AN INVESTIGATION OF THE EFFECTS OF NORMAL AGING ON REASONING

ABILITY: A DUAL-PROCESS APPROACH

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Jamie Alyson Prowse Turner

Abstract

Research has provided a great deal of evidence that reasoning performance declines with age (De Neys & Van Gelder, 2009; Fisk & Sharp, 2002; Gilinsky & Judd, 1994; Salthouse, 2005). Understanding these age-related differences is important because reasoning is an integral part of everyday cognitive functioning, the decline of which may result in older adults relying on heuristic strategies that can result in bias (Bacon, Handley, & Newstead, 2003). The objective of the current research was to use a dual-process theory framework to explain why there are age-related differences in reasoning. In addition to a variety of reasoning tests (i.e., a syllogistic task, base rate task, and the Cognitive Reflection Test), the present dissertation included independent tests of capacity (working memory, processing speed, and inhibition) and thinking styles to account for these age-related differences.

Chapter 2 focused on two recently proposed levels of Type 2 analytic thinking, algorithmic (individual differences in capacity) and reflective (individual differences in rational thinking dispositions) (Stanovich, 2009). It was hypothesized that a) both reasoning performance and capacity performance would differ with age, b) these components would contribute independently to performance on three reasoning tasks, and c) that they would explain at least some of the age-related differences in reasoning performance. Older adults demonstrated lower algorithmic capacity relative to younger adults and measures of capacity were related to performance on all three tasks. Furthermore, capacity attenuated the age-related differences in reasoning. Older adults also demonstrated a lower score than young adults on the measure of thinking dispositions; however, this predicted age-related differences only on the base rate task (and marginally on the syllogistic task). Furthermore, on the syllogistic reasoning task, a belief-bias component of reasoning was related to the age-related differences in reasoning.

Chapter 3 focused on whether the performance differences between young and older adults demonstrated in Chapter 2 could be attributed to differences in metacognitive skills. Four aspects of metacognition were examined: 1) differences in conflict detection, 2) confidence in individual answers, 3) confidence in overall performance, and 4) scores on the self-report measure Metamemory in Adulthood. There was little evidence to suggest that there were difference in metacognitive ability between young and older adults, thus the results were not consistent with the hypothesis that metacognition plays a role in the age-related reasoning

differences. In Chapter 3, I also investigated the hypothesis that conclusion believability and latency may be cues to confidence, and that perceived difficulty of the task may be an alternate measure of confidence, that is related to performance and response time. The data reveal that the conclusion believability and latency cues were important predictors of confidence, especially for the older adults, and that perceived task difficulty was related to performance and latency on both the syllogistic and base rate tasks.

Chapter 4 focused on the effects of perspective instructions on age-related differences in reasoning. In particular, I investigated whether reasoners would engage in a more logical, analytic style of thinking when prompted to reason from an alternative perspective. Results indicated that a shift in perspective may be advantageous for the older adults. This is promising because although older adults' limited capacity increases reliance on heuristic output and decreases processing power, there may be a straightforward way to mediate these age-related differences in reasoning ability, simply by asking them to reason from another's perspective.

Overall, this research significantly expanded the current knowledge regarding age-related differences in reasoning. Moreover, the findings were consistent with a dual-process theory of reasoning, which provided an integrative framework that accounts for the patterns of findings presented in this dissertation.

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Dedication

       I would like to dedicate this dissertation to my husband and my son, Justin and Dylan, who are the sunlight in all of my days. Justin, without your support and sacrifice I would not have made it through my dissertation.

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LIST OF ABBREVIATIONS

3MS	Modified Mini Mental State Exam
AOT	Actively Open-Minded Thinking Scale
BR	Base rate Task
CRT	Cognitive Reflection Test
DPT	Dual-process Theory
D	Different
ED	Education
INH	Inhibition
MIA	Metamemory in Adulthood
MSE	Mean Square Error
PS	Processing Speed
RT	Response Time
S	Same
SE	Standard Error
SR	Syllogistic Reasoning
T1	Type 1
T2	Type 2
WM	Working Memory
WRAT	Wide Range Achievement Test

Chapter 1

General Introduction

It is well documented that there are age-related differences in reasoning ability measured by normative standards (Fisk & Sharp, 2002; Gilinsky & Judd, 1994; Salthouse, 2005). Specifically, the ability to resolve conflict between logic and belief is known to decline sharply with age (De Neys & Van Gelder, 2009). This difference is often reflected in older adults providing more responses based on prior knowledge, opinion, and belief, rather than logic or rules, limiting their ability to reason objectively (Klaczynski & Robinson, 2000). Traditional approaches in this field focus on cognitive capacity to explain age-related reasoning differences (Fisk & Sharp, 2002; Salthouse, 2005); however, this is only one of several factors proposed by dual-process researchers to have an impact on reasoning performance (e.g., thinking style) (Evans, 2010; Stanovich, 2009; Thompson, 2009, 2010). The purpose of this thesis was to build a comprehensive view of age-related differences in reasoning. Specifically, the focus of this dissertation was to examine four possible junctures (i.e., capacity, thinking style, metacognitive ability, and strategy choice) where these factors could account for the age-related differences in reasoning. Detailed theoretical and empirical background relevant to each chapter is provided below; the focus is on developing the large theoretical context. Additional chapter-specific issues are developed in Chapter 3 and 4. A brief overview of Chapters 3 and 4 is also provided here.

1.1.Dual-Process Theory

Dual-process theories (DPTs) of reasoning propose two qualitatively different types of processes that underlie reasoning: Type 1 and Type 2 (see Evans and Frankish, 2009 for review; Stanovich, 2009). Type 1 (heuristic) processes are automatic, rely on experience, and produce highly contextual representations that give rise to intuitive judgements. In contrast, the Type 2 processes (analytic), reflect slower, controlled processing, and are serial and rule-based. Recently, Type 2 processes have been divided into two independent components – the reflective and algorithmic levels (Stanovich, 2009). The algorithmic level is argued to be a measure of individual differences in fluid intelligence, which includes, but is not limited to, differences in working memory, processing speed, and inhibition. Stanovich (2009) argues that the differences

in the reflective mind can be measured by individual differences in thinking dispositions, which are predispositions to engage in logical, Type 2 thinking (Kokis, Macpherson, Toplak, West, & Stanovich, 2002; Macpherson & Stanovich, 2007; Sá, West, & Stanovich, 1999; Stanovich, 1999; 2004; 2011; Stanovich & West, 1997; 1998). On this view, Type 1 processes dominate unless something happens to cue intervention by Type 2 processes. Indeed, the reflective level is argued to trigger the override (i.e., intervention and overturning of the initial intuitive response by T2 processes) of Type 1 processing and the likelihood of a successful override is dependent on the capacity based, algorithmic level. There are instances where Type 1 processes can result in an appropriate response (e.g., when there is no conflict between belief and logic); however, the judgements derived from Type 1 processes are seldom re-evaluated by Type 2 processes (Thompson, 2009). In the few cases where re-evaluation occurs, it is not guaranteed that an alternative response will be produced (Evans, 2010; Stanovich, 2011; Stanovich & West, 2000; Thompson, 2009).

Overriding an erroneous Type 1, intuitive response can be difficult because these types of responses are subjectively appealing, feel intuitively correct, and support prior beliefs, opinions, and knowledge (Epstein, 1994; Klaczynski & Robinson, 2000; Thompson, 2009, 2010). This is especially problematic for reasoning problems that pit intuition against logic (i.e., conflict problems), where the participant is strongly cued to respond intuitively, but the intuitive response conflicts with the logical response (De Neys & Van Gelder, 2009). In other words, when the Type 1 output disagrees with logical analysis provided by Type 2 processes, individuals have more difficulty than when the two systems output similar responses. Consider the following example taken from our stimulus set:

No addictive things are ramadions
Some cigarettes are ramadions
Therefore, some cigarettes are not addictive things
YES / NO

This problem strongly cues the response NO because this conclusion is not believable; however, the response based on the logical validity of the conclusion is YES, consequently producing a conflict between logic and belief.

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Resolving such conflict is even more challenging for older adults (De Neys & Van Gelder, 2009; Gilinsky & Judd, 1994). In fact, when older and younger adults' performance on conflict problems is compared, older adults provide more intuitive responses than younger adults; however, when there is no conflict (i.e., the two systems produce the same response), older adults perform on par with younger adults. In other words, older adults are at a significant disadvantage when faced with problems where they need to separate logic and intuition (De Neys & Van Gelder, 2009; Gilinsky & Judd, 1994).

Although there is evidence to suggest that capacity based declines (i.e., working memory and processing speed) explain the age-related difficulty in overriding the intuitively cued response on conflict problems (Fisk & Sharp, 2002; Gilinsky & Judd, 1994; Salthouse, 2005), these studies do not always directly measure whether these variables attenuate the age-related differences in reasoning. In addition, there are other issues that need to be addressed, including the limited measures of reasoning utilized previously, inconsistencies in the literature, and alternative factors that have been proposed to explain the age-related differences.

Although Salthouse intended to measure reasoning performance across a multitude of tasks, many of the reasoning tasks examined were taken from intelligence tests (e.g., Wechsler test battery) (Salthouse, 2005), which often do not test the ability to override an initial compelling response, a critical component of reasoning ability (Stanovich, 2011). Furthermore, the studies that have utilized tasks of this nature (Fisk & Sharp, 2002; Gilinsky & Judd, 1994) have been restricted to a single task, namely syllogistic reasoning. One goal of the current research was to investigate the relationship between age and reasoning performance in multiple tasks, including a syllogistic task, designed to test the ability to override an intuitive response.

An additional goal of the current study was to examine inconsistencies in the literature regarding working memory and processing speed. Fisk and Sharp (2002) have indicated that the relationship between working memory and age-related variance (Gilinsky & Judd, 1994), is attributed to a slowing in processing speed. In contrast, Salthouse (2005) argued that differences between young and older adults cannot be solely attributed to slower processing in older adults because these differences are found in situations when there are no time constraints. To resolve this discrepancy, working memory and processing speed were measured to determine if one or both of these factors attenuate age-related variance in reasoning, in untimed reasoning tasks.

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Although researchers tend to focus on the capacity part of the algorithmic level, there is a reflective, goal driven process that is also important in the success of overriding intuitive responses (Stanovich, 2009). In fact, Stanovich argues that reasoning ability is related to the disposition to trigger override of Type 1 output and the ability to engage Type 2 processing to further examine the Type 1 response. Evidence for the role of the reflective level stems from research that demonstrates thinking dispositions (a measure of reflective processes) predict variance in reasoning after the algorithmic effects are partialled out (Kokis, Macpherson, Toplak, West, & Stanovich, 2002; Stanovich, 2009; Stanovich & West, 1997; Toplak, West & Stanovich, 2011; West, Toplak, & Stanovich, 2008). By extension, we predicted that individual differences in both the capacity of the algorithmic mind and in the goals and preferences of the reflective mind would be related to age-related differences in reasoning ability.

1.2. Reasoning Tasks

In order to measure reasoning ability, we utilized three reasoning tasks: an evaluation syllogistic reasoning task (refer to Appendix A), a base rate task (refer to Appendix B for examples), and the Cognitive Reflection Test (CRT; Frederick, 2005) (refer to Appendix C). The syllogistic task, which we adapted from Shynkaruk and Thompson (2006), requires participants to judge the validity of a conclusion following from two premises. The base rate task, adapted from De Neys and Glumicic (2008), requires participants to indicate the likelihood that the stereotypical description of an individual belongs to one of two categories. Both tasks include conflict, no-conflict, and neutral problems. The inclusion of neutral problems provides a baseline condition in which there is no conflict. Given that there is no default intuitive response for the neutral problems, it will be necessary for participants to engage Type 2, analytic processing to solve the problems. Neutral problems are often included in studies with younger adults (e.g., De Neys & Glumicic, 2008), but are rarely included in studies with older adults. Inclusion of neutral baseline problems will potentially facilitate understanding of age-related differences.

According to dual-process theory and prior research, performance should be lower when Type 2 processing is required to overcome Type 1 outputs (conflict) than in situations where both the Type 1 and 2 outputs are identical (no-conflict) (e.g., De Neys & Van Gelder, 2009). Also, because Type 2, analytic processing is believed to decline with age, this difference should

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be greater in older adults. In other words, we anticipated that performance would decrease on the conflict and neutral problems relative to no-conflict problems, because Type 2 processing is required for these problems. Furthermore, this should occur for both age groups, with older adults showing a greater impairment.

The third task we utilized, the CRT (Frederick, 2005), was intended to measure the ability to override an erroneous intuitive response in favour of analytic engagement that can lead to the correct response. The following is one of the three items from the CRT.

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

This task consists solely of conflict problems and it is not possible to solve these problems without inhibiting the initial compelling response (i.e., 5 cents for the above problem) and engaging in Type 2 processing. Consistent with predictions for the other two tasks, it was expected that young adults would outperform older adults.

1.3. Algorithmic Processes

Dual-process theory predicts two different findings stemming from limits to cognitive capacity in the algorithmic level (Stanovich, 1999, 2011). First, capacity should explain age related changes in reasoning performance and a difference in capacity should be reflected in a reliance on heuristic processing. Thus, on conflict problems, reasoners with a lower capacity should show a greater tendency to select heuristically cued responses (i.e., belief- and stereotype-based) relative to those with higher capacities. Furthermore, performance on no-conflict problems should not be related to capacity, because the Type 1 and Type 2 outputs are identical. Second, because performance on neutral problems is dependent on the ability to engage Type 2 processes, and because lower capacity leads to less processing power, those with lower capacity should struggle when reasoning with neutral problems. The present study aimed to provide a comprehensive account of capacity related variables that have yet to be examined in this context.

We used four measures to assess cognitive capacity. First, to assess verbal ability we used the vocabulary subtest portion of the Wide Range Achievement Test, 4th Edition (WRAT4)

(Wilkinson & Robertson, 2006). Prior research has demonstrated that vocabulary is a good index of crystallized intelligence (Klaczynski & Robinson, 2000) and has been found to be related to quality of reasoning (Gilinsky & Judd, 1994; Klaczynski, 1997; Klaczynski & Robinson, 2000), thus it was important that we match our two age groups on verbal ability to ensure that this was not a confound in the current research.

The other three factors measured were working memory, processing speed, and inhibition, which are correlated but conceptually distinct measures (Salthouse, 2005). Research has indicated that these factors are related to reasoning ability (e.g., De Neys & Van Gelder, 2009; Fisk & Sharp; 2002; Gilinsky & Judd, 1994; Stanovich, 2011), however it is not clear whether these factors independently attenuate age-related differences in reasoning. Following from this, if cognitive capacity can explain age-related variance in reasoning, then individuals higher in working memory capacity, inhibitory control, and processing speed should be better able to engage in Type 2 thinking and override intuitive responses. The following paragraphs lay out the predictions in more detail.

1.3.1. Working Memory Capacity. Many reasoning tasks require the maintenance of information prior to it being operated upon (Salthouse, 2005); consequently, it is not surprising that individuals with a greater working memory capacity exhibit greater reasoning ability than those with a lower capacity (Capon, Handley, & Dennis, 2003; De Neys & Verschueren, 2006; Kokis et al., 2002; Kyllonen & Christal, 1990; Markovits, Doyon, & Simoneau, 2002; Quayle & Ball, 2000). It has also been argued that age-related difficulties in reasoning are mediated by differences in working memory capacity (Gilinsky & Judd, 1994; Salthouse, 2005). However, recent research has suggested that it might not be working memory capacity per se, but a correlated construct, namely processing speed or inhibition, that is responsible for the difference (e.g., De Beni, Palladino, Pazzaglia, & Cornoldi, 1998; Fisk & Sharp, 2002; Salthouse, 1991; 2000). Additional algorithmic abilities, including processing speed and inhibitory control, may also play an important role by either directly affecting reasoning ability (Fisk & Sharp, 2002) or by indirectly affecting working memory (De Beni et al., 1998). Thus, one goal of the present research was to determine if working memory predicts age-related variance in reasoning performance when additional capacity factors are included.

In the present study, working memory capacity was measured by performance on the List Span Task (Daneman & Carpenter, 1980; De Beni et al., 1998). Given our previous arguments that capacity should account for age-related differences on conflict problems, we predicted that working memory capacity would be related to ability on conflict problems, but not the no-conflict problems. Also, we argued that neutral problems require some level of Type 2 processing, therefore it was expected that working memory would attenuate age-related variance on the neutral problem responses as well. This is consistent with dual-process theorists who assume that Type 2 processes decline, relative to Type 1 processes, in old age (Gilinsky & Judd, 1994).

1.3.2. Processing Speed. A slowing of basic information-processing is another variable that is argued to be responsible for various age-related deficits in cognitive functioning (Salthouse, 1996; 2000; 2005). Contributions of processing speed fit well within the dual-process framework, given that processing speed has been shown to be important in the mediating relationship between age and cognition (Levitt, Fugelsang, Crossley, 2006; Salthouse 1996). However, the findings regarding the relationship between processing speed and reasoning ability are mixed. On one side, previous research has shown that when working memory ability is partialled out, the relationship between reasoning performance and working memory becomes non-existent and processing speed becomes the most significant predictor (Fisk & Sharp, 2002). This is consistent with the idea that the age-related declines in speed of processing may mediate working memory effects (Fisk & Sharp, 2002; Levitt et al., 2006; Salthouse, 1991; 2000; Salthouse & Babcock, 1991). Other researchers have suggested that the decline in processing speed with age has a relatively smaller influence on performance compared to working memory (see Salthouse, 2005 for a review). For example, there are still large accuracy differences between age groups when processing time is not limited, which implies that the age-related differences are not simply attributable to slower processing speed (Salthouse, 1994; see Salthouse, 2005 for review). In an attempt to reconcile these mixed results, we examined the relationship between processing speed and working memory in reasoning tasks, which reasoners were given unlimited time to complete.

1.3.3. Inhibition. As we age, it appears that there is a decline in the ability to utilize inhibitory mechanisms to control cognitive processing (Hasher, Stoltzfus, Zacks, & Rypma,

1991; Hasher & Zacks, 1988). Evidence for this argument is that older adults are more susceptible to Stroop-type interference effects compared to young adults (Troyer, Leach, & Strauss, 2006). Thus, another possibility is that it might not be the loss of working memory capacity or decrease in processing speed, per se, which is responsible for age-related differences in reasoning, but less efficient inhibitory mechanisms. In fact, it has been suggested that deficits in working memory can be attributed to poor inhibitory mechanisms (e.g., De Beni et al., 1998). Specifically, differences in inhibitory ability have been attributed to a difference in attention resources localized in a component of working memory, the central executive (De Beni et al., 1998; Handley et al., 2004). In this case, age-relate differences in reasoning should be attenuated by inhibition, but perhaps not working memory.

Indeed, there is abundant evidence that the ability to inhibit irrelevant information is necessary for rational thinking (De Neys, Schaeken, & d'Ydewalle, 2005; De Neys & Van Gelder, 2009; Handley, Capon, Beveridge, Dennis, & Evans, 2004; Houdé, 1997; Markovits & Barrouillet, 2002; Markovits & Doyon, 2004; Moutier, Plagne-Caveux, Melot, & Houdé, 2006). Contextual information (e.g., belief) may interfere with logic and result in biased reasoning. The importance of inhibitory control has been highlighted in a wide range of reasoning tasks (e.g., deductive, inductive, conditional, and relational) (Handley et al., 2004; Houdé et al., 2000; Moutier, Angeard, & Houdé, 2002; Moutier & Houdé, 2003; Simoneau & Markovits, 2003). Research examining inhibitory control in children has demonstrated that inhibitory control was related to successful Type 2 thinking (Handley et al., 2004) and we sought to examine this possibility in older adults. Inhibition was expected to be a factor for only the conflict problems, because generating a T2 response requires inhibition of the strong intuitive response, whereas inhibition is not necessary for the no-conflict problems. There was no anticipated relationship between inhibition and neutral problem performance.

1.4. Reflective Level

In addition to the capacity of the algorithmic level, another individual difference variable that plays a role in reasoning ability is the reflective level or rational thinking dispositions: the predisposition to engage in logical analytic, Type 2 thinking (Kokis et al., 2002; Macpherson & Stanovich, 2007; Sá, et al., 1999; Stanovich, 1999; 2004; 2011; Stanovich & West, 1997; 1998). Stanovich and West (1997; 1998) proposed a measure of actively open-minded thinking to assess

variability in thinking dispositions. Actively open-minded thinking is defined as the willingness to search actively for evidence against one's views and to fairly weigh counterevidence against such views (Stanovich & West, 1997; 1998; 2007); and is often measured by the Actively Open-Minded Thinking Scale or AOT (Stanovich & West, 1997; 1998; 2007).

