experiential thinking. Ultimately this type of research could be informative in discovering interventions or enhancements of the environment to assist in helping individuals to maximise the genetic potential in each of the dual modes of processing.

In order to make the best judgments and decisions possible, CEST emphasises the importance of understanding experiential and rational processes in order to master them (Epstein, 2003). Rational processes can correct for biases that result from the experiential mode. Further, rational processes can be practiced and become automatic so that experiential processing becomes less prone to bias. One example of an extensive program to train individuals in using the rational mode (over the experiential mode) is in the field of Intelligence Analysis, where making poor decisions can cost lives (Wastell, 2010). Some of the strategies recommended are: training in the recognition of biases, and training in a range of analytical skills such as probability theory, counterfactual and counterintuitive reasoning, exploratory methods such as free association, analysis of competing hypotheses and the search for negative evidence. It also emphasizes ongoing training and development, and practice of techniques to develop automaticity for future crises. Training in programs such as this could be beneficial in many other life

domains, especially for individuals that are identified as having low WMC or a thinking style that is averse to rational processing.

Some researchers have used priming procedures in order to temporarily induce one mode or another. For example, participants were primed with explicit instructions to either think intuitively (rely on first impressions and gut instincts) or rationally (reflecting on previous business classes) to solve a real-world business problem (Dane, Baer, Pratt, & Oldham, 2011). The researchers found that those who problem solved in a way that was different from their typical style generated more creative problem-solving ideas in a real-world business problem. Another procedure that was used to prime thinking modes gave instructions to think about future decisions as a prime for rational processing, or to reflect on past decisions as a prime for experiential processing (Godek & Murray, 2008). In other studies, very explicit instructions were used before the task to manipulate the thinking strategy used including words such as 'define' 'identify' 'evaluate' for the rational style of solving and 'imagine...vividly', 'trust...holistically', and 'incubate' for the intuitive style of solving (Pretz, 2008). These types of priming procedures might represent a way of stimulating different thought processes especially for those who find it difficult to adopt the suitable mode for a given task.

Individual differences in experiential and rational processing have been invoked to explain poorer decisions and maladaptive behaviour across many diverse areas including problem gambling (Toplak, et al., 2007), alcohol use (Thush, et al., 2008) cigarette use (Hine, et al., 2009), mate-selection (Shiloh & Shenhav-Sheffer, 2004) and juror decision-making (Gunnell & Ceci, 2010). Distractions and conflicting input from the two modes of processing put demands on individuals' attention such that those with

lower WMC, lower rationality or higher experientiality could be at higher risk for making poor decisions. By developing an awareness of these limitations, individuals with these styles could be prepared and could adopt strategies to enable better reasoning and decision-making.

Conclusions

Overall, this research gives support to dual process theories of cognition, and to the proposition that individuals possess thinking styles related to these two modes of processing that affect their judgment and decisions. Across three studies we found that individual differences in working memory processes are an important contributor to rational processing, and that this observable association is due to shared genetic effects. The research also provided evidence that a preference for rational cognition confers advantages in judgment and decision-making tasks. The differences between adolescent and adult samples reported here indicate that preferences for experiential and rational processing are still in the development stages in adolescence, and that there is a general trend towards increasing reliance on experiential processing with age. The current research highlighted important pathways to unbiased judgment and normative decision-making and provided suggestions for future research. We would hope that individuals may eventually harness the full capacity of both experiential and rational processes, develop the awareness of when each mode is optimal, and maintain the motivation to use them appropriately.

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