Strong evidence that thinking dispositions are related to critical thinking has been found in young adults by Stanovich and colleagues (Stanovich and West, 1997; 1998; 2007; West et al., 2008). They discovered that after partialling out the variance due to intelligence, measures of thinking dispositions (i.e., AOT) predicted unique variance in reasoning ability. The present research was the first study to investigate the potential role of thinking dispositions in older adults' reasoning and the potential role the reflective level plays in age-related differences in reasoning ability.

1.5. Summary

In sum, the first goal in the current research was to investigate the role of the algorithmic and reflective levels of Type 2 processes. Thus, in Chapter 2, the focus was on the role of capacity constraints and thinking dispositions in age-related differences in reasoning. It was expected that age-related differences between these factors would explain, at least part of, the reasoning performance difference between young and old adults.

In the third chapter, I investigated whether age-related differences in metacognitive ability could explain some of the residual variance in age-related differences in reasoning.. Metacognitive ability is referred to as the ability to correctly assess one's knowledge (Hertzog & Hultsch, 2000; Hertzog & Robinson, 2005; Koriat, Ma'ayan, & Nussinson, 2006; Pliske & Mutter, 1996). Thompson (2009) has argued that metacognitive processes are commonly used to assess the output of the heuristic system and to determine if there is a need for analytic engagement. In other words, metacognitive skills often determine whether a reasoner will attempt Type 2 processing. To investigate whether age-related differences in reasoning can be explained by differences in metacognitive ability, we examined four different constructs: conflict detection, confidence in individual answers and overall performance, and a self-report measure of this ability. In addition to these measures, we examined the role of conclusion believability and latency as cues to confidence, and perceived task difficulty as an alternative measure of confidence.

In Chapter 4, I sought to determine the extent to which age-related reasoning differences, in part, reflect a failure of older adults to fully exploit available analytic resources. To test this hypothesis, reasoners were asked to adopt an alternative perspective while reasoning. It has been proposed that shifting perspectives allows participants to differentiate between the writer's intentions and their own beliefs (Thompson, Evans, & Handley, 2005). From a dual-process viewpoint, having participants reason from a perspective other than their own (e.g., writer) requires them to engage in analytic thinking (Beatty & Thompson, 2012; Thompson et al., 2005). In young adults, researchers have successfully demonstrated that a perspective shift promotes an analytic mode of thought and reduces reliance on beliefs (Beatty & Thompson, 2012; Dias, Roazzi, & Harris, 2000; Greenhoot, Semb, Colombo, & Schreiber, 2004; Thompson et al., 2005). Therefore, in the present study we sought to determine if a perspective shift would improve reasoning in older adults. If age-related differences in reasoning abilities are, in part, due to a failure of older adults fully exploiting their analytic reasoning capacity, the perspective manipulation should be successful

Overall, this dissertation examined whether four factors (i.e., capacity, thinking style, metacognitive ability, and strategy choice) could account for the age-related differences in reasoning. The current dissertation is organized in a manuscript format, with three stand alone manuscripts. The manuscripts stem from one extensive study comparing 72 young and 72 old adults and, collectively, expand our understanding of reasoning and aging under a dual-process theory framework. Chapters 2-4 focus on specific factors that may contribute to the age-related differences in reasoning. Chapter 5 provides a summary of key findings and conclusions.

Chapter 2

Dual-Process Theory of Reasoning and Aging

Abstract

The ability to resolve conflict between logic and intuition, in favour of logic, is known to decline sharply with age (De Neys & Van Gelder, 2009; Gilinsky & Judd, 1994). Prior researchers have argued that capacity factors are related to age-related differences in reasoning performance (Fisk & Sharp, 2002; Gilinsky & Judd, 1994; Salthouse, 2005). However, the extent to which these factors and other potentially important factors, suggested by dual-process theories of reasoning, attenuate the age-related differences in reasoning has yet to be determined. Seventy-two older (M = 80.0 years) and 72 younger (M = 24.6 years) adults were given measures of verbal ability, working memory, processing speed, inhibition, thinking dispositions, and completed three reasoning tasks: a syllogistic reasoning task, a base rate task, and the Cognitive Reflection Test. Our results indicate that age-related declines in algorithmic capacity and reflective processes account for a significant portion of age-related variance in reasoning. Overall, this study provides evidence consistent with a dual-process theory of age-related differences in reasoning.

Dual-Process Theory of Reasoning and Aging

2.1. Introduction

Overriding an erroneous Type 1, intuitive response can be difficult because these types of responses are subjectively appealing, feel intuitively correct, and support prior beliefs, opinions, and knowledge (Epstein, 1994; Klaczynski & Robinson, 2000; Thompson, 2009, 2010). This is especially problematic for reasoning problems that pit intuition against logic (i.e., conflict problems), where the participant is strongly cued to respond intuitively, but the intuitive response conflicts with the logical response (De Neys & Van Gelder, 2009). In other words, when the Type 1 output disagrees with logical analysis provided by Type 2 processes, individuals have more difficulty than when the two systems output similar responses.

Resolving such conflict is even more challenging for older adults (De Neys & Van Gelder, 2009; Gilinsky & Judd, 1994). In fact, when older and younger adults' performance on conflict problems is compared, older adults provide more intuitive responses than younger adults; however, when there is no conflict (i.e., the two systems produce the same response), older adults perform on par with younger adults. In other words, older adults are at a significant disadvantage when faced with problems where they need to separate logic and intuition (De Neys & Van Gelder, 2009; Gilinsky & Judd, 1994).

Although there is evidence to suggest that capacity based differences (i.e., working memory and processing speed) explain the age-related difficulty in overriding the intuitively cued response on conflict problems (Fisk & Sharp, 2002; Gilinsky & Judd, 1994; Salthouse, 2005), these studies do not always directly measure whether these variables attenuate the age-related differences in reasoning. In addition, there are other issues that need to be addressed, including the limited measures of reasoning utilized previously, inconsistencies in the literature, and alternative factors that have been proposed to explain the difference.

We used four measures to assess algorithmic capacity: verbal ability, working memory, processing speed, and inhibition (see Chapter 1 for an overview of these factors). Research has indicated that these factors are related to reasoning ability (e.g., De Neys & Van Gelder, 2009; Fisk & Sharp; 2002; Gilinsky & Judd, 1994; Stanovich, 2011), however it is not clear whether these factors attenuate age-related differences in reasoning. If cognitive capacity can explain age-related variance in reasoning, then individuals higher in working memory capacity, inhibitory

control, and processing speed should be better able to engage in Type 2 thinking and override intuitive responses. In addition to the capacity of the algorithmic level, another individual difference variable that plays a role in reasoning ability is the reflective level or rational thinking dispositions: the predisposition to engage in logical analytic, Type 2 thinking (Kokis et al., 2002; Macpherson & Stanovich, 2007; Sá, et al., 1999; Stanovich, 1999; 2004; 2011; Stanovich & West, 1997; 1998). Strong evidence that thinking dispositions are related to critical thinking has been found in young adults by Stanovich and colleagues (Stanovich and West, 1997; 1998; 2007; West et al., 2008). The present research was the first study to investigate the potential role of thinking dispositions in older adults' reasoning and the potential role the reflective level plays in age-related differences in reasoning ability. It was expected that this age-related difference would explain, at least part of, the reasoning performance difference between young and old adults.

With respect to the present study, we hypothesized that individuals with a disposition to an analytic reasoning style would perform better on both conflict and neutral problems because both problem types require Type 2, analytic engagement to provide the logical response. Also, because older adults have been shown to have a tendency to respond based on heuristic cues, rather than analytic cues (Klaczynski & Robinson, 2000), it was predicted that older adults would report a thinking style that is more intuitive than younger adults. Finally, it was also expected that this age-related difference would explain, at least part of, the reasoning performance difference between young and old adults.

In sum, researchers have shown that older adults show differences in working memory and processing speed relative to young adults and that these two factors contribute to variance on reasoning tasks, however, what is unclear is the extent to which these factors, along with the additional proposed factors (i.e., inhibition and reflective processes), attenuate the age-related difference in reasoning.

2.2. Method

2.2.1. Participants

Seventy-two younger adults (46 female) ($M = 24.6$ years; SD = 7.54) and seventy-two older adults (55 female) ($M = 80.0$ years, SD = 7.28) were recruited for this study. Young adults

were recruited from the University of Saskatchewan campus in exchange for course credit or monetary compensation[1]. Older adults were recruited from the community through an informal information session or posters placed at community living residences or through mailing invitations to participate to members of the Saskatoon Council on Aging, a non-profit organization with programs and services for seniors in Saskatoon, SK. All older adults were offered a nominal honorarium for their participation. In addition to their gender and age, participants were also asked how many years of formal education they had completed (elementary, high school, and university), as well as the highest level of education they had obtained.

Older adults were screened for mild cognitive dysfunction using the Modified Mini-Mental State Exam (3MS; Teng & Chui, 1987). Any participant not meeting the minimum required score of 79 was excluded and replaced in the study (see Teng & Chui, 1987 for explanation). A total of 6 participants were replaced. In addition, all participants completed the word reading subscale of the Wide Range Achievement Test, 4th Edition (WRAT4) (Wilkinson & Robertson, 2006) in order to assess and match participants' verbal ability.

2.2.2. Materials

2.2.2.1.Working Memory Measure. Working memory capacity was assessed using the List Span Task (Daneman & Carpenter, 1980; De Beni et al., 1998). This task requires participants to hold target words in working memory (i.e., the last word in a list of 5 words, for a total of 3-6 words in each set), while completing a distracter task (i.e., knocking when an animal word was presented), and takes approximately 5-8 minutes to administer. Following completion, we calculated the list span for each participant, the highest level at which all the final words were recalled in the correct order. Young adults had a range of 0-6 words, while older adults had a range of 0-5 words; the higher the score the higher the working memory.

2.2.2.2. Processing Speed Measure. Processing speed was measured using the Letter Comparison and Pattern Comparison tests as described by Salthouse (1996). The letter comparison test consists of two sets of adjacent letter sets of three, six, or nine letters presented in random order. Participants must visually scan each adjacent set and write S or D, indicating if the adjacent sets were the same or different, respectively. The pattern comparison test consists of

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[1] There were no differences between these two groups on any of the dependent measures.

sets of two adjacent line patterns composed of three, six, or nine line segments and again participants are asked to scan the adjacent sets and write S or D accordingly. Participants completed two 30s trials for both tasks. The dependent measure was the number correct minus the number of incorrect responses produced within 30s for each trial. This number was then standardized and averaged across the letters and line versions to produce a composite processing speed score.

2.2.2.3. Inhibition Measure. The Victoria Stroop Test (Troyer et al., 2006) was used to measure response inhibition. This task requires participants to respond as quickly as possible to three different stimuli cards: dots, words, and colors. The dots card contains 24 dots printed in blue, green, red, or yellow, which are presented in a pseudo-random order within the array, each color appearing once in each row. The words card consists of common words (when, hard, and, over) printed in the same four colors and participants are asked to name the color the word is printed in, disregarding the verbal stimuli. The colors card consists of the color names "blue, green, red, and yellow" printed in lower case with the print color never corresponding to the color name; participants are instructed not to read the word, but to tell the researcher the color in which the word is printed. The order of the cards is presented in the same sequence to each participant: dots, words, colors. Participants are instructed to name the colors across the rows from left to right and are timed on each task. Errors are also coded for and are only classified as an error if not spontaneously corrected by the participant. The dependent measure for this task is a ratio of dots time/colors time, with an increased ratio indicating poor inhibitory capacity.

2.2.2.4. Thinking Dispositions. One way to appraise the reflective level is to have reasoners complete a measure of thinking dispositions. We chose the Actively Open-Minded Thinking scale (AOT) developed by Stanovich and colleagues (1997; 2007; 2008), which measures preference for analytic versus heuristic thinking. Lower AOT scores reflect a preference for intuitive heuristic-based thinking, while higher scores indicate a self-reported tendency for cognitive flexibility (Stanovich & West, 1997); thus, it was anticipated that in situations of conflict, individuals with low AOT scores would be more likely to respond based on T1 output than on T2 output. All items were scored such that higher scores represented a greater tendency toward open-minded thinking. Examples of items are "People should always take into consideration evidence that goes against their beliefs," and "No one can talk me out of something

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I know is right" (reverse scored). The responses for each item in the questionnaire were strongly agree (6), moderately agree (5), slightly agree (4), slightly disagree (3), moderately disagree (2), and strongly disagree (1). The score on the scale was obtained by summing the 41 responses to the items.

2.2.2.5. Reasoning Tests. In order to assess reasoning ability participants were asked to complete three reasoning tasks.

2.2.2.5.1. Syllogistic Reasoning task. Participants were presented with 12 syllogistic reasoning problems, taken from Shynkaruk & Thompson (2006) (Appendix A), and shown on a high-resolution computer monitor using *E-Prime* (Schneider, Eschman, & Zuccolotto, 2002). Each reasoning problem consisted of a pair of quantified premises followed by a conclusion. All problems were multiple-model problems (i.e., required the construction of two or three models to test conclusion's validity). Four of the problems led to believable conclusions, four to unbelievable, and four to neutral conclusions. On each trial, participants were shown the premises and conclusion simultaneously and asked to evaluate the logical validity of the conclusion (whether it is entailed by the premises); half of the conclusions for problems in each believability condition were valid and half were invalid. These combinations led to the divisions of conflict (valid-unbelievable and invalid-believable), no-conflict (valid-believable and invalid-unbelievable), and neutral (valid-neutral and invalid-neutral) problems. Participants were asked to decide whether the conclusion given at the end of the problem follows logically from the information given within that problem. They were informed that "to answer each question, you must assume that all information which you are given is true; this is very important." Participants were instructed to choose "yes" if the conclusion followed logically from the premises and "no" if it did not. The keys corresponding to each response alternated across participants, so that for half of the participants one key corresponded to "no and for the remainder it corresponded to "yes." Problems were presented in a different random order for each participant. Before beginning the task, participants were provided with a practice problem to familiarize them with the type of problems they would encounter.

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2.2.2.5.2. Base rate Task. A total of 12 base rate problems adapted from De Neys and Glumicic (2008) (see Appendix B for examples) were presented to participants on a high-resolution computer monitor using *E-Prime*. These problems consist of two parts: first, participants read a scenario describing the sample composition (e.g., a sample with 4 men and 996 women); second they were shown a short personality description of one of the participants (which was stereotypical or neutral). They were then asked to indicate to which population group the participant most likely belongs. Four of the problems were conflict (larger base rate and personality description not congruent), four were no-conflict (larger base rate and personality description congruent), and four were neutral (personality description does not evoke stereotype). The problems were presented in a different random order for each participant. There were two base rate probabilities; within each problem type, two problems were presented with a 995/5 and two with a 996/4 base rate ratio. For each ratio, participants were asked to make one judgement about the smaller category and one about the larger category.

2.2.2.5.3. The Cognitive Reflection Test (CRT). The CRT (Frederick, 2005) was used to measure the ability to override intuitive responses. This test consists of three questions that require individuals to override an impulsive T1 answer by engaging in Type 2 processing, and thus, is a quick measure of Type 1 response tendencies (Appendix C). This test was presented in paper and pencil format and participants took as long as necessary to complete this task.

2.2.3. Procedure

All of the older adults were pre-screened using the 3MS at the beginning of the experiment. The other measures were divided into two blocks, Block A, computer based reasoning tasks (i.e., syllogistic and base rate task) and Block B, pen and paper measures (i.e., verbal ability measure, working memory, processing speed, inhibition, AOT, and CRT). Half of the young and older adults saw Block A tests first and the other half saw Block B tests first. Within Block A, task order was randomized to control for order effects; Block B was not randomized. In an attempt to counter unfamiliarity and physical slowing that some older adults may experience when responding on a computer, for the syllogistic and base rate tasks, all older

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adults were asked to answer aloud and the experimenter pressed the corresponding keyboard key[2]. All participants were tested individually, in a single session that lasted between 1.5 – 2.5 hours (older adults required more time for many of the tasks).

2.3. Results

2.3.1. Transformations

Inhibition score distributions were positively skewed; consequently log transformations were performed. All subsequent analyses were performed using the transformed scores. Skewness values for the other variables (education, verbal ability, working memory, processing speed, AOT, and CRT) were not significant and therefore, they were not transformed.

2.3.2. Scoring

Means and standard deviations for all variables are set out in Table 2.1. It should be noted that a high score on the inhibition ratio indicates poor inhibitory control; in all other cases, higher scores indicate greater ability. For the syllogistic reasoning task, an answer was scored as the correct response when reasoners responded "yes" to valid conclusions and "no" to invalid conclusions. For the base rate task, we took a different approach because it is not possible to derive a measure of normative accuracy without combining the base rate with probability estimates for the personality description (Pennycook, Fugelsang, & Koehler, 2012; Pennycook & Thompson, 2012; Thompson et al., 2011). Thus, we used the proportion of base rate responses chosen as the dependent variable. An answer was scored as the base rate response when participants chose the group corresponding to the larger base rate. For the CRT, an answer was scored as the correct response when reasoners provided the mathematically correct response. Scores on the AOT were obtained by summing the 41 responses to the items.

2.3.3. Analysis Strategy

The data are reported in three sections. The first section examines potential age-related effects on education, verbal ability, WM, processing speed, inhibition, AOT, and performance on the syllogistic, base rate tasks, and CRT by computing independent t-tests between young and older adults. Refer to Table 2.1 for these data. In the second section, to test the hypothesis that

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[2] It should be noted that when the experimenter pressed the response key, the experimenter was blind to the questions on the screen. Thus, any age-related differences should be attributed to age and not experimenter bias.

older adults would be at a disadvantage on problems requiring Type 2 thinking, we used ANOVAs to examine age-related change in performance on conflict, no-conflict, and neutral problems, for the syllogistic and base rate tasks and differences on the CRT. Finally, to further examine the extent to which the algorithmic and reflective levels attenuate age-related differences in reasoning, the correlation and regression analyses are reported for the algorithmic capacity constructs, syllogistic task, base rate task, and the CRT, respectively.

Table 2.1

Means and Standard Deviations for all Variables by Age Group.

	Younger Adults		Older Adults		
	Mean	SD	Mean	SD	*p*-value
Education	16.24 yrs	2.32	14.02 yrs	3.65	$p < .001$
Verbal	111.22	9.18	113.11	13.31	$p = .324$
WM	3.26	1.42	1.38	1.66	$p < .001$
Speed	.52	.62	-.84	.54	$p < .001$
Inhibition	1.21	.11	1.34	.19	$p < .001$
AOT	176.69	19.69	164.84	23.86	$p = .002$
CRT	.44/3	.39	.13/3	.25	$p < .001$
SR performance	.69	.14	.56	.15	$p < .001$
BR performance	.73	.19	.59	.16	$p < .001$

Note: Data were not available for all older adults on education (missing 3), inhibition (missing 1), AOT (missing 2), and the MIA (missing 1). SR performance = syllogistic reasoning proportion correct. BR performance = base rate proportion correct.

Consistent with our expectations, younger adults had more years of education, greater working memory capacity, faster processing speed, higher inhibitory ability, and performed better on the CRT than their older adult counterparts. Young and old adults were matched on verbal ability; therefore no difference was expected between the groups. Also consistent with our predictions, older adults were less likely than young adults to give correct responses to the syllogism task and the CRT, and were more likely to respond on the basis of the stereotypes on

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the base rate task. Additionally, an important and novel finding was that older and young adults differed on the AOT, with older adults expressing more reliance on heuristic styles.

It is important to note the mean scores for verbal ability for each group were higher than average ($M = 100$; Wilkinson & Robertson, 2006), $t(71) \geq 8.36$, $p < .001$; demonstrating that our group of participants had a higher verbal capacity than the average young or older adult. Also, the average total years of education for the older adults was 2 years of post-secondary education, which is a higher level of education than is normally found in older populations.

Next, to test the hypothesis that older adults would provide more intuitive responses, computed ANOVA's for the syllogistic and base rate tasks, and the CRT.

2.3.4. Syllogistic Reasoning Task ANOVA. The SR response data were analyzed using a 3 (problem type: conflict, no-conflict, and neutral) x 2 (age group) mixed-factors ANOVA, with age group as the between-participants variable. Our dependent variable was the number of correct responses, defined as whether participants said "YES" to valid problems or said "NO" to invalid problems. The means for each group appear in Table 2.1.

There was a main effect of age, with younger adults (.69) providing more correct responses than older adults (.56), $F(1, 142) = 29.12$, $MSE = .12$, $p < .001$, $\eta_p^2 = .17$. There was also a main effect of problem type, $F(1.96, 272.01) = 79.90$, $MSE = .045$, $p < .001$, $\eta_p^2 = .36$; with no-conflict (.79) > neutral (.60) > conflict (.48), $t \geq 4.82$, $SE \geq .024$, $p < .001$. The two main effects were qualified by an interaction $F(2, 284) = 20.48$, $MSE = .043$, $p < .001$, $\eta_p^2 = .13$. As shown in Figure 2.1, the differences between older and younger adults were observed on conflict and neutral problems [$t(142) = 7.20$, $SE = .042$, $p < .001$ and $t(129.05) = 2.08$, $SE = .032$, $p = .039$, respectively], but not on no-conflict problems, $t(142) = .292$, $SE = .036$, $p = .770$.

Figure 2.1. **Proportion of Correct Responses for the Syllogistic Task as a Function of Problem Type and Age**
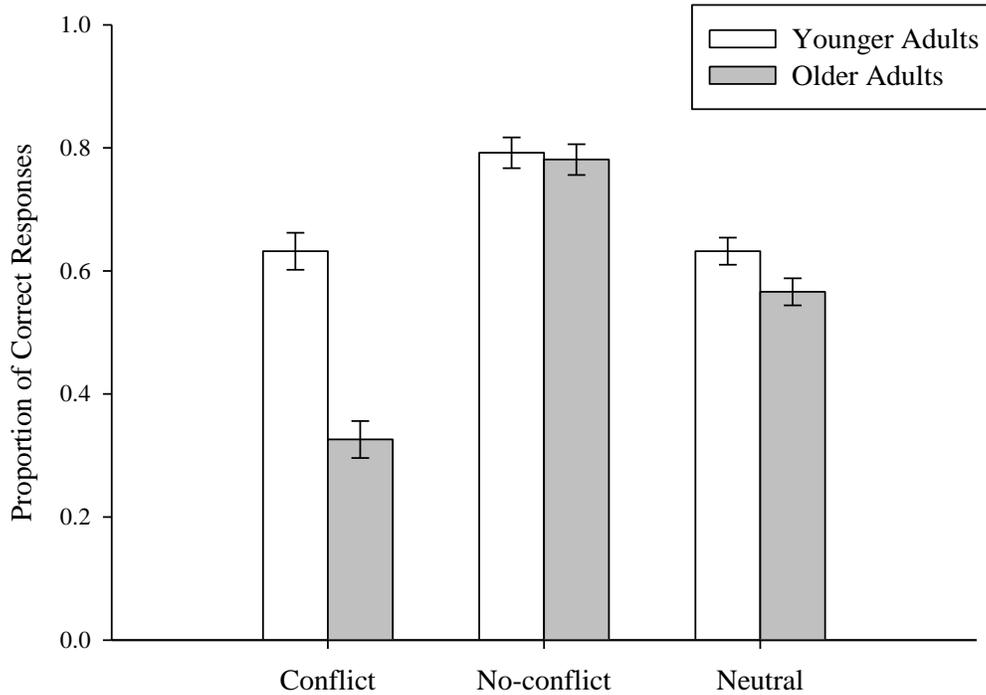
Note. Error bars represent the standard error.

2.3.5. Base Rate Task ANOVA. The BR data were also analyzed using a 3 (problem type: conflict, no conflict, and neutral) x 2 (age group) mixed-factors ANOVA, with age group as the between-participants variable. The dependent variable for this analysis was the number of base rate responses. The means for each group appear in Table 2.1. Consistent with predictions there was a main effect of age; younger adults based their responses on the base rate more often (.73) than older adults (.59), $F(1, 142) = 23.41$, $MSE = .092$, $p < .001$, $\eta_p^2 = .14$. As seen in previous research (De Neys & Glumicic, 2008), there was a main effect of problem type, $F(1.79, 254.45) = 245.21$, $MSE = .06$, $p < .001$, $\eta_p^2 = .63$; such that base rate choices were the highest for

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the no-conflict problems (.96), intermediate for neutral problems (.70), and lowest for the conflict problems (.34), $t(143) \geq 9.41$, $SE \geq .025$, $p < .001$. Overall, the pattern of these results is consistent with the syllogistic task, because performance was lowest for the conflict problems, followed by the neutral and highest on the no-conflict problems.

Both of these effects were qualified by an interaction that was also consistent with predictions, $F(2, 284) = 16.99$, $MSE = .054$, $p < .001$, $\eta_p^2 = .11$. As shown in Figure 2.2, and consistent with the syllogistic task, the differences between older and younger adults were observed on conflict and neutral problems [$t(131.64) = 4.48$, $SE = .057$, $p < .001$, and $t(142) = 4.89$, $SE = .21$, $p < .001$, respectively], with older adults providing fewer base rate responses than the young adults. Again, we assumed that these two problem types require a level of analytic processing to choose the base rate option; consequently, the results are consistent with the conclusion that the ability to engage in Type 2, analytic processing differs with age. There was a marginal difference on the no-conflict problems with older adults showing a slightly higher level of base rate responding, $t(130.28) = 1.88$, $SE = .022$, $p = .062$.

**Figure 2.2. Proportion of Base Rate Responses for the Base rate Task as a Function of
Problem Type and Age**
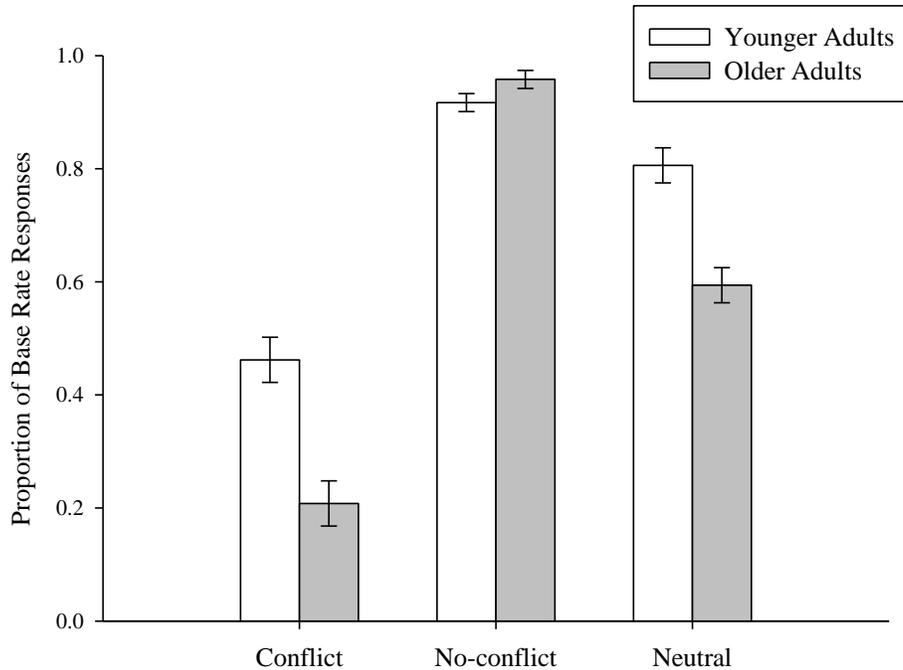
Note. Error bars represent the standard error.

2.3.6. Cognitive Reflection Test ANOVA. The CRT data were also analyzed using a 3 (problem) x 2 (age group) mixed-factors ANOVA, with age group as the between-participants variable. Data are presented in Figure 2.3. Young adults were more accurate ($M = .44$) than older adults ($M = .13$), $F (1, 138) = 29.82$, $MSE = .323$, $p < .001$, $\eta_p^2 = .178$. There was also an interaction between problem and age, $F (2, 276) = 3.86$, $MSE = .106$, $p = .022$, $\eta_p^2 = .027$. Young adults were equally accurate on the bat and ball and the widget problems [$t (71) = 1.09$, $SE = .064$, $p = .278$] and had the highest accuracy for the lily pad problem [$t (71) \geq 2.98$, $SE \geq .056$, $p \leq .004$]. Older adults had the highest accuracy for the widget and the lily pad problems [$t (71) = 1.00$, $SE = .044$, $p = .321$] and lowest accuracy for the bat and ball problem [$t (71) \geq 1.94$, $SE \geq .045$, $p \leq .057$]. One interpretation for the finding that performance on all problems, regardless of

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age, was on the floor (i.e., less than 1 out of 3) is that the initial response for these problems is very compelling and thus, neither young or older adults are considering alternatives.

Figure 2.3. Proportion of Correct Responses (out of 3) for the Cognitive Reflection Test as a Function of Problem and Age
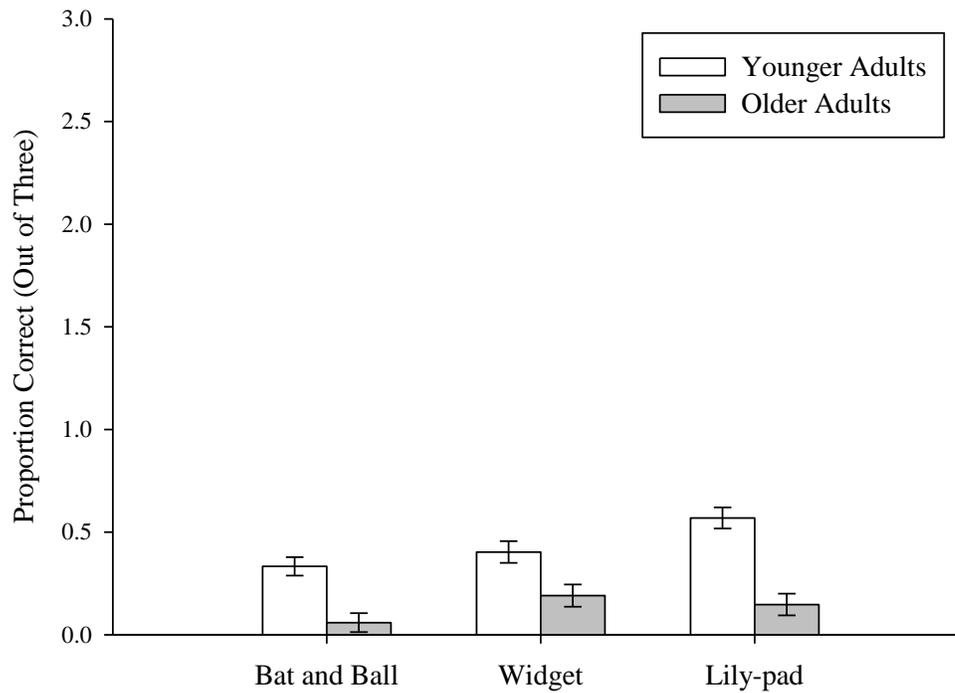
Note. Error bars represent the standard error.

To test our hypothesis that the measures of the algorithmic and reflective levels were related to the age-related difference, we ran correlation and regression analyses. Refer to Table 2.2 for the zero-order correlations among the major variables in the study.

Table 2.2

Correlations Between Age, Education, Verbal Ability, Working Memory, Processing Speed, Inhibition, AOT, CRT, Syllogistic Task Performance, and Base Rate Task Performance.

	1	2	3	4	5	6	7	8	9	10
1) Age	-									
2) ED	-.334**	-								
3) Verbal	.104	.217*	-							
4) WM	-.566**	.219*	.031	-						
5) PS	-.808**	.406**	.040	.531**	-					
6) INH	.395**	-.039	-.104	-.280**	-.271**	-				
7) AOT	-.265*	.533**	.075	.257*	.305**	-.024	-			
8) CRT	-.436**	.175*	.075	.385**	.465**	-.267**	.216*	-		
9) SR	-.412**	.205*	.161[a]	.285**	.395**	-.094	.261*	.460**	-	
10) BR	-.356**	.278**	.054	.356**	.345**	-.167*	.373**	.290**	.284**	-

$* p < .05$; $** p \leq .001$; [a] $p < .10$; two-tailed
Note. AOT = the Actively Open-Minded Thinking Scale; CRT = Cognitive Reflection Test; SR = overall syllogistic task performance; BR = overall base rate task performance

Working memory was positively correlated with all three of the reasoning tasks. This is consistent with previous findings and suggests that those with higher working memory capacity are better reasoners (Capon et al., 2003; De Neys & Verschueren, 2006; Kyllonen & Christal, 1990; Markovits et al., 2002; Quayle & Ball, 2000). Processing speed was also correlated with the syllogistic task, the base rate task, and the CRT, suggesting that as processing speed increases, so does reasoning performance. Processing speed was also correlated with working memory, providing evidence that these measures tap similar processes. Inhibition was unrelated to performance on the syllogistic task, but negatively correlated with the base rate task and the CRT, suggesting that performance on these tasks improved as inhibitory ability increased. All of the above correlations provide strong evidence that individual differences in algorithmic capacity are associated with reasoning performance. There was also evidence for the importance of reflection in reasoning, because the AOT was also correlated with performance on the syllogistic task, base rate task, and the CRT. These results provide evidence that a flexible thinking style is related to better reasoning performance. Scores on the AOT were also correlated with education, suggesting that a higher level of education is associated with more flexible thinking. Additionally, providing support for the argument that the there is some overlap between the algorithmic and reflective processes (Stanovich, 2009), is the fact that the AOT was correlated with WM and PS.

The correlations in Table 2.2 indicate that most of the variables are correlated with one another, and with performance on the reasoning tasks, which raises the question of whether all of these variables would predict unique variance in age-related reasoning differences. The following regression analyses sought to remedy this question.

2.3.7. Shared Variance between the Algorithmic Capacity Constructs. To test the hypothesis that age-related differences in working memory may be attributed to differences in processing speed (Salthouse, 1991; 2000; Salthouse & Babcock, 1991) or to poor inhibitory mechanisms (De Beni et al., 1998), hierarchical regression analyses were conducted to examine the proportion of variance in working memory associated with age after controlling for processing speed and inhibition. The results from the regression are summarized in Table 2.3 and reveal substantial attenuation (82%) in working memory variance after controlling for

processing speed; however, the remaining age-related variance in working memory was greater than 0 ($R^2 = .057$; $p = .001$).

These results support the assumptions of previous researchers, that some, but not all, of the age-related differences in working memory may be an artifact of slower speed of processing (Salthouse, 1994; 1996; 2000; Salthouse & Babcock, 1991). However, significant residual age-related variance in working memory remained that was independent of processing speed. There was little evidence to support the assumption that age-related differences in working memory can be attributed to poor inhibitory mechanisms. The attenuation of age-related variance in working memory was small (22%) and there was significant age variance remaining after the control of inhibition ($R^2 = .252$; $p < .001$).

Table 2.3
Proportions of Shared Age-related Variance in Algorithmic Capacity Constructs

	Age alone R^2	After WM R^2 change	After PS R^2 change	After Inhibition R^2 change
WM	.323**	--	.057** (.82)	.252** (.22)
PS	.652**	.378** (.42)	--	.580** (.11)
Inhibition	.156**	.082** (.47)	.089** (.43)	--

Note. WM = working memory; PS = processing speed. The numbers in brackets indicate the proportion of shared variance among mediating and criterion predictors.
** $p \leq .001$

2.3.8. Syllogistic Task Regression. To test the hypothesis that the aforementioned variables would attenuate age-related differences in reasoning, we ran a hierarchical regression with four blocks of variables. In block one, education and verbal ability were entered, followed by the measures of algorithmic capacity as a block (working memory, processing speed, and inhibition), the Actively Open-minded Thinking scale, and finally, age. Age was entered last to determine if there were any additional unspecified age-related effects (see Gilinsky & Judd, 1994) and if the variables significantly attenuated the age-related differences in reasoning ability (by comparing the regression of age alone to the age-related variance after variables were partialled out). Results from the regression analysis are summarized in Table 2.4. Based on the hypothesis that performance would vary by problem, separate regressions were performed for conflict, no-conflict, and neutral problems.

Table 2.4

Hierarchical Regression for the Syllogistic Reasoning Task.

Predictor	Conflict Problems	No-conflict Problems	Neutral Problems
	Cumulative R^2 in hierarchical steps		
Education (B1)			
Verbal (B1)	.058*	.010	.014
WM (B2)			
PS (B2)	.243**	.025	.038
Inhibition (B2)			
AOT (B3)	.262**	.029	.046
Age (B4)	.332**	.029	.059
	R^2 Change		
Education (B1)			
Verbal (B1)	.058*	.010	.014
WM (B2)			
PS (B2)	.186**	.015	.024
Inhibition (B2)			
AOT (B3)	.018[a]	.003	.008
Age (B4)	.070**	.000	.089
	R^2 age alone		
Age only	.266**	.000	.036*
	Standardized Beta weights for predictors		
Education (B1)	.199* (3.8)	-.046	.059
Verbal (B1)	.101	.098	.090
WM (B2)	.126	-.093	.119
PS (B2)	.408** (10.3)	.151	.072
Inhibition (B2)	.047	-.008	.012
AOT (B3)	.159[a] (1.8)	.067	.108
Age (B4)	-.509** (7.0)	.013	-.219
	Standardized Beta weights from Age alone regression		
Age only	-.515**	-.015	-.190*

Note. B1= block 1; B2 = block 2; B3 = block 3; B4 = block 4.

WM = working memory; PS = processing speed; AOT = Actively Open-Minded Thinking scale.
The numbers in brackets indicate the percentage of unique variance explained by that factor.
* $p < .05$; ** $p \leq .001$; [a] $p < .10$

2.3.8.1. Conflict problems

The overall regression equation was significant, [F (7, 137) = 9.21, $p < .001$], with the cluster of factors accounting for 33.2% of variance in responses on conflict problems. The criterion variables in the first block of the regression analysis were education and verbal ability, and they accounted for 5.8% of the variance ($p = .018$), with education being the only factor to contribute unique variance (3.8%; $p = .021$). Entered second as a block, working memory, processing speed, and inhibition accounted for 18.6% of the variance ($p < .001$), with processing speed being the only significant predictor of this block, accounting for 10.3% of unique variance ($p < .001$). The third block consisted of the AOT and was only marginally significant ($p = .075$).

In the fourth block, when the overlap with the other variables is partialled out, age remained a significant predictor (7.0%) in the ability to choose the correct response to conflict problems ($p < .001$). The attenuation of the age-related effects by all of the factors was substantial, 73.7% (i.e., [1- (.070/.266)]*100; see Salthouse, 1991), with a reduction from 26.6% to 7%, the remaining variance suggests there is at least one additional factor, which we have not considered, that can predict age-related differences on this task. We discuss this possibility below.

2.3.8.2. No-conflict problems

As expected, there were no age differences in performance on the no-conflict problems and none of the variables were significant in the regression equation, F (7, 137) = .55, $p = .796$, providing evidence that the age-related differences in algorithmic and reflective processes do not impact performance on no-conflict problems. This is likely because reasoners can use their Type 1 output and still provide the correct response.

2.3.8.3. Neutral problems

For neutral problems, the overall regression equation was also not significant, F (7, 137) = 1.17, $p = .327$. It is possible that the neutral problems in the syllogistic task may require less Type 2, analytic engagement than previously thought, or perhaps the neutral problems are too difficult to successfully engage the analytic system. Although prior t-tests revealed that young adults outperformed older adults on these problems, the regression suggests that age has little to do with this performance difference. These results indicate that reasoners might be adopting a strategy that does not require a great deal of T2 engagement. One possible strategy, based on the difficulty of the task, is that reasoners are just giving up and guessing. However, performance for

both groups was above chance. Moreover, both young (70%) and older adults (63%) demonstrated a "yes" bias for these problems, such that these values were both greater than 50% (guessing) [t (71) ≥ 3.08, SE ≥ .03, p ≤ .003], but did not differ from one another, t (129.77), SE = .05, p = .160. These results suggest that both young and older adults are adopting a strategy in the form of a systematic bias to say yes, which may be another form of heuristic processing.

      2.3.9. Additional Age-related Variance. The regression analysis for the conflict problems suggests that at least some of the difference between older and younger adults cannot be attributed to algorithmic capacity (or the marginal effect of thinking dispositions). One possibility discussed by Gilinsky and Judd (1994) is a greater tendency for belief bias, endorsing conclusions on the basis of belief rather than based on logic (Evans, Barston, & Pollard, 1983), as we age. The standard way to measure this is through a belief index and a validity index. To compute a belief index, mean acceptance (i.e., proportion of yes responses) for unbelievable problems (i.e., valid-unbelievable and invalid-unbelievable) was subtracted from mean acceptance for believable problems (i.e., valid-believable and invalid-believable). To compute the validity index, mean acceptance for invalid problems was subtracted from the mean acceptance for valid problems.

      The effect of belief was larger for older adults (.45) than for the young adults (.16), t (133.45) = 5.48, SE = .054, p < .001. Also, young adults were better at discriminating between valid and invalid problems (.37) than older adults (.12), t (142) = 5.40, SE = .047, p < .001. Both of these results suggest that older adults were demonstrating a greater belief-bias than young adults, which is consistent with prior research (Gilinsky & Judd, 1994) and suggests another factor that likely contributes to the age-related difference in reasoning ability.

      2.3.10. Base Rate Task Regression. The regression analysis for base rate data was identical to the syllogistic task, with the DV in this regression being the proportion of base rate responses. Results from the regression are summarized in Table 2.5. Again, regressions were performed for conflict, no-conflict, and neutral problems.

Table 2.5
Hierarchical Regression for the Base Rate Task.

Predictor	Conflict Problems	No-conflict Problems	Neutral Problems
	Cumulative R^2 in hierarchical steps		
Education (B1)			
Verbal (B1)	.084*	.019	.031
WM (B2)			
PS (B2)	.187**	.039	.115*
Inhibition (B2)			.
AOT (B3)	.231**	.041	.147*
Age (B4)	.237**	.086	.167**
	R^2 Change		
Education (B1)			
Verbal (B1)	.084*	.019	.031
WM (B2)			
PS (B2)	.103**	.020	.084*
Inhibition (B2)			
AOT (B3)	.044*	.002	.032*
Age (B4)	.006	.046*	.019[a]
	R^2 for age alone		
Age only	.130**	.032	.115**
	Standardized Beta weights for predictors		
Education (B1)	.296** (8.4)	-.066	.177
Verbal (B1)	-.049	.133	-.003
WM (B2)	.232* (3.8)	-.144	.197* (2.8)
PS (B2)	.158	-.008	.117
Inhibition (B2)	.001	-.069	-.070
AOT (B3)	.246* (4.4)	-.051	.210* (3.2)
Age (B4)	-.154	.411*	-.269[a] (2.0)
	Standardized Beta weights from Age alone regression		
Age only	-.361**	.180*	-.339**

Note. B1= Block 1; B2 = Block 2; B3 = Block 3; B4 = Block 4. WM = working memory; PS = processing speed; AOT = Actively Open-Minded Thinking scale.
The numbers in brackets indicate the percentage of unique variance explained by that factor.
* $p < .05$; ** $p \leq .001$; [a] $p < .10$

2.3.9.1. Conflict problems

As was the case in the syllogistic task, the regression equation for conflict problems was significant, [$F (7, 137) = 5.78, p < .001$], with the cluster of variables accounting for a significant portion (23.7%) of total variance. The first block of variables entered (education and verbal

ability) accounted for 8.4% ($p = .003$), with education independently contributing to all the variance ($p = .001$). The criterion variables in the second block were working memory, processing speed, and inhibition, and while this block contributed to 10.3% ($p = .001$), only working memory accounted for a unique portion of this variance, 3.8% ($p = .014$). The third block, the AOT, also accounted for unique variance 4.4% ($p = .007$); however, the fourth block (age) was not significant ($p = .298$). The attenuation of the age-related effects was almost at the ceiling, 95.4%, with a reduction from 13% to 0%. Thus, the predictors account for almost all of the age-related variance in conflict problem performance differences between young and old adults. Thus, on both the syllogistic and base rate tasks, the algorithmic capacity block was a significant predictor, and the measure of reflective processes (AOT) was a predictor on the base rate and syllogistic (marginally) tasks. Age only predicted residual variance on the syllogistic task.

2.3.9.2. No-Conflict Problems

Also consistent with the syllogistic task, the regression model for no-conflict problems was not significant, $F (7, 137) = 1.75$, $p = .103$. The results of this regression lend further support to the idea that algorithmic and reflective processes are not be related to performance on no-conflict problems. Regardless of the process employed, both will lead to the correct answer.

2.3.9.3. Neutral problems

The regression results for neutral problems were not consistent with the syllogistic task, but were almost identical to the conflict problems in this task, with the exception of the first block. The overall regression equation was significant, accounting for 16.7% of variance in neutral problem performance, $F (7, 137) = 3.71$, $p = .001$. The first block entered into the equation was not significant. Consistent with the conflict problems blocks 2 and 3 were significant, accounting for 8.4% ($p = .007$) and 3.2% ($p = .029$) of unique variance, respectively. Again, working memory (2.8%, $p = .044$) and the AOT (3.2%, $p = .029$) were the significant criterion variables. Age did not predict unique variance in neutral problem performance.

Referring to the data in Table 2.5, it can be seen that the attenuation of the age-related effects was substantial, 83.5%, with a reduction from 11.5% to 1.9%. Thus, consistent with the conflict base rate problems, the predictors account for almost all of the age-related variance in neutral problem performance differences between young and old adults.

2.3.10. Cognitive Reflection Test Regression. All three problems on the CRT can be classified as conflict problems, thus only one hierarchical regression was performed. Results from the regression are summarized in Table 2.6.

Table 2.6
Hierarchical Regression for the Cognitive Reflection Test.

Predictor	CRT performance
Cumulative R^2 in hierarchical steps	
Education (B1)	
Verbal (B1)	.024
WM (B2)	
PS (B2)	.256**
Inhibition (B2)	
AOT (B3)	.264**
Age (B4)	.266**
R^2 Change	
Education (B1)	
Verbal (B1)	.024
WM (B2)	
PS (B2)	.232**
Inhibition (B2)	
AOT (B3)	.008
Age (B4)	.002
R^2 for age alone	
Age only	.191**
Standardized Beta weights for predictors	
Education (B1)	.139
Verbal (B1)	.048
WM (B2)	.160[a] (1.8)
PS (B2)	.366** (8.0)
Inhibition (B2)	-.123
AOT (B3)	.103
Age (B4)	-.084
Standardized Beta weights for age alone	
Age only	-.436**

Note. B1= Block 1; B2 = Block 2; B3 = Block 3;
B4 = Block 4. WM = working memory;
PS = processing speed;
AOT = Actively Open-Minded Thinking scale.
The numbers in brackets indicate
 the percentage of unique variance
explained by that factor.
* $p < .05$; ** $p \le .001$; [a] $p < .10$

The predictors accounted for 26.6% of the variance in CRT scores, $F(7, 137) = 6.72$, $p < .001$. However, only processing speed accounted for a significant portion of unique variance in performance (8%). No other variables contributed unique variance. The attenuation of the age-related effects was 99%, with a reduction in variance from 19% to 0%. One possible explanation for the absence of relationships with other factors is that there is no age-related variance to predict. Performance for both young and old adults was on the floor and thus, there is an attenuated range for the performance scores on this task.

2.4. Discussion

Across three reasoning tasks, we demonstrated that both algorithmic and reflective processes contribute to age-related differences in reasoning performance. Our work advances on previous work (Fisk & Sharp, 2002; Gilinsky & Judd, 1994; Salthouse, 2005) and has demonstrated that capacity differences (i.e., working memory and processing speed) explain age-related differences in reasoning performance. The current research also explored the possibility that reflective processes may explain the age-related differences in reasoning performance. We were successful in demonstrating that algorithmic capacity and reflective processes attenuate age-related reasoning differences, thus providing evidence for a dual-process theory of reasoning and aging. Indeed, we provided evidence for the hypothesis set forth from the DPT framework that both algorithmic and reflective components of the analytic system contribute to age-related differences in reasoning ability.

Results were consistent with prior research, which had demonstrated that older adults were at a disadvantage on conflict problems, but were spared on no-conflict problems (De Neys & Van Gelder, 2009). This is important because it clarifies that the age-related difference is not necessarily a general decline in ability, as is often claimed in the literature (e.g., Salthouse, 2005).

2.4.1. Algorithmic Processes

The results provided evidence that the algorithmic level of the analytic system is a contributing factor to age-related differences in reasoning ability. It was hypothesized that reasoners with less processing power would be at a disadvantage because it would limit their ability to engage in Type 2 processing. In all three reasoning tasks, the algorithmic block predicted reasoning performance, although the factor that emerged as unique was different for

the base rate task (i.e., WM), than for the syllogistic task and CRT (i.e., PS). It is important to note however, that processing speed and working memory are correlated factors, and that controlling for processing speed attenuated a substantial portion the age-related variance in working memory. Thus, the significance of one factor does not rule out the importance of the other because both would be expected to play a role, but with different balances of influences depending on task demands. This is consistent with an argument posited by Salthouse (2005), who argued that the positive correlations between most of the capacity variables increases the likelihood that variance predicted by one variable will attenuate the age-related effects of the other related variables. Due to the fact that older adults demonstrated lower processing speed and working memory capacity it is not surprising that they were at a disadvantage on conflict problems relative to no-conflict problems and to young adults. This is consistent with the wide range of literature suggesting that these processing factors underlie age-related differences in cognitive abilities (e.g., Fisk & Sharp, 2002; Rozas, Juncos-Rabadàn, Soledad, Gonzàlez, 2008; Salthouse, 2005).

On both the syllogistic and base rate tasks, older adults had lower performance on conflict problems than the no-conflict problems and performance was lower on conflict problems than young adults' performance. Also, older adults provided more Type 1, intuitive responses on the CRT than young adults. This is consistent with previous arguments (Klaczynski & Robinson, 2000) that older adults rely more on prior opinion and belief when making decisions.

The picture for the neutral problems is less clear. Although older adults' performance on neutral problems was lower than young adults, for both the syllogistic and base rate tasks, none of the capacity factors were significant predictors of performance on the syllogistic task, while working memory and the AOT predicted performance on neutral base rate problems. This was only partially consistent with our predictions because we assumed that neutral problems require Type 2 processing and performance on these problems should be predicted by capacity. It is possible that because older adults are less inclined to engage in this type of thinking they are utilizing a strategy of guessing; however, performance on neutral problems was above chance.

An alternative explanation for the findings is provided by Thompson's (2009) metacognitive model. Specifically, because there is no compelling response generated when a reasoner attempts to solve a neutral problem, engagement in Type 2 processing will be dependent on how solvable the problem is deemed to be. Judgements of solvability can be based

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on familiarity, expertise, complexity, or motivation. The problems in the syllogistic task contain non-words and thus, the judgement of solvability would likely be low because these problems are unfamiliar, complex, and individuals do not have expertise in solving these problems. Consequently, the likelihood of individuals attempting to solve the problem may also be low and reasoners may tend to give up. Another possibility is that both young and older adults are adopting the same strategy (to say "yes"), a strategy that does not require working memory. For this reason, there is only a slight young adult advantage of 6.5% on these problems. If this judgement or strategy choice is made at the outset of the reasoning process there is a strong possibility that Type 2 processing will not be attempted, which would explain the null relationship between performance and capacity.

2.4.2. Reflective Processes

Older adults reported a greater self-expressed tendency to rely on intuitive modes of thinking than young adults, as evidenced by their lower score on the AOT. Previous findings and our results suggest that older adults rely on their Type 1, intuitive system more so than their Type 2, analytic system (Klaczynski & Robinson, 2000) and the AOT results demonstrate that older adults subjectively report this as well.

To test the hypothesis that thinking style would predict performance, scores on the AOT were entered into the regression analyses for each task. It was discovered that the AOT was a unique predictor on the base rate task and a marginal predictor on the syllogistic task, suggesting that those who report a preference for analytic thinking choose a greater number of base rate and logically valid responses, than those who expressed tendencies to be less analytic. Although the AOT was correlated with the CRT, such that better performance was associated with a tendency for more open-minded thinking, the AOT was not a unique predictor of CRT performance.

It is important to note that the AOT measures a tendency to engage in reflective thinking; however, reasoners still need enabling conditions to override the initial T1 response. First, reasoners need to possess the mindware, the knowledge of logical rules (Stanovich, 2009), to realize their beliefs are in conflict with the logical rules of the task. This may be absent in a syllogistic task, due to the fact that these problems are unfamiliar and complex. Second, reasoners need a cue to override the T1 response. If reasoners have a strong feeling of rightness (i.e., a metacognitive experience, which can signal when additional analysis is needed; Thompson, 2009; Thompson et al., 2011) in the initial response, it is unlikely that the response

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will be re-examined. The questions in the CRT are believed to be answered with a strong feeling of rightness (Frederick, 2005), thus the cue to rethinking the initial response may be absent in the CRT, especially for the older adults.

2.4.3. Inhibition

Although inhibition was correlated with the CRT and the base rate task, it was not a unique predictor of performance in any of the three tasks. This was surprising because the ability to inhibit information has been implicated in successful analytic engagement (Handley et al., 2004; Houdé et al., 2000; Moutier et al., 2002; Moutier & Houdé, 2003; Simoneau & Markovits, 2003). It can be argued that while we were able to measure inhibition, perhaps the Victoria Stroop Test measured the ability to inhibit or suppress irrelevant information (e.g., belief-based information) and that older individuals do not treat stereotypical or belief-based information as irrelevant (see Stanovich 2009 for argument regarding the Stroop as a measure of suppression). In other words, it is possible that reasoners may explicitly value belief-based and stereotypical information differently than base rate and logical validity information. It is also possible that older adults have a more firmly established or entrenched heuristic system, based on experience, so that evidence that contradicts their beliefs can rightly be given less weight (i.e., Bayesian analysis; Hahn & Oaksford, 2007). In other words, it makes less sense for them to discard the heuristic information, in favour of a set of numbers or logic. If this is the case, then it should not be surprising that inhibition does not attenuate age-related reasoning differences, because it is not necessary. However, more research is needed to determine the validity of this claim.

2.4.4. Education

We controlled for verbal ability scores, but we did not control for education. The data revealed that education predicted performance of conflict problems on both the syllogistic and base rate tasks. This is consistent with prior findings, that education can positively influence performance on cognitive tasks (Everson-Rose, Mendes de Leon, Bienias, Wilson, & Evans, 2003; McDowell, Lindsay, & Tuokko, 2004). Thus, education also explains age-related differences in reasoning performance.

2.4.5. Age

The fact that age contributed to unique variance in the conflict problems on the syllogistic task, but none of the base rate problems or the CRT implies that there is at least one additional age-related factor unaccounted for by the regression that predicts age-related differences in

performance on syllogistic conflict problems. As discussed previously, one likely candidate is susceptibility to belief bias (Gilinsky & Judd, 1994). Our results also support this possibility. When the belief-based response was consistent with logic, there were no response differences between age groups; when belief and logic were in conflict; older adults provided a greater percentage of belief-based responses than the younger adults. Furthermore, older adults were more susceptible to belief and demonstrated greater difficulty in their ability to distinguish between valid and invalid conclusions than the young adults. Further support for this assertion is that age did not account for unique variance in any of these latter conditions.

2.4.6. Conclusions

On the assumption that belief-based and stereotypical responses are an output of the Type 1, heuristic system, our results lend credence to the conclusion that older adults have trouble shifting from Type 1 to Type 2 processing. Specifically, older adults appear to be at a disadvantage when they need to engage in Type 2 thinking to override the intuitive response. Older adults' inability to override a potent response based on beliefs or stereotypes in favour of logic or probability was related to capacity and in some cases, thinking style. On no-conflict problems where this shift is not necessary to reason effectively older adults perform at the same level as young adults.

Furthermore, the data lend support to a dual-process theory of reasoning. Older adults provided more belief-based or stereotypical responses and had greater capacity differences than young adults, on all tasks, and the regression results provide evidence that these differences predicted age-related variance in reasoning performance. There was also some evidence to support the conclusion that reflective processes contribute to the age-related difference in reasoning. Older adults had lower scores than young adults on the AOT (measure of reflective processes) and these lower scores predicted performance on the base rate task and the syllogistic task (marginally).

Overall, this the most optimistic view we can give of the factors that attenuate age-related difference in reasoning, because our sample is not representative of the general population, especially the general population of older adults. In fact, our sample of older adults is above average in many aspects. Both measures of education and verbal ability were above the typical scores for this cohort and even the mean age of the older adults was 80 years. Therefore,

it should not be anticipated that with a more average group of participants that we would see a great deal of correct or base rate responses. If anything, one would predict the opposite; that an average sample would make more belief-based and stereotypical responses, than our above average sample.

2.4.7. Link to Chapters 3 and 4

The fact that the cluster of variables entered into the regression equations only accounted for, at most, a third of the variance in age-related reasoning differences, suggests that there are additional factors related to age-related differences in performance on these problems. One possibility is metacognitive ability. Specifically, it is quite possible that the ability to engage Type 2 thinking and provide a correct or base rate response is related to how well reasoners are able to monitor their performance. This possibility will be examined further in Chapter 3. In Chapter 3, we will also investigate why performance was on the floor for the CRT. It is possible that the initial intuitive responses for the CRT questions are very compelling and thus, reasoners are responding to these questions with high confidence.

In addition, although we found results consistent with our predictions that the variations in algorithmic and reflective processes predict the age-related difference in reasoning ability, missing from this picture is whether this is a strategic choice to conserve cognitive resources or a "lack of choice" because the older adults do not have the capacity to engage in Type 2 processing. We intend to examine this in Chapter 4, where we will ask participants to reason from an alternative perspective.

Overall, we provided evidence for our conclusion that we should switch to a modern approach of explaining these age-related differences in reasoning. Specifically, that a dual-process theory of reasoning and aging is an integrative theory, that is successful in accounting for previous findings and the findings of the current research. However, our subsequent research seeks to answer some of the aforementioned questions and extend this model of reasoning and aging.

Chapter 3

Metacognition, Monitoring, and Age

Abstract

The goal of this paper was to extend the model of reasoning and aging proposed in our previous paper (Chapter 2) with a focus on metacognition and monitoring. We attempted to determine the extent to which the age-related differences in reasoning can be attributed to four measures of metacognition: conflict detection, confidence in individual answers and overall performance, and a self-report measure of this ability. In addition, we examined the hypothesis that conclusion believability and latency would be related to confidence, and that perceived task difficulty would be an additional measure of confidence that would be related to performance. Seventy-two older ($M = 80.0$ years) and 72 younger ($M = 24.6$ years) adults completed three reasoning tasks and were asked to provide confidence judgements for each problem and after two of the tasks. Response times were also recorded. Confidence and response time were used as measures of conflict detection. The data indicate that older and younger adults use similar cues to confidence, suggesting that metacognitive processes are similar for both age groups. Furthermore, results were not consistent with the hypothesis that metacognition plays a role in successful reasoning ability in both young and old adults. Indeed, there is a limited degree to which metacognition explains the age-related difference in reasoning and in terms of dual-process theory.

Metacognition, Monitoring, and Age

In Chapter 2, we demonstrated that individuals often struggle with resolving conflict between logic and intuition, in a variety of reasoning tasks. We provided evidence that individual differences in conflict resolution reflected individual differences in the algorithmic and reflective components of the analytic system. We also showed that these components predicted, at least some of, the age-related differences in reasoning ability. However, as discussed in Chapter 2, this cannot be the whole story because the factors only accounted for, at most, 33% of the variance in age-related differences in reasoning performance. A potentially important missing part of the picture is age-related differences in self-monitoring or metacognition. Metacognitive ability is referred to as the ability to correctly assess one's knowledge (Hertzog & Hultsch, 2000; Hertzog & Robinson, 2005; Koriat, Ma'ayan, & Nussinson, 2006; Pliske & Mutter, 1996). Thompson (2009) has argued that metacognitive processes are commonly used to assess the output of the heuristic system and to determine if there is a need for analytic engagement. In other words, metacognitive skills often determine whether a reasoner will attempt Type 2 processing.

To investigate whether age-related differences in reasoning can be explained by differences in metacognitive ability, we examined four different constructs: conflict detection, confidence in individual answers and overall performance, and a self-report measure of this ability. In addition to these measures, we examined the role of conclusion believability and latency as cues to confidence, and perceived task difficulty as an alternative measure of confidence.

3.1. Conflict Detection

Relative to younger adults, older adults struggle to override conflict between logic and intuition, when reasoning (Chapter 2; De Neys & Van Gelder, 2009). Consider the following example taken from our stimulus set[3]:

<div align="center">
No well-educated people are Pennes
Some judges are Pennes
Therefore, some well-educated people are not judges
YES/NO
</div>

This problem strongly cues the response "YES" because this conclusion is believable; however, the logically valid response is "NO", consequently producing a conflict. In the current

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[3] The stimulus set was identical to the set described in Chapter 1.

study, we sought to determine whether older adults' difficulty on these problems reflects age-related differences in awareness that the problem presents conflict. Alternatively, it is possible that older adults are aware of the conflict and attempt to engage in Type 2 processing, but nonetheless make more incorrect and stereotypical responses than younger adults (either erroneously or deliberately).

Research examining performance on conflict problems in young adults has identified a variety of reasons why beliefs or stereotypes can dominate over logical reasoning (see De Neys & Glumicic, 2008 for review). One view suggests a lax conflict monitoring system, in which reasoners are simply unaware that there may be an alternative response (Ehrlinger, Johnson, Banner, Dunning, & Kruger, 2007; Kahneman, 2003; Kahneman & Frederick, 2002). This is assumed to occur because the initial response is compelling and participants do not realize there may be an alternative response, and as a result, participants do not initiate a process to inhibit the intuitive response (see De Neys & Franssens, 2009 for discussion). For example, in a prior study, reasoners' did not mention the conflict in their think aloud protocols while solving conflict problems in a base rate task (De Neys & Glumicic, 2008).

Other research suggests, however, that conflict detection occurs, but there is a failure to execute the inhibition process (De Neys & Franssens, 2009). According to this view, there is a level of awareness of the conflict, but for one reason or another, reasoners do not change their initial response (e.g., De Neys & Franssens, 2009; Denes-Ray & Epstein, 1994; Sloman, 1996). Indeed, researchers have demonstrated this across multiple tasks (De Neys & Franssens, 2009), through multiple implicit measures including confidence responses (De Neys, Cromheeke, & Osman, 2011); response time (Bonner & Newell, 2010; De Neys & Glumicic, 2008; Stupple & Ball, 2008); memory access (De Neys & Franssens, 2009) and fMRI studies (De Neys, Vartanian, & Goel, 2008). In this chapter we will focus on confidence and response time as our implicit measures of conflict detection.

3.1.1. Confidence. Recent research has provided evidence that reasoners demonstrate lower confidence in conflict problems compared to no-conflict problems (De Neys et al., 2011). This difference in confidence has been taken as a measure of conflict detection based on the assumption that, if reasoners detect the conflict, but fail to verbalize it or fail to override their initial response, reasoners should express lower confidence in their response. Their results across two tasks (base rate and conjunction fallacy) support the viewpoint that reasoners may not

override their initial response, despite awareness of a conflict. We anticipated that if there was an indication of conflict awareness, confidence would be lower for judgements following conflict problems than for judgements following no-conflict problems.

To examine confidence, we asked individuals to provide subjective judgements regarding their performance after each response. Although this method of conflict detection has only been used previously in young adults, the same rationale applies to older adults. Specifically, if older adults detect conflict, their confidence should be tempered accordingly on conflict problems relative to no-conflict problems, regardless of whether they are able to resolve the conflict. In contrast, if older adults are unaware of the conflict then confidence should remain the same across conflict and no-conflict problems. In addition, participants completed a base rate as well as syllogistic reasoning task, we anticipate that if conflict detection is consistent across reasoners, then the patterns should be the same for both tasks. It is not possible to examine conflict detection for the CRT task because it consists solely of conflict problems; however, for the sake of completeness and to examine how compelling each of the CRT problems are, we will examine the age-differences in confidence for each of the CRT problems. There are two possible outcomes predicted: 1) if older adults are unaware of conflict, their confidence will be high; 2) if older adults have awareness of conflict, their confidence may be tempered accordingly.

3.1.2. Response Time. An additional measure of conflict detection in the current research is latency or response time. Prior research has shown that young adults take longer to provide a response to conflict problems than to no-conflict problems (Bonner & Newell, 2010; De Neys & Glumicic, 2008; Pennycook & Thompson, 2012; Stupple & Ball, 2008; Thompson, Prowse Turner, & Pennycook, 2011). This increase in response time has been attributed to conflict detection (e.g., De Neys & Glumicic, 2008); because faster response times are thought to indicate the faster, Type 1 processing while slower responding is thought to be representative of analytic, Type 2 engagement associated with processing that occurs after detection of conflict. Consistent with this assumption, it was predicted that for both tasks reasoners would take longer for conflict problems than for no-conflict problems.

3.2. Metacognition

An additional goal of this research was to examine the metacognitive ability of individuals using measures of calibration, the ability of individuals to match their confidence judgements to their performance. For the syllogistic reasoning task, there is an objective measure

of performance, namely whether individuals choose the logically valid conclusion; however, for the base rate task we used the base rate response as our measure of performance because there is no measure of normative accuracy for the base rate task (see Chapter 2 for discussion). Two measures of confidence were taken; 1) participants rated their confidence in each item and 2) provided a post-hoc estimate of the overall number of correct responses.

Good calibration is an important aspect of the reasoning process. If reasoners' confidence judgements are high and are not calibrated to their performance, it could be argued that they may not engage in Type 2 thinking, because they believe their response is accurate (Pliske & Mutter, 1996). If older adults are confident in their responses, they may not think it necessary to engage in Type 2 thinking to consider alternatives to the compelling intuitive response. If older adults demonstrate confidence that does not match their ability, this may explain part of the age-related difference in reasoning performance.

Prior research on calibration in reasoning tasks has indicated that young adults may have poor metacognitive ability; they typically express overconfidence in their ability (Prowse Turner & Thompson, 2009; Shynkaruk & Thompson, 2006). Research on calibration in older adults has yet to be conducted in a reasoning task; however, in other domains the available research is mixed and appears to be task dependent. For example, Pliske and Mutter (1996) showed that for general knowledge tasks, older adults are better calibrated than their younger. However, Crawford and Stankov (1996) observed that in tasks examining both fluid and crystallized intelligence, both younger and older adults demonstrated overconfidence, but older adults' to a greater extent. Considering that reasoning tasks are comparable to a fluid intelligence test, it is possible that older adults will demonstrate overconfidence, thus, exhibiting a poor metacognitive ability.

On the other hand, it has been documented that older adults believe their cognitive abilities decline with age (Cavanaugh & Poon, 1989; Hertzog & Dixon, 1994; Hertzog, Saylor, Fleece, & Dixon, 1994; Hultsch, Hertzog, & Dixon, 1987, Lineweaver & Hertzog, 1998; Perlmutter, 1978; Wells & Esopenko, 2008). Therefore, one could argue that if older adults believe this is true, it could impact their subjective assessments by reducing confidence in their performance, resulting in good calibration.

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3.3. Metamemory in Adulthood

Our final measure of metacognitive ability was a self-report measure of ability. We drew from the metamemory literature, because there is no subjective measure of metacognition in reasoning. To examine whether reasoner's beliefs about their cognitive abilities differed with age and predicted variance in the age-related reasoning differences, we utilized the Metamemory in Adulthood questionnaire as a measure of these beliefs (Dixon & Hultsch, 1983). This instrument has multiple subscales and was designed to represent the construct of metamemory in a multidimensional way. We had two predictions relating to the Metamemory in Adulthood questionnaire. First, older adult participants would report that their cognitive abilities decline with age, a finding that has been well-documented (Cavanaugh & Poon, 1989; Hertzog & Dixon, 1994; Hertzog et al., 1994; Hultsch et al., 1987, Lineweaver & Hertzog, 1998; Perlmutter, 1978; Wells & Esopenko, 2008). It was anticipated that, consistent with prior research, older adults would have a lower MIA score and lower scores on the task, capacity, change, and locus subscales than young adults (Dixon & Hultsch, 1983), suggesting that they do in fact believe their abilities decline with age. More importantly, this measure was expected to contribute to a portion of the age-related variance in reasoning that was not accounted for by previous factors (i.e., education, verbal ability, working memory, processing speed, inhibition, and thinking dispositions; Chapter 2).

3.4. Cues to Confidence

In addition to the variables discussed in Chapter 2, we were also interested in whether older and younger adults would be equally sensitive to two additional factors that are related to confidence (i.e., the believability of the conclusion, latency, and perceived task difficulty).

3.4.1. Conclusion believability. It was demonstrated in the previous chapter that both younger and older adults struggle with neutral problems. One possible explanation for this finding is that there is no strongly cued response based on belief (i.e., believability of the syllogisms or stereotypical information in the base rate problems), in neutral problems. Prior research has demonstrated that reasoners are more confident when decisions can be based on belief, then when such cues are not available (Shynkaruk & Thompson, 2006). If reasoners are relying on belief information to make their judgement, this should be reflected in lower confidence judgements for the neutral problems, than confidence expressed for the conflict and no-conflict problems. Also, if a decrease in confidence in the neutral problems is present, we

have additional evidence that the decrease in confidence is related to a degree of uncertainty present in the reasoners and that reasoners are using belief as a cue to confidence.

3.4.2. Latency. Previous research has demonstrated that latency (RT) is also a cue to confidence, in both children (Ackerman & Zalmanov, 2012) and young adults (Thompson et al., 2011). This is demonstrated by a negative correlation between response time and confidence, such that the longer reasoners spend on the problem, the less confident they are. Our goal was to extend this investigation to older adults to determine if these findings are age-invariant.

3.5. Additional Measure of Confidence

Difficulty. Finally, we also assessed reasoners perceived difficulty of the task as a measure of global confidence. There is research to support the idea that task difficulty has an impact on performance (Shynkaruk & Thompson, 2006), however a direct measure of this has yet to be taken. Thus, we asked participants directly to describe the difficulty of each task. If individuals' perceived difficulty of the task is related to performance, we expect that as perceived difficulty increases performance will decrease. It is also predicted that the higher the perceived difficulty of the task, the longer it will take participants to respond. This hypothesis is based on the assumption that task difficulty and the likelihood of analytic engagement (which is assumed to take additional time) should be positively correlated.

3.6. Method

3.6.1. Participants

The same seventy-two younger adults (46 female) (M = 24.6 years; SD = 7.54) and seventy-two older adults (55 female) (M = 80.0 years, SD = 7.28) described in Chapter 2 were analyzed in this chapter[4].

3.6.2. Materials and Procedure

The materials, stimuli, and procedure used to assess performance were described in Chapter 2.

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[4] These participants scored in the above average range on a measure of verbal ability and therefore might not be highly representative of the average young or older adult.

3.6.3. Confidence Judgements. For all three reasoning tasks, following each response, participants were asked to rate their confidence in the correctness of their judgement on the following scale: How confident are you that your answer is correct?

0%   10%   20%   30%   40%   50%   60%   70%   80%   90%   100%

Not at all   Moderately   Extremely

After solving all of the problems for the syllogistic and base rate tasks, reasoners were asked the following additional questions.

1) You have just completed 12 problems. Of these 12 answers, how many do you believe you answered correctly?

2) Judging your overall performance on this task, how do you think you would score relative to the others who have completed this task? You will score better than

   0-10%   10-20   20-30   30-40   40-50   50-60   60-70   70-80   80-90   90-100%

   of the others who have completed the task.[5]

3) On a scale of 1 to 10, with 1 corresponding to extremely easy and 10 corresponding to extremely difficult, please evaluate the difficulty of the reasoning task that you just completed.

3.7. Results

The data are reported in several sections. The first section reports the ANOVAs for the confidence and RT data to test the hypotheses regarding the role of prior beliefs in confidence and conflict detection. The second section contains the calibration analyses for the syllogistic and base rate tasks to examine the role of metacognition in age differences in reasoning performance. Third, we report the results for the MIA. Finally, the analyses regarding latency and perceived difficulty as cues to confidence are reported.

3.7.1. Confidence in the Syllogistic Task

A 2 (age group) x 3 (problem type) mixed factors ANOVA was computed for the confidence scores, to test two hypotheses: 1) reasoners would use the believability of the conclusion as a cue to confidence and 2) that lower confidence would be reported for conflict problems than for no-conflict problems, if reasoners detected conflict. The mean levels of confidence for older and younger adults as a function of problem type on the syllogistic task are plotted in Figure 3.1. Overall, older ($M = 71.99$) and younger adults ($M = 73.56$) were equally

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[5] This question was eliminated from the analysis.

confident in their performance on the syllogistic task, $F(1, 142) = .31$, $MSE = 858.45$, $p = .577$ $\eta_p^2 = .002$; however, there was an interaction between age and problem type, $F(2, 284) = 5.13$, $MSE = 80.03$, $p = .006$, $\eta_p^2 = .035$. Young adults were equally confident on all problems, $t \geq$ -.143, $SE \geq 1.21$, $p \geq .098$; however, older adults were equally confident on conflict ($M = 73.61$) and no-conflict problems ($M = 75.00$) [$t(71) = 1.13$, $SE = 1.23$, $p = .262$], and more confident on both of these problems than on neutral ($M = 67.34$) [$t(71) \geq -3.49$, $SE \geq 1.71$, $p \leq .001$]. That is, when the believability of the conclusions was available as a cue (i.e., for conflict and no-conflict problems), reasoners were more confident in their responses than when believability was not present.

Figure 3.1. Confidence Values for the Syllogistic Task as a Function of Problem Type and Age.
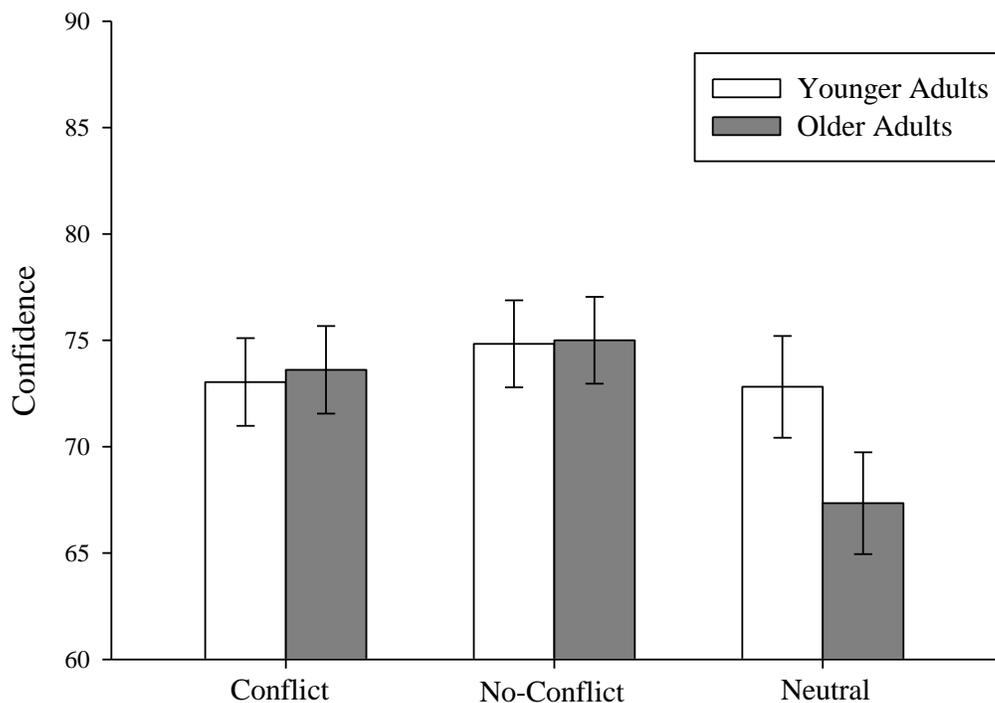
Note. Error bars represent the standard error.

It has been argued (e.g., De Neys et al., 2011) that conflict detection should, in theory, lower confidence. The fact that both age groups had similar levels of confidence between conflict and no-conflict problems suggests reasoners may not detect conflict in a syllogistic task. Surprisingly, when the analysis is broken down by correct versus incorrect responses, reasoners were more confident when providing a correct response ($M = 74.55$) than when providing an incorrect response ($M = 69.49$), $t(141) = 5.69$, $p < .001$. Thus, when reasoners say "yes" to valid and "no" to invalid problems they are more confident than when they provide an incorrect response, regardless of whether the problem is conflict, no-conflict, or neutral. This pattern holds for both young and older adults, $p < .001$.

In sum, older, but surprisingly not younger, adults were more confident when they could use beliefs to make a decision, than when belief cues were absent. Neither group's judgements were sensitive to conflict, suggesting that on this task, people may not be aware that two alternative answers are possible. One possibility for this finding is that the logic of the task is more complex (e.g., task consists of multiple-model problems and non-words, including argonelles), than tasks where sensitivity to conflict has previously been observed. It is also possible that reasoners do not possess the mindware, the knowledge of logical rules (Stanovich, 2009), necessary to realize their beliefs are in conflict with the logical rules of the task.

3.7.2. Confidence in the Base Rate Task.

To test the hypotheses that a) reasoners would use the stereotypical information as a cue to confidence and b) that lower confidence would be reported for conflict problems than for no-conflict problems, we computed another 2 (age) x 3 (problem type) ANOVA. The mean levels of confidence for older and younger adults as a function of problem type for the base rate task are plotted in Figure 3.2. Overall, older adults ($M = 74.20$) were marginally less confident than younger adults ($M = 78.60$) on the base rate task, $F(1, 142) = 3.27$, $MSE = 638.70$, $p = .073$, $\eta_p^2 = .022$. Consistent with the idea that conflict detection lowers confidence, there was a main effect of problem type, [$F(1.69, 239.99) = 75.25$, $MSE = 122.72$, $p < .001$, $\eta_p^2 = .346$], such that participants were the most confident on problems with no conflict ($M = 83.40$), followed by problems with conflict ($M = 77.07$), and were least confident on neutral problems ($M = 68.73$), $t \geq 6.07$, $SE \geq 0.92$, $p < .001$. These findings are consistent with the syllogistic task and prior research (Shynkaruk & Thompson, 2006) and suggest that the ability to make judgements on the basis of belief (e.g., stereotypical information) is a strong cue to confidence. There was no

interaction between age and problem type, $F(2, 284) = .786$, $MSE = 103.71$, $p = .457$, $\eta_p^2 = .006$, meaning that older adults were not particularly more reliant on beliefs, than younger adults.

Figure 3.2. Confidence Values for the Base Rate Task as a Function of Problem Type and Age.
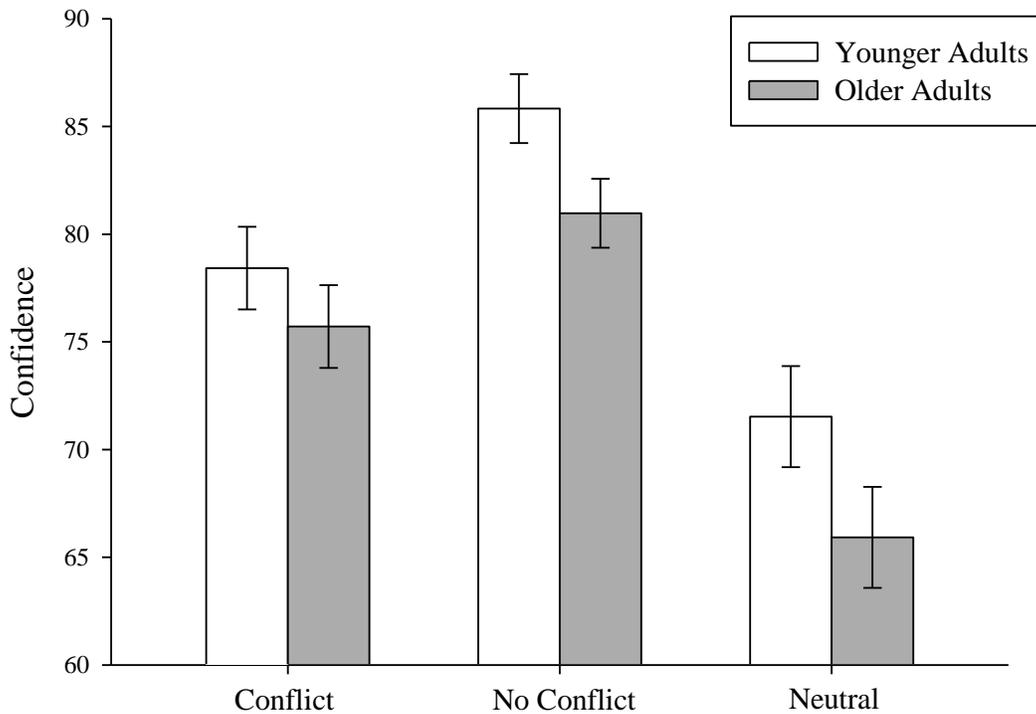
Note. Error bars represent the standard error.

In contrast to the syllogistic task, both young and older adults expressed lower confidence on the conflict problems compared to the no-conflict problems. Under the assumption that lower confidence is related to conflict detection (De Neys et al., 2011), it could be argued that both age groups detected conflict in the base rate task. Furthermore, if reasoners were aware of the probabilistic weight of the base rate information, they should express higher confidence when they chose the base rate response compared to the stereotypical response. Indeed, this analysis supports this assumption, both young and older adults' confidence was higher when reasoners provided the base rate response ($M = 76.89$) than when a stereotypical response was chosen ($M =$

71.85), t (127) = 4.40, SE = 1.15, $p < .001$. Thus, when reasoners provide a stereotypical response, there is evidence to suggest that they are aware this response may not be warranted.

3.7.3. Cognitive Reflection Test (CRT)

The confidence data for the CRT were analysed as a 3 (problem) x 2 (age-group) mixed ANOVA, with age as the between-subjects variable. Data are presented in Figure 3.3. Older adults were less confident (M = 74.14) than young adults (M = 87.99), F (1, 140) = 18.83, MSE = 1083.77, $p < .001$, η_p^2 = .119. Confidence also varied as a function of problem with confidence being higher for the bat and ball problem (M = 91.42), than for the widget (M = 77.41) and lily pad (M = 74.36) problems, F (1.89, 263.98) = 27.04, MSE = 460.97, $p < .001$, η_p^2 = .162. This pattern was the same for both age groups, F (2, 280) = 1.95, MSE = 434.58, p = .144, η_p^2 = .014. One interpretation of this finding is that the initial response for the bat and ball problem is more compelling than the initial responses for the other two problems. This assumption is supported by the accuracy results (see Chapter 2), because both young and older adults' accuracy on the bat and ball problem was lower than the other problems[6]. Taken together, these results suggest that reasoners are not considering that there might be an alternative answer.

Overall, these results suggest that reasoners are sensitive to conflict on the base rate task, but not the syllogistic task. These results also suggest that the believability of the conclusion (based on belief or stereotypical information) provides reasoners with a cue to confidence.

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[6] For young adults, there was no significant difference between performance on the bat and ball and widget problems.

Figure 3.3. Confidence Scores on the CRT as a Function of Problem and Age.
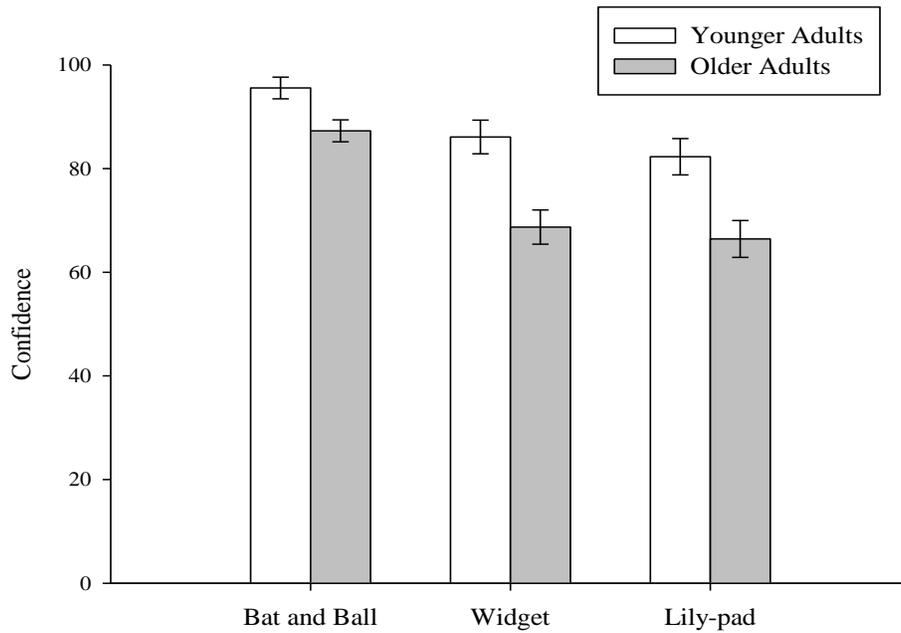
Note. Error bars represent the standard error.

3.7.4. Response Time

Another measure of conflict detection is response time (RT). If reasoners detect and try to resolve conflict, then RT should be longer for conflict than for no-conflict problems. All RT measures were converted to $\log^{10}$ prior to analysis. There were no RT data for the paper and pencil CRT task[7].

3.7.4.1. ***Syllogistic Task RT.*** The mean RTs for older and younger adults as a function of problem type are plotted in Figure 3.4. Not surprisingly, older adults were slower at responding ($M = 32.96$ sec) than the young adults ($M = 24.25$ sec), $F (1, 142) = 7.25$, $MSE = .150$, $p = .008$. RT did not vary as a function of problem type, $p = .810$, nor did it interact with age, $p = .102$[8].

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[7] It should be noted that although RT for older adults was recorded when the experimenter pressed the response key, the experimenter was blind to the questions on the screen. Thus, any age-related RT differences should be attributed age and not experimenter bias. Any additional RT from the experimenter would be small and constant across all problems.

[8] When the data are analysed using the validity by belief factorial structure, the data replicate past findings that RT is the longest for invalid-believable problems (Thompson, Streimer, Reikoff, Gunter, & Campbell, 2003).

These results are consistent with the confidence data and provide further evidence that reasoners may not detect conflict in a syllogistic task.

Figure 3.4. Response Time (RT) Means for the Syllogistic Task as a Function of Age and Problem Type.
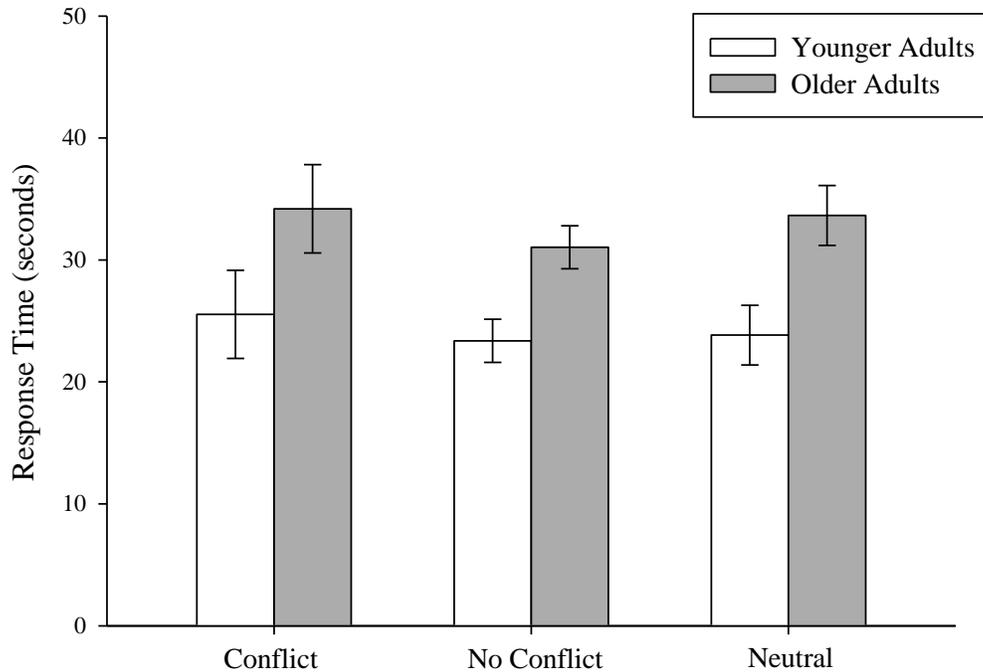
Note. Error bars represent the standard error.

3.7.4.2. Base rate RT. The mean RTs for older and younger adults as a function of problem type are plotted in Figure 3.5. Older adults were slower to respond on the base rate task ($M = 33.7$ sec) than younger adults ($M = 22.0$ sec), $F(1, 142) = 53.98$, $MSE = .060$, $p < .001$. Response time also varied as a function of problem type, where neutral problems took longer to solve ($M = 31.9$ sec) compared to conflict ($M = 26.0$ sec) and no conflict problems ($M = 25.9$ sec), which took equal time to solve, $F(1.77, 251.75) = 42.81$, $MSE = .007$, $p < .001$. These two effects were qualified by an interaction between problem type and age, $F(2, 284) = 9.21$, $MSE = .007$, $p < .001$. Although the pattern was similar for both age groups (i.e., conflict and no conflict took equal amounts of time to solve, $p \geq .127$, and neutral took the longest time to solve, $p <$

.001), the response time difference between the conflict and no conflict problems compared to neutral problems for young adults was approximately 2.5 seconds, whereas for older adults it was 10 seconds.

Figure 3.5. Response Time (RT) Means for the Base Rate Task as a Function of Age and Problem Type.
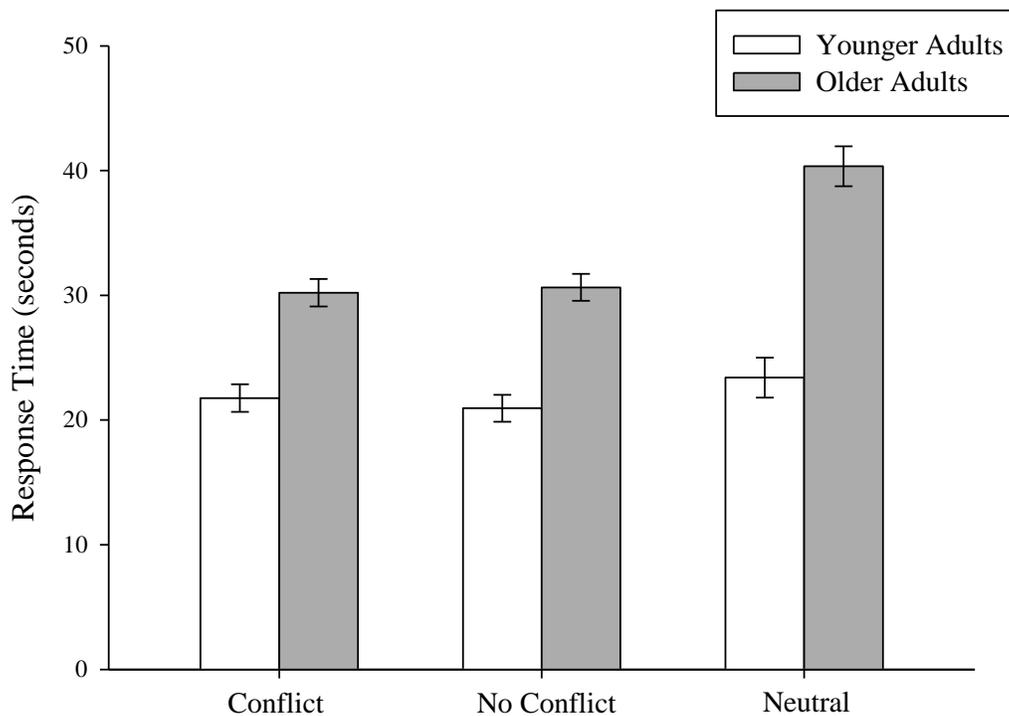
Note. Error bars represent the standard error.

If longer RTs reflect additional processing, it can be concluded that neutral problems took longer for young and older adults to solve than the other problems because they required additional analytic processing in order to come to a response. The fact that there was no difference between conflict and no conflict problems suggests that reasoners are sensitive to the conflict in terms of confidence, but are not attempting to resolve it, which would take time. In fact, these results are at odds with previous base rate data that showed conflict problems take

longer to solve than no-conflict problems (e.g., De Neys & Glumicic, 2008; Pennycook & Thompson, 2012; Thompson et al., 2011.

Careful examination of the items used revealed an anomalous item, which may have distorted the findings. The following problem may have been treated as a neutral problem rather than as a no-conflict problem:

In a study 1000 people were tested. Among the participants there were 996 kindergarten teachers and 4 executive managers. Lilly is a randomly chosen participant of this study. Lilly is 37 years old. She is married and has 3 kids. Her husband is a veterinarian. She is committed to her family and always watches the daily cartoon shows with her kids. What is most likely?

(A) Lilly is a kindergarten teacher

(B) Lilly is an executive manager

Examination of the confidence and response time data for the problem revealed that participants responded differently to this problem than the other no-conflict problems. Participants took a very long time to solve this problem (significantly longer than all other no-conflict problems), $t\,(143) \geq 5.28$, $SE \geq .14$, $p < .001$, and were less confident on this problem than all other no-conflict problems, $t\,(143) \geq 3.32$, $SE \geq 1.28$, $p \leq .001$. When this problem was removed, the RT results are consistent with previous research on young adults: neutral > conflict > no-conflict, $t\,(71) \geq 2.23$, $SE \geq .11$, $p \leq .029$. The older adults' RT data revealed the same pattern, conflict = no-conflict < neutral, regardless of inclusion or exclusion of the Lilly problem. Further evidence to support the argument that this no-conflict problem may not be fitting the criterion comes from unreported results from Pennycook & Thompson (2012). They found that when asked to rate the probability that Lilly is a kindergarten teacher, based just on the description, that the ratings were closer to 50 than to 100 (where 100 would demonstrate a strong stereotypical belief that Lilly was a kindergarten teacher) $(M = 61.78)$[9], whereas the other no-conflict problems elicited ratings closer to 100. It is possible that the stereotype in this problem is not as compelling for young adults, than the stereotypes in the other no-conflict problems. Indeed, confidence for this problem was lower than for all of the other no-conflict

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[9] This value was based on the mean responses from a two response paradigm (see Pennycook & Thompson, 2012 for explanation), where the mean 1st response was 57.97 and the mean 2nd response was 65.60.

problems, t (143) ≥ 3.32, SE ≥ 1.28, p ≤ .001. Furthermore, when this problem is removed from the confidence analysis, there results remain the same.

3.7.5. Calibration

To compare metacognitive skills for old and young adults, we computed correlations between confidence and accuracy for each age group, for each task. In addition, we computed calibration scores and analysed them between age groups, with multiple t-tests. Calibration measures the extent to which confidence reflects accuracy[10]. We compared old and young adults on two measures of calibration, which are described in detail below. In order to compute calibration a measure of performance was necessary. For the syllogistic reasoning task, performance was defined in terms of accuracy (i.e., the proportion of trial that participants responded "yes" to valid problems and saying "no" to invalid problems). For the base rate task, we used the proportion of base rate responses chosen as a way of measuring performance. Calibration scores were not computed for the CRT because of the low number of problems within this task (3) and because, reasoners were not asked to provide an estimated number correct following this task.

3.7.5.1. Correlations. To determine whether there was a relationship between confidence and performance, we computed correlations between mean confidence scores and mean performance scores. Consistent with prior research (Prowse Turner & Thompson, 2009; Shynkaruk & Thompson, 2006), the correlation between confidence and accuracy on the syllogistic task for young adults, was low and not-significant, r = .196, p = .098, and this pattern held for the older adults, r = .176, p = .140. When we computed correlations between confidence and the tendency to provide the base rate response, the results were significant for young adults, r = .471, p < .001, but not for older adults, r = .169, p = .157. These correlations suggest that young adults' confidence was related to performance on the base rate task, but not on the syllogistic task.

3.7.5.2. Item by Item Calibration. To obtain the first calibration score, item by item calibration, we computed a correlation for each participant, between item by item confidence judgements and accuracy. To test whether reasoners were better calibrated for the compelling

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[10] Accuracy for the base-rate task is a bit of a misnomer because it is not possible to derive a measure of normative accuracy for these data (see explanation in Chapter 1; also Pennycook, Fugelsang, Koehler, 2012; Thompson et al., 2011); however for the purpose of these analyses the number of base-rate responses will be termed accuracy.

problems (i.e., conflict and no-conflict), than on all problems, this score was computed for all problems and then again excluding neutral problems. We anticipated that reasoners with better calibration would have a better metacognitive ability.

3.7.5.2.1. Syllogistic Reasoning Task. The correlation between accuracy and confidence for all problems did not differ between younger ($M = .16$) and older adults ($M = .13$), $p = .646$. This pattern was similar when the neutral problems were excluded, however, there was a trend towards an age difference between younger ($M = .20$) and older ($M = .09$) adults, $p = .094$. Even though these correlations are all significantly greater than 0, $t \geq 2.21$, $p \leq .030$, they are quite small and roughly similar for young and old adults, and indicate that reasoners' ability to estimate confidence on an item by item basis is not precise.

3.7.5.2.2. Base Rate Task. The pattern of results for the base rate task was identical to the syllogistic task. There was no difference between younger ($M = .20$) and older adults ($M = .13$) on item by item correlations for all problems, $p = .234$; nor was there a difference between young ($M = .22$) and older adults ($M = .13$) when neutral problems were excluded, $p = .202$. Again, these correlations were all greater than 0, $t \geq 3.00$, $p \leq .004$, but too small to conclude that reasoners are effective at calibrating on an item by item basis.

In sum, it does not appear that reasoners have the metacognitive ability to calibrate themselves on an item by item basis, regardless of age and task.

3.7.5.3. Global Calibration. The second score that we computed was called global calibration. Global calibration is the difference between the estimated number correct (out of 12) – total number correct. The data are presented in Table 3.1.

Table 3.1

Global Calibration Means for the Syllogistic and Base rate Tasks.

	Young Adults	Old Adults	
Syllogistic Reasoning Task			
Overall	-1.03	-.38	$t(117.11)=-1.31, p = .193$
Overestimators	1.55	2.90	$t(46.78)=-3.11, p = .001$
Underestimators	-2.63	-3.35	$t(45.99)=1.54, p = .130$
Base Rate Task			
	Young Adults	Old Adults	
Overall	.54	1.07	$t(142)=-1.14, p = .257$
Overestimators	2.42	3.18	$t(76)=-1.99, p = .050$
Underestimators	-2.79	-2.50	$t(37)=-.579, p = .566$

3.7.5.3.1. Syllogistic Reasoning Task: At first glance, it appears that both younger and older adults are fairly accurate at assessing their global performance because there was no difference between their global calibration scores; however, the difference between the estimate and total correct was significantly different than 0 for the young adults, $p < .001$, and there was no difference for the older adults, $p = .381$. This result suggests that only the older adults were accurate in assessing their global performance. However, when the data were split into overestimators and underestimators, older adults ($n = 22$) who overestimated their ability, do so to a greater extent than the younger adults ($n = 30$); however, there is no difference between young ($n = 41$) and old ($n = 34$) adults who underestimated their ability.

3.7.5.3.2. Base Rate Task. Consistent with the syllogistic task, examination of global calibration revealed no overall difference between young and old adults. Contrary to the syllogistic task though, the global calibration scores differed from 0 for both groups (young $p = .080$; old $p = .003$). Also, for this task, both young and older adults overestimate their performance on average, whereas both groups underestimate their performance on the syllogistic task. Again, older adults who overestimated their ability ($n = 40$), did so to a greater extent than the younger adults ($n = 38$) and there was no difference between young ($n = 19$) and old ($n = 20$) adults who underestimated their ability. Fifteen younger and twelve older adults were able to assess their global performance with 100% accuracy.

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Consistent with the correlation and item by item data, reasoners do not show evidence for metacognitive ability in terms of calibration. Reasoners, systematically over- or underestimate performance, with little evidence for differences between age groups.

3.7.6. Metamemory in Adulthood (MIA)

The questions on the MIA were reverse coded and the values were summed to create the total MIA score. There are 108 questions and a total possible value of 5 on each question. Scores ranged from 274 to 444, with the highest possible score of 540. One older adult failed to complete all of the questions and was excluded from the analysis. Young adults had a significantly higher average MIA total score ($M = 379.13$; $SD = 25.71$) compared to the older adults ($M = 356.10$; $SD = 25.15$), $t(141) = 5.41$, $p < .001$. This finding is consistent with previous findings on the MIA (Dixon & Hultsch, 1983) and suggests that young adults report having a better metamemory than older adults. As described below (see Table 3.2), the MIA data were broken down into the 8 respective subscales for subsequent age group comparisons using independent t-tests.

Table 3.2

Means for Each Subscale of the MIA.

	Young Adults	Older Adults	*p*-value
Internal (9 questions)	31.93 (4.47)	30.58 (4.20)	$p = .064$
External (9 questions)	31.29 (7.05)	35.18 (4.40)	$p < .001$
Task (16 questions)	65.75 (5.94)	62.59 (4.66)	$p = .001$
Capacity (17 questions)	59.15 (9.07)	49.94 (9.06)	$p < .001$
Change (18 questions)	58.31 (10.79)	46.49 (9.86)	$p < .001$
Locus (9 questions)	32.03 (5.63)	29.14 (4.77)	$p = .001$
Anxiety (14 questions)	41.32 (10.01)	43.08 (8.69)	$p = .262$
Achievement (16 questions)	59.35 (6.90)	59.08 (5.80)	$p = .806$

Note. Standard Deviations in parentheses

Consistent with prior research, young adults scored higher on the task, capacity, change and locus subscales of the MIA than older adults (Dixon & Hultsch, 1983). These results provide

further evidence that young adults report greater knowledge about their basic memory processes and memory capacity, a stronger belief in memory stability across time, and greater control over remembering abilities compared to older adults. Indeed, it is well documented that older adults believe they have a poor memory capacity and tend to avoid cognitive activities on the basis of this belief (Cavanaugh & Poon, 1989; Hertzog & Dixon, 1994; Hertzog et al., 1994; Hultsch et al., 1987, Lineweaver & Hertzog, 1998; Perlmutter, 1978; Wells & Esopenko, 2008. It is also not surprising that older adults report lower scores on the change subscale because they have likely witnessed declines in their memory to some extent, whereas young adults may not have had this experience.

Older adults scored higher on the external subscale than young adults, which demonstrates that older adults make use of a greater number of memory strategies (e.g., writing appointments on a calendar). This finding is inconsistent with Dixon and Hultsch (1983); however, the older adults in this study were higher than average on verbal ability and education and perhaps these two factors contribute to an understanding of the effectiveness of strategies.

Also consistent with previous research, older and younger adults did not differ on the internal subscale, anxiety or achievement (Dixon & Hultsch, 1983). Young relative to older adults reported they had the same knowledge regarding how emotion can influence cognitive performance and the importance of having a good memory and performing well on cognitive tasks.

3.7.6.1. Correlation Analyses. Correlations were computed to examine if there were relationships among total MIA score, confidence on the syllogistic and base rate tasks, performance on the syllogistic or base rate tasks, AOT scores, RT, or the CRT, for either younger or older adults. For both the syllogistic and base rate tasks, there were no correlations between the MIA and confidence, performance or RT, for either age group. Scores on the MIA were unrelated to confidence and performance on the CRT and were unrelated to scores on the AOT.

3.7.6.2. Regression Analyses. To determine whether the total MIA score contributed to any of the remaining age-related variance in performance on the three tasks (see Chapter 2 for discussion), the total MIA score was entered in to the regression analysis following the AOT and age was entered last. These data are presented in Table 3.3.

Table 3.3
Hierarchical Regressions for the Syllogistic Task, Base Rate Task, and the CRT.

Conflict SR problems	Conflict BR problems	Neutral BR problems	CRT
R^2 *change for age after Chapter 2 variables entered*			
.070	.006	.019	.002
R^2 *change for age after all variables and MIA entered*			
.063	.002	.018	.002
R^2 *for age alone*			
.266**	.130**	.115**	.191**

Note. Only the problem types that had a significant regression equation in Chapter 2 were examined further.
* $p < .05$; ** $p \leq .001$; [a] $p < .10$

The addition of the MIA did not account for additional residual variance in conflict syllogistic problems, conflict or neutral base rate problems, or the CRT. These results suggest that older, relative to young adults, expressed lower beliefs in their metamemory (i.e., lower total MIA scores), but these beliefs did not contribute unique variance to the age-related differences in reasoning performance.

3.7.7. Latency as a Cue to Confidence. To test the hypothesis that latency would be a cue to confidence for both young and older adults, we computed correlations between confidence and response time for both the syllogistic and base rate tasks. Consistent with prior research (Ackerman & Zalmanov, 2012; Thompson et al., 2012), the correlations between confidence and response time, for both age groups, on both the syllogistic task (young: $r = -.34$; older: $r = -.30$) and for the base rate task (young: $r = -.40$; older: $r = -.37$), were significantly different from 0, $t \leq$ -6.77, $p < .001$. The negative correlation implies that the longer reasoners took to solve the problem, the less confident they were and this pattern held when the neutral problems were excluded, $t \leq -5.56$, $p < .001$.

3.7.8. Perceived Task Difficulty on the Syllogistic Task. Older ($M = 7.50$) and younger adults ($M = 7.03$) judged this task to be equally difficult, $t (129.36) = 1.49$, $p = .138$. Consistent with our assumption that perceived difficulty was another measure of confidence, perceived difficulty was correlated with overall confidence and confidence on each of the problem types, $r \geq -.278$, p

$\leq .001$. The results also supported the predictions that performance would decrease as perceived difficulty increased ($r = -.159$, $p = .057$) and that individuals will take longer to respond if the perceived difficulty is judged to be high ($r = .385$, $p < .001$).

3.7.9. Perceived Task Difficulty on the Base Rate Task. Unlike the syllogistic task, older adults judged the base rate task ($M = 5.89$) to be more difficult than young adults ($M = 4.47$), t (142) = 3.90, $p < .001$. In addition, both groups judged this task to be easier than the syllogistic task, $p < .001$. As with the syllogistic task, confidence decreased as perceived difficulty increased. The smallest correlation occurred with the no-conflict problems, $r = -.182$, $p = .029$ and the largest with the neutral problems, $r = -.273$, $p = .001$. Also consistent with the syllogistic task, performance decreased, as perceived difficulty increased ($r = -.277$, $p = .001$) and the greater the perceived difficulty, the longer it took participants to respond ($r = .326$, $p < .001$). These data suggest that although reasoners spend more time on the syllogistic or base rate task, if they perceive it to be difficult, this does not translate into better performance.

3.7.10. Additional Factors. Regression analyses were conducted for confidence on the syllogistic task, base rate task, and the CRT, to determine whether the predictors of performance (see Chapter 2) were similar to the predictors of confidence. In this case, we entered all variables in one multiple regression because there is no prior research to suggest a hierarchical regression for the confidence data. The regression equation was not significant for either the syllogistic task, $R^2 = .069$, F (7, 137) = 1.37, $MSE = 271.52$, $p = .225$, or for the base rate task, $R^2 = .028$, F (7, 137) = 1.56, $MSE = 213.83$, $p = .153$, providing further evidence that performance and confidence are predicted by different variables (Prowse Turner & Thompson, 2009; Shynkaruk & Thompson, 2006).

The CRT revealed a different pattern; the factors predicted 23% of the variance in CRT confidence, $R^2 = .230$, F (7, 137) = 5.55, $MSE = 344.71$, $p < .001$. Inhibition ($b = -.295$, t (137) = -3.39, $p = .001$), processing speed ($b = .289$, t (137) = 2.12, $p = .036$), and verbal ability ($b = -.207$, t (137) = -2.50, $p = .014$) accounted for significant unique variance in confidence on the CRT. In addition, education was a marginally significant predictor, $b = .176$, t (137) = 1.81, $p = .072$. This implies that the some of the factors that cue confidence in the CRT are different than those for the syllogistic and base rate tasks. One possibility is that the factors that cue confidence

on the CRT are related to the ability to perform the task, whereas the cues for confidence in the other tasks may be task-related (e.g., latency).

To rule out the possibility that individuals with higher levels of intellectual ability are naturally more likely to engage in intellectually challenging activities and to be more confident about their skills than individuals with lower levels of intellectual ability, verbal ability scores were correlated with the scores on the MIA, AOT, and confidence on the syllogistic task, base rate task, and the CRT. None of the correlations were significant, $r \leq -.154$, $p \geq .066$, which suggests that this is not the case.

3.8. Discussion

In Chapter 2, we demonstrated that both the algorithmic and reflective components of the analytic system explained age-related variance in reasoning performance; however, these factors only accounted for, at most, 33% of the variance. Our goal in the current paper was to determine if these age-related differences could also be attributed to metacognitive differences. Specifically, we tested four different junctures where this might be the case; conflict detection, confidence in individual answers and overall performance, and self-report measure of metacognitive ability. In the case of conflict detection, older and young adults performed similarly, except in a few instances. In terms of our calibration measures, there were minor differences between older and younger adults and thus, little evidence to suggest that this measure of metacognitive ability could explain the differences between young and older adults' performance. Finally, older adults expressed less belief in their metamemory than young adults, but this difference did not explain any of the age-related differences in reasoning. In sum, it appears that differences in metacognitive abilities do not explain age-related differences in reasoning. It was also revealed that conclusion believability and latency were cues to confidence and that perceived task difficulty, an additional measure of confidence, was related to performance and RT on both the syllogistic and base rate tasks.

3.8.1. Conflict Detection. The confidence and response time data do not indicate that either group was sensitive to the conflict in the syllogistic task, because there were no differences between conflict and no-conflict problems for either variable. However, reasoners appeared to be sensitive to the accuracy of their response; confidence was higher for both conflict and no-conflict problems when reasoners provided the correct response than when they provided the

initial intuitive response. These results suggest that the age-related differences in reasoning on the syllogistic task cannot be due age differences in conflict detection. The most likely explanation for the inability of reasoners to detect conflict is the difficult nature of the task. The problems included were multiple-model problems and all problems contained non-words (e.g., argonelles). By increasing the difficulty of the task, it is possible that the reasoners do not possess the knowledge of logical rules or the mindware (Stanovich, 2009) to realize their beliefs are in conflict with these rules.

Assuming that reasoners are less confident when they detect a conflict between two answers, we have evidence to show that older and young adults detect conflict on the base rate task; both groups were more confident on no-conflict than on conflict problems. Once the anomalous problem is removed, the response time data give a similar picture for the younger adults. Young adults took longer to respond to the conflict problems, than to the no conflict problems, which suggests that young adults were sensitive to the conflict. The fact that older adults' performance is low on conflict problems and that response time is not longer for conflict problems suggests that that older adults may be sensitive to the conflict (i.e., confidence lower on conflict than no-conflict problems), but that they do not attempt to resolve the conflict. It is also possible that the general cognitive slowing discussed in Chapter 2 may eliminate the sensitivity of response time as an indicator. Regardless, on the base rate task both younger and older adults do not seem to be caught up in the dilemma afforded by the conflict. Collectively, the conflict detection results suggest that conflict detection, if present, does not trigger successful T2 intervention in either young or old adults. These results do not lend support to the conclusion that age-related reasoning differences may be related to conflict detection.

3.8.2. Metacognitive Ability. There is a limited degree to which we can use the metacognitive ability data to explain age-related variance in reasoning. There were no major differences in the correlations or calibration measures, and it appears that both young and old adults have poor metacognitive ability. The only indication that there may be calibration between confidence and performance was the fact that reasoners were more confident for correct and base rate responses than for incorrect or stereotypical responses. Also, there was a correlation between the tendency to choose base rate responses and confidence for the young adults. These results suggest that reasoners, young or old, were fairly confident in their responses and may not have believed it necessary to engage in analytic thought to consider the other answer. In sum, poor

metacognitive ability cannot explain part of the age-related difference in reasoning performance because there were no major differences between young and older adults.

3.8.3. Metamemory in Adulthood. Individuals who stated they were more cognitively active and have stronger beliefs regarding the strength of their memory, as measured by the MIA, tended to be more confident and perform better on some cognitive tasks than individuals who did not hold these beliefs; however, these beliefs did not contribute to age-related variance in any of the reasoning tasks. Thus, although older adults believe that their cognitive abilities decline with age, these beliefs do not predict age-related variance in reasoning performance.

3.8.4. Cues to Confidence. We also provided further evidence that conclusion believability is a cue to confidence (Prowse Turner & Thompson, 2009; Shynkaruk & Thompson, 2006). Across both tasks, young and older adults were less confident on the neutral problems[11] than on either conflict or no-conflict problems. Without belief information (i.e., believability of the conclusion or stereotypical information), reasoners slow down and decrease their confidence. Latency is also a strong cue to confidence for both young and older adults. The longer it took participants to respond, the less confident they were in their response. These results demonstrate that the confidence in older adults' responses can be related to the time it takes to retrieve or select it, which adds to the current literature that has shown this in children and young adults (Ackerman & Zalmanov, 2012; Kelley & Lindsay, 1993; Thompson et al., 2011). We can conclude from these findings that older and younger adults use similar cues to confidence, suggesting that metacognitive processes are similar for both age groups.

3.8.5. Perceived Difficulty. Furthermore, perceived difficulty of the task was related to performance and the average time it took reasoners to respond. That is, as the perceived difficulty of the task increased, reasoners provided less correct responses and less base rate responses and took longer to respond. Interestingly, older adults reported that the syllogistic task was harder than the base rate task, yet expressed very similar levels of confidence across the two tasks.

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[11] The difference was marginally significant for young adults on the syllogistic task, $p = .098$.

3.8.6. Conclusions and Direction for Chapter 4. There was little evidence to suggest that younger and older adults differ in metacognition. Young and old adults demonstrated similar levels of conflict detection and low levels of metacognitive ability (i.e., the ability to accurately assess their performance). In addition, both groups use similar cues to confidence (i.e., conclusion believability and latency). With regards to the dual-process theory of reasoning and aging, our results do not suggest that aspects of monitoring and metacognitive processes can explain age-related differences in reasoning. On the syllogistic task, it does not appear that reasoners are sensitive to conflict and consequently, performance remains low. On the base rate task, it appears that reasoners may be aware of the conflict, but choose not to engage T2 thinking. If reasoners were prompted to engage in analytic thinking, we could test the hypothesis that age-related differences in reasoning abilities could, in part, be due to a failure of older adults to fully exploit their analytic reasoning capacity; a possibility that is explored in Chapter 4.

Chapter 4

Can Instructions to Reason from an Objective Perspective Moderate the Age-related Difference

in Reasoning?

Abstract

To test the hypothesis that a simple strategy of taking another's perspective could be effective in countering some aspects of the age-related differences in reasoning, reasoners were asked to adopt an alternative perspective when reasoning. This manipulation could encourage reasoners to engage in a more analytic style when prompted to do so. Seventy-two older ($M = 80.0$ years) and 72 younger ($M = 24.6$ years) adults completed a syllogistic reasoning task, responding to problems from their perspective and from the perspective of the writer. Confidence ratings were also recorded. The manipulation did not improve performance for the young adults, in fact it hindered their performance; however, reasoning after switching from one's own perspective to the writer's perspective improved older adults' performance on conflict problems (i.e., logic and belief lead to different responses). These findings suggest that asking older adults to switch perspectives may cue them to engage analytic thinking, which is consistent with the hypothesis that age-related differences in reasoning abilities may be, in part, due to a failure of older adults to fully exploit their analytic reasoning capacity.

Can Instructions to Reason from an Objective Perspective Moderate the Age-related Difference in Reasoning?

In Chapter 2, we demonstrated that older adults are inclined to provide intuitive responses more often than young adults. This response tendency leads to lower performance on conflict problems than on the no-conflict problems. The goal of the current paper was to examine whether this difference reflects the propensity to rely on Type 1 or Type 2 output (i.e., strategy choice) or the limited success with which Type 2 thinking is implemented (i.e., capacity limitations). One way to test this is to implement a perspective manipulation in which participants are asked to reason about information from someone else's perspective versus one's own. It has been proposed that shifting perspectives allows participants to differentiate between the writer's intentions and their own beliefs (Thompson, Evans, & Handley, 2005). From a dual-process viewpoint, having participants reason from a perspective other than their own (e.g., writer) requires them to engage in analytic thinking (Beatty & Thompson, 2012; Thompson et al., 2005). In young adults, researchers have successfully demonstrated that a perspective shift promotes an analytic mode of thought and reduces reliance on beliefs (Beatty & Thompson, 2012; Dias, Roazzi, & Harris, 2000; Greenhoot, Semb, Colombo, & Schreiber, 2004; Thompson et al., 2005). Therefore, in the present study we sought to determine if a perspective shift would improve reasoning in older adults. If age-related differences in reasoning abilities are, in part, due to a failure of older adults to fully exploit their analytic reasoning capacity, the perspective manipulation should be successful (i.e., the older adults' inclination to respond based on beliefs should be modulated by taking another's perspective) and the age difference should be observed only when reasoning from the personal perspective. In contrast, if performance is limited by cognitive ability, then older adults should be impaired regardless of perspective.

To test this hypothesis, both younger and older adults were asked to solve problems from their perspective and from an alternative perspective. If taking another's perspective reduces age-related increases in heuristic thinking, this would imply that older adults can become more logically capable under conditions that motivate them toward to analytic thought.

4.1. Perspective Effect

Three important conclusions have emerged from studies utilizing the perspective manipulation. First, participants reasoning from an alternative perspective were more likely to approach the task logically and were better able to discern logical necessity than those who

reasoned from their own perspective (Thompson et al., 2005). It was proposed that reasoning from an alternative perspective may prompt participants to grant the truth of the premises (Thompson et al., 2005). Second, this manipulation appears to be effective across many groups. For example, the perspective manipulation has been effective a) when varied both between subjects (Dias et al., 2005; Thompson et al., 2005) and within subjects (Beatty & Thompson, 2012; Greenhoot et al., 2004); b) in children (Markovits et al., 1996), unschooled adults (Dias et al., 2005), and university students (Beatty & Thompson, 2012; Eyal, Liberman, & Trope, 2008; Greenhoot et al., 2004; Thompson et al., 2005). Thus, we assumed that this manipulation had the potential to be effective in older adults. Finally, the perspective manipulation improves reasoning performance across a variety of problem types (Dias et al., 2005). These data suggest that switching perspectives shifts the participants into an analytic thinking style and is successful in many contexts. In sum, it was hypothesized that adopting another's perspective would encourage T2 thinking in both young and old adults (assuming that they have to the capacity to do so), and improve performance for both conflict and no-conflict problems.

4.2. Conflict Detection

In addition to determining whether the perspective manipulation will improve performance, we were also interested in determining how a perspective manipulation affects conflict detection. If reasoning from another's perspective invokes analytic thinking, it is reasonable to assume that this may also bring awareness to the conflict between belief and logic on conflict problems. Based on the rationale that lower confidence on conflict problems compared to no-conflict problems is related to conflict detection (De Neys et al., 2011), we utilized a subjective assessment of confidence as a proxy for conflict detection, which was consistent with the design in Chapter 2. It was anticipated that if conflict was detected, confidence would be lower for the conflict problems than for the no-conflict problems. Furthermore, if the perspective manipulation aids in this awareness, it was predicted that there would be a larger difference between conflict and no-conflict problems for the alternative perspective than for the personal perspective.

4.3. Perceived Difficulty

We also measured reasoners perceived difficulty of the task. Consistent with the results from Chapter 2, it was hypothesized that the more difficult the task was perceived to be, the lower performance (i.e., accuracy) would be.

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4.4. Thinking Dispositions

The final goal of this chapter was to examine the role of thinking dispositions in the likelihood of adopting another's perspective. It is well documented that both the characteristics of the task and individual differences (e.g., intelligence and thinking style) play an important role in performance on reasoning tasks (Klaczynski, Gordon, & Fauth, 1997; Sa, West, & Stanovich, 1999; Stanovich & West, 1997). In Chapter 2, we discussed and provided support for the model recently proposed by Stanovich (2009) that separates the analytic system of thinking (based on these individual differences) into two components, algorithmic and reflective processes. It is this latter component that is thought to trigger the override of the heuristic system output. Thinking dispositions were measured using the Actively-Open Minded Thinking scale (AOT; Stanovich et al., 1997, 2007, 2008), which measures the preference for analytic versus heuristic thinking. If there is a relationship between thinking dispositions and the perspective manipulation, it would suggest that a factor other than capacity is the limiting factor in engaging in T2 thinking. If this is the case, those with lower AOT scores would be less likely to switch thinking styles and override their beliefs when reasoning from the writer's perspective, than when reasoning from their own perspective.

4.5. Method

4.5.1. Participants

The same seventy-two younger adults (46 female) (M = 24.6 years; SD = 7.54) and seventy-two older adults (55 female) (M = 80.0 years, SD = 7.28) from Chapter 2 were analyzed in this chapter[12].

4.5.2. Materials

Participants completed eight syllogistic reasoning problems (from one of two different sets), once from their perspective and once from the writer's perspective (for a total of 16 problems) (Appendix D) using *E-Prime*. Each problem consisted of two premises and three possible conclusions. The problems were either of the form All A are B, All C are B or the form All B are A, All C are B, with a conclusion relating A and C. There were 4 versions of each form. The premises were presented as statements that had appeared in a recent newspaper (i.e., A

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[12] Again, these participants were above average and thus, the sample is not representative of the average young or older adult.

writer states that:…). Content was assigned to the A, B, and C terms in the following manner: A and C referred to a familiar category (e.g., roses and flowers) and the B term referred to a non-word (e.g., gebbers). Inclusion of a non-word limits the believability of the premises, which has been shown to influence performance (Thompson, 1996). Each premise set was followed by three conclusions: determinate in the form A are C, determinate in the form A are not C, and indeterminate in the form A may or may not be C. The following is an example taken from our stimulus set:

All things with gebbers are flowers. Roses have gebbers.
a) Roses are flowers
b) Roses are not flowers
c) Roses may or may not be flowers

Each set of eight problems contained four valid problems and four invalid problems, two out of the eight valid conclusions coincided with the believability of the conclusion (i.e., two problems were no-conflict and 6 were conflict problems). The eight problems were presented twice to participants in immediate succession. Following the first presentation reasoners were asked "Do you believe it follows that…", which prompted reasoners to provide a response from their own perspective. Following the second presentation of the premises, they were asked "According to the writer's statement...,", prompting them to make a judgement from an alternative perspective. These presentations were made on consecutive separate screens. They received the following instructions, which were adapted from Thompson et al. (2005).

You are going to see eight reasoning problems. The problems represent a statement that appeared in a recent newspaper. You will be asked to evaluate the statements from two perspectives: from the perspective of the writer and from your own perspective. Do not be concerned if some of the terms in some of the problems seem unfamiliar to you. When evaluating the statements from the perspective of the writer, please select a conclusion based on your interpretation of the writer's intended meaning (i.e., what do you think that the writer of this statement meant to convey?) When evaluating the statements from your own perspective, please select a conclusion based on your interpretation of premises (i.e., what do you believe to follow from the statements?)

Problems were presented in a different random order for each participant; however, consistent with previous methodology (Thompson et al., 2005), participants made a judgement from their own perspective first[13]. The assignment of the two problem sets was counterbalanced, such that half of the participants in each age group saw the first set and the other half saw the second set.

4.5.3. Confidence Judgements. For all three reasoning tasks, following each response, participants were asked to rate the confidence in the correctness of their judgement on the following scale: How confident are you that your answer is correct?

0%   10%   20%   30%   40%   50%   60%   70%   80%   90%   100%

Not at all   Moderately   Extremely

After solving all of the problems for the syllogistic and base rate tasks, reasoners were asked additional questions.

1) You have just completed 8 problems. Of these 8 answers, how many do you believe you answered correctly?
2) On a scale of 1 to 10, with 1 corresponding to extremely easy and 10 corresponding to extremely difficult, please evaluate the difficulty of the reasoning task that you just completed.

4.5.4. Procedure. The procedure was described in Chapter 2 (see p.17 in Chapter 2). This task was presented and counterbalanced within the computer based tasks.

4.6. Results

The results were analysed in several sections. First, to test the hypothesis that adopting another's perspective would improve performance for the older adults, we ran 2 (perspective: writer, own) x 2 (problem: conflict, no-conflict) x 2 (age group) mixed-factors ANOVA on the accuracy data. Second, we ran a similar analysis for the confidence data, to examine whether confidence values vary as a function of perspective and whether the data indicate that reasoners were sensitive to the conflict between logic and belief. Third, we report the results of the AOT and finally, we discuss the relationship between perceived task difficulty and performance and whether the factors in Chapter 2 (i.e., education, verbal ability, working memory, processing

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[13] Our manipulation was within subjects, but has also been successful as a between subjects manipulation.

speed, inhibition, and age) predict successful perspective switching (i.e., ability to override intuitive responses).

4.6.1. Performance. For performance, a response was scored as correct when reasoners chose the correct determinate responses (i.e., A are C or A are not C) for the valid problems or the indeterminate option (i.e., A may or may not be C) for invalid conclusions. Results are reported in Figure 4.1. Older adults were less accurate ($M = .44$) than young adults ($M = .57$), F (1, 142) = 17.29, $MSE = .134$, $p < .001$, $\eta_p^2 = .109$. Reasoning from the writer's perspective did not improve accuracy overall ($M = .50$) compared to reasoning from one's own perspective ($M = .51$), F (1, 142) = .30, $MSE = .037$, $p = .587$, $\eta_p^2 = .002$. There was an interaction of perspective with age group, F (1, 142) = 8.02, $MSE = .023$, $p = .005$, $\eta_p^2 = .053$. Young adults were impaired by the perspective manipulation: their accuracy decreased from .59 to .54, when they switched to the writer's perspective, t (71) = -2.21, $SE = .024$, $p = .030$. However, it appears older adults benefited, to an extent, from the perspective manipulation: they had a marginal increase from .42 to .46, t (71) = 1.77, $SE = .021$, $p = .081$.

Consistent with prior findings (see Chapter 2), reasoners were more accurate on no-conflict problems ($M = .60$) than on conflict problems ($M = .41$), F (1, 142) = 93.33, $MSE = .057$, $p < .001$, $\eta_p^2 = .397$. There was also an interaction between perspective and problem type, F (1, 142) = 9.34, $MSE = .027$, $p = .003$, $\eta_p^2 = .062$. Specifically, there was no difference on conflict problems between the writer (.44) and one's own perspective (.39) [t (71) = 1.47, $SE = .022$, $p = .144$], but for no-conflict problems there was a decrease in performance from one's own perspective (.63) to the writer's perspective (.57) [t (71) = -2.52, $SE = .020$, $p = .013$]. There was no evidence for an interaction between problem type and group [F (1, 142) = 2.45, $MSE = .057$, $p = .119$, $\eta_p^2 = .017$]. Nonetheless, the perspective manipulation affected only conflict problems in older adults [performance increased when switching perspectives from .28 to .37, t (71) = 2.96, $SE = .029$, $p = .004$] and there was no difference for the no-conflict problems [.56 to .55, t (71) = -.552, $SE = .025$, $p = .583$]. In contrast, for younger participants, performance did not vary on conflict problems when switching perspectives [.50 to .48, t (71) = -.63, $SE = .033$, $p = .531$] and there was a decrease for the no-conflict problems [.69 to .60, t (71) = -2.84, $SE = .031$, $p = .006$].

Figure 4.1. Proportion of Correct Responses as a Function of Perspective, Problem, and Age.
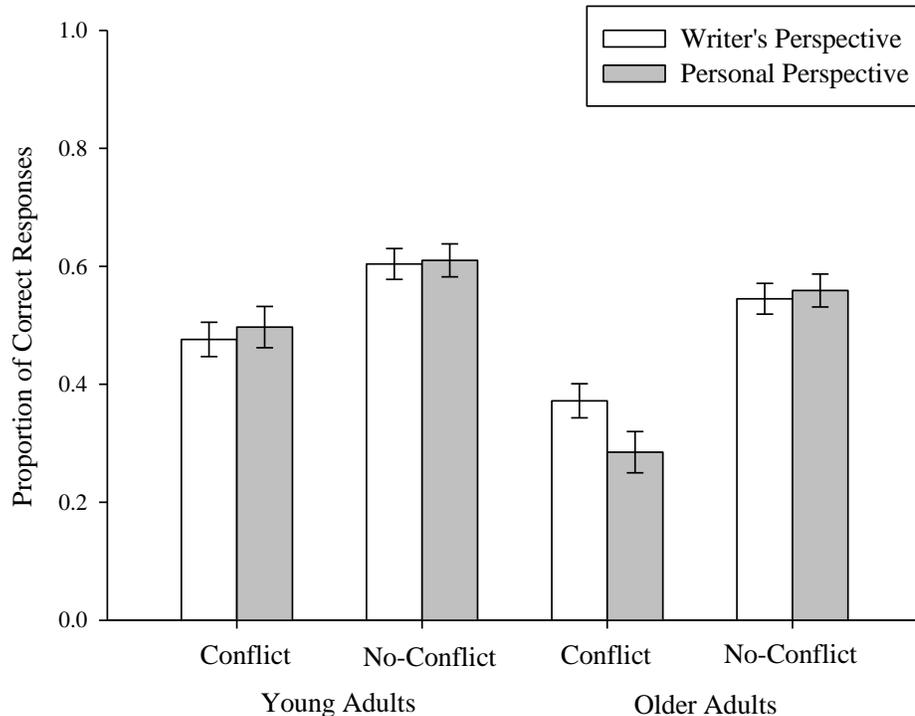
Note. Error bars represent the standard error.

7.6.2. Confidence. Confidence data for young and older adults as a function of perspective and problem type are plotted in Figure 4.2. Reasoners were more confident when reasoning from their own perspective ($M = 81.76$) than when reasoning from the writer's perspective ($M = 79.96$), $F (1, 142) = 9.85$, $MSE = 47.58$, $p = .002$, $\eta_p^2 = .065$. There were no differences in confidence between young ($M = 81.98$) and older adults ($M = 79.74$), $F (1, 142) = .65$, $MSE = 1107.78$, $p = .420$, $\eta_p^2 = .005$. Also, there was no difference in confidence for the conflict compared to the no-conflict problems, $F (1, 142) = .16$, $MSE = 57.40$, $p = .689$, $\eta_p^2 = .001$; however, problem type did interact with perspective, $F (1, 142) = 7.45$, $MSE = 19.18$, $p = .007$, $\eta_p^2 = .050$. On the no-conflict problems, a change in perspective, from their own perspective (82.13) to the writer's perspective (79.33) decreased confidence, $t (143) = -3.83$, $SE = .73$, $p < .001$. Reasoners were equally confident (80.58 for their own to 81.39 for the writer) on

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the conflict problems, $t\ (143) = 1.06$, $SE = .62$, $p = .198$. No other interactions were significant, $F \leq 1.58$, $p \geq .211$.

Figure 4.2. Confidence Scores as a Function of Perspective, Problem, and Age.
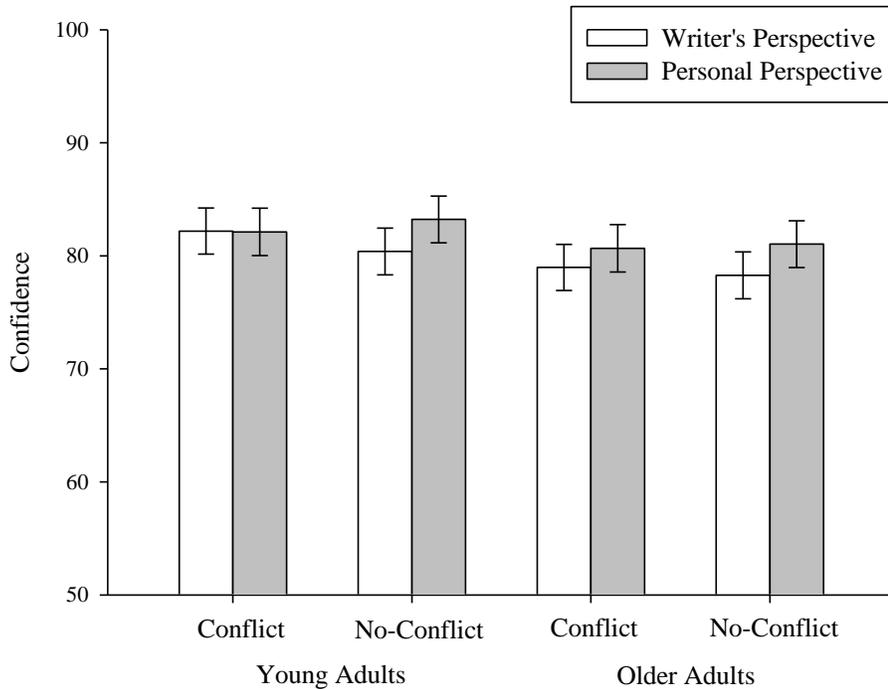
Note. Error bars represent the standard error.

4.6.3. Thinking Dispositions. To examine the relationship between the perspective manipulation and thinking style, we computed a perspective index for the impact of the perspective manipulation on accuracy and accuracy broken down by each problem type. The performance index score was computed by subtracting the number of conclusions correct from the writer's perspective from the number correct from their own perspective. A positive difference or no difference indicates that the perspective manipulation did not promote successful analytic thinking (i.e., overriding heuristic system output). These indices were then correlated with the AOT scores to test our hypothesis that participants with lower AOT scores would be less likely to demonstrate an increase in performance when reasoning from another's

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perspective. Contrary to this hypothesis there were no significant correlations with the AOT, $r =$ -.080, $p = .344$. Neither of the problem type perspective indices were correlated with AOT scores [conflict, $r = .102$, $p = .227$ and no-conflict, $r = .016$, $p = .848$]. This suggests that the perspective manipulation was equally effective for individuals with high and low AOT scores.

4.6.4. Predictors of Successful Perspective Switching. Regression analyses were conducted for the perspective manipulation with the predictors from Chapter 2. All variables were entered in one multiple regression because there is no prior research to suggest a hierarchical regression. The dependent variable for this regression was the perspective index for accuracy discussed above. The regression equation was not significant, $R^2 = .085$, $F (7, 137) =$ 1.72, $p = .109$. Thus, the individual factors examined in Chapter 2 do not predict a tendency to successfully engage the analytic system (i.e., by providing the correct response) when adopting another perspective.

4.6.5. Perceived Difficulty. Older adults judged this task to be more difficult ($M = 6.85$) than young adults ($M = 5.72$), $t (142) = 2.94$, $SE = .38$, $p = .004$. However, unlike the syllogistic and base rate tasks, perceived difficulty was not related to performance when reasoning from the writer's perspective, $r = .087$, $p = .297$ or from one's own perspective, $r = .026$, $p = .757$.

4.7. Discussion

We have provided promising evidence that a simple manipulation may eliminate some of the reliance on intuitive responding found in older adults. When asked to reason from an alternative perspective, older adults showed a marginal improvement in their performance (a medium sized effect of 0.11). This implies that although there is a decrease in capacity contributing to a difference in performance with age (Chapter 2), some of the difference may be countered by asking older adults to reason from an alternative viewpoint. These results provide evidence for an additional component in the model of dual-process theory of reasoning and aging discussed in the former chapters. Specifically, there is evidence to suggest that some of the age-related difference in reasoning may be related to a preference to respond based on heuristic outputs versus outputs of the analytic system (i.e., a failure of older adults to fully exploit T2 capacity).

In addition, the data also show that this performance increase for older adults was restricted to conflict problems. Thus, the older adults' performance was consistent with the

hypothesis that adopting another's perspective can shift thinking into an analytic style and consequently may encourage reasoners to temporarily abandon T1 response tendencies. Although, it is well known that people are often reluctant to relinquish beliefs (e.g., Evans, Newstead, Allen, & Pollard, 1994; Klahr & Dunbar, 1988; Klayman & Ha, 1987; Kuhn, Amsel, O'Loughlin, 1988; Newstead, Pollard, Evans, & Allen, 1992; Schauble, 1996), we have successfully demonstrated older adults are able to do so, to a degree, when reasoning from another perspective.

In contrast, however, young adults did not benefit from the shift in perspective. One explanation for the difference between groups is that young and older adults interpreted the perspective manipulation differently. Specifically, it is possible that the young adults may have interpreted the instruction to adopt the writer's perspective to mean that the writer would endorse the conclusion that is given because it was the writer who advanced it. This would increase the probability of accepting the conclusion. Indeed, we found that young adults accepted more conclusions (chose a determinate response more often than an indeterminate response) from the writer's perspective than from their own perspective. This was not the case for the older adults, for whom the perspective switch appeared to induce a more logical, analytic approach. An alternative explanation is that the perspective manipulation encouraged both groups to alter their personal perspective (which always occurred first). The response given in the personal perspective was less likely to be accurate for older than younger adults; thus, changing the response provided for the personal perspective would result in younger adults' performance decreasing and older adults' performance increasing.

Other perspective manipulations have also been effective in inducing analytic thinking. For example, asking participants to think about events occurring in the distant future has increased analytic thinking in younger adults (Eyal et al., 2008). It is believed that this is effective because representations can be made more abstract by distancing them from direct experience. An additional manipulation garnering similar results, was completed by Dias and colleagues (2005), who had unschooled adults think about the premises as true on a different planet. These manipulations could also be examined to determine the generalizability of these results.

For both age groups, performance on conflict problems was lower than that for the no-conflict problems, which is consistent with the findings from the syllogistic and base rate tasks

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(Chapter 2). For the present task, there was no evidence that either age group was sensitive to the conflict between logic and belief; given that there were no differences in the confidence ratings for the two types of problems. Furthermore, switching perspectives did not appear to increase awareness of the conflict, because there were no differences between problem types in either perspective.

Finally, we also wanted to determine whether thinking dispositions would predict success in adopting another's perspective. It was predicted that AOT would be related to effective perspective switching, such that low AOT scorers would be less likely to successfully adopt another's perspective. However, there was no relationship between AOT scores and reasoning analytically from another's perspective. Although prior research has found a relationship between AOT and different response strategies in a perspective task (Beatty & Thompson, 2012), the current task is quite different than the task employed in other research (i.e. argument evaluation task) and perhaps a task of this nature requires a different type of thinking style. Furthermore, this task is challenging and similar to the syllogistic task utilized in Chapter 2, in which performance was also unrelated to AOT scores. Again, it is possible that this task requires mindware (Stanovich, 2009) to reason effectively, and that many of the participants lack this. Thus, even if reasoners have a predisposition to engage in analytic thinking (higher scores on the AOT), they may lack the mindware necessary to override their initial intuitive response. To examine this possibility, researchers could gather information on basic comprehension of the problem (e.g., having participants provide a step-by-step approach to solving the problems) and relevant skills (e.g., training in standard logic) held by the participants or increase basic comprehension (e.g., through training the participants; Prowse Turner & Thompson, 2009)

4.7.1. Conclusions. We have provided evidence to indicate that a simple intervention, that of adopting an objective perspective, can decrease older adults' reliance on intuitive responses to some extent. Indeed, it appears possible that older adults can engage in additional T2 processing when motivated to adopt an alternative perspective. These results suggest that a portion of the age-related differences in reasoning may be attributed to a failure to exploit available T2 processing resources. That is, although some of the variance in reasoning performance can be attributed to differences in algorithmic capacity, additional variance may be explained by propensity to engage in heuristic rather than analytic thought. Furthermore, it is possible that this is a strategy employed by the older adults to conserve cognitive resources.

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Thus, the age-related difference in reasoning may be mediated by the use of strategies that maximise the use of available T2 resources. These results further the dual-process theory of reasoning and aging by demonstrating that some of the age-related reasoning differences may be attributed to a strategy choice.

Chapter 5

General Conclusions

The objective of the current dissertation was to develop and test a dual-process account of age-related differences in reasoning ability. Previous research in this field has implicated cognitive capacity as a major contributor to these differences; however, it was not evident that capacity attenuates the age-related difference in performance. In addition to cognitive capacity, dual-process theory posits additional factors that could mediate age-related declines in reasoning. Consistent with this view, it was demonstrated here that both the algorithmic and reflective components of the analytic system contribute to differences in reasoning performance between young and old adults, along with strategic use of available Type 2 resources. Surprisingly we found few differences in metacognitive processes between old and young adults, so that metacognitive processes cannot explain differences in reasoning ability among the two groups. As the following summary shows, this body of research suggests that a dual-process approach to effects of age on reasoning provides an integrative account for the results obtained both in the current dissertation, and previously.

Young adults outperformed the older adults on all four reasoning tasks, the syllogistic, base rate, CRT, and perspective tasks. Older adults were at a disadvantage when they needed to engage the analytic system; however they performed on par with the young adults when decisions could be based on beliefs or stereotypes, which is consistent with prior research (De Neys & Van Gelder, 2009). Specifically, the dual-process approach allowed us to explain both aspects of reasoning that remain stable (e.g., reliance on beliefs) and those that are sensitive to age effects (e.g., individual capacity factors). The data confirm that older adults have trouble shifting from heuristic to analytic processing and that this may be due to a combination of processing capacity limitations, education, belief bias, thinking style, and strategy choice.

The data indicate that some of these differences may be related to educational differences between older and young participants; although our older adults were above average in their level of education, older adults had a lower level of education than the young adults, and education contributed to unique variance in two of the three tasks. There was also evidence that actively open-minded thinking is related to performance, at least on the base rate task. The relationship between the AOT and performance on the syllogistic task was marginal, and the relationship between the AOT and performance on the CRT was non-significant. Although the

AOT measures a preference for reflective thinking, there are other factors important in whether reasoners will override the initial T1 response. First, reasoners need to possess the mindware, that is, the knowledge of logical rules (Stanovich, 2009), to realize their beliefs are in conflict with the logical rules of the task. Due to the difficult and unfamiliar nature of the syllogistic task, the necessary mindware may be absent. Evidence for this argument can be gained by examining the relationship between perceived difficulty and conflict detection. The difficulty ratings for the perspective task fell between the ratings for the syllogistic task and the base rate task, but were on the higher end of the scale; however, in both the syllogistic and perspective tasks, there was little evidence to suggest reasoners were sensitive to conflict, whereas reasoners were sensitive to conflict in the base rate task. As the perceived difficulty of the task increased, the ability to detect conflict decreased, and also the length of time to respond increased, which suggests that longer time may be related to analytic engagement, but there are other components necessary for successful execution of T2 thinking.

Second, reasoners need a cue to override the T1 response. If reasoners have a strong feeling of rightness (i.e., a metacognitive experience, which can signal when additional analysis is needed; Thompson, 2009; Thompson et al., 2011) in the initial response, it is unlikely that the response will be re-examined. The questions in the CRT are believed to be answered with a strong feeling of rightness (Frederick, 2005), thus the cue to rethinking the initial response may be absent in the CRT, especially for the older adults. Overall, these results provide evidence that limits to algorithmic capacity are related to age-related differences, but also provide evidence that, at least some of the difference is related to individual differences in the reflective level as well.

In Chapter 3, we found that although young and old adults frequently gave a belief-or stereotyped response to conflict problems (older adults to a greater extent), there was evidence that the conflict was detected, at least on the base rate task. With regard to the syllogistic task, there was little evidence to suggest that reasoners detected the conflict; however, participants appeared to be aware when they provided a correct versus an incorrect response. In the base rate task, the confidence and response time data suggest that young adults detected conflict, which is consistent with prior research (De Neys, Cromheeke, & Osman, 2011; De Neys & Franssens, 2009). The confidence data for the older adults suggests that older adults also noticed the conflict. There was no corresponding effect on RT, perhaps because their relatively slow and

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more variable processing speeds made response time a relatively insensitive measure of conflict detection.

It is also clear that belief information in the problems (i.e., believability of the conclusion or stereotypical information) is a strong cue to confidence and that without belief information (for example on neutral problems), reasoners slow down and report lower confidence, which is demonstrating that belief adds a level of certainty to their judgements. Results were also consistent with the conclusion that latency was a cue to confidence, the longer reasoners took to solve the problem, and the less confident they were. It was also demonstrated that perceived task difficulty was related to performance and latency, reasoners spent more time on tasks they perceived to be difficult, however this increase in time does not translate into better performance.

Promising results were also revealed in Chapter 4, suggesting that older adults may be able to counter some of the difference on conflict problems by reasoning from another perspective. Although this manipulation was not effective for the young adults, it is possible that they interpreted this task differently than the older adults. Also, the older adults started from a lower baseline level in the self-perspective condition, providing greater opportunities to benefit from the switch to the writer's perspective.

5.1. Limitations. As we have stated previously, our older adults were above average for their age on a number of cognitive measures. This raises the possibility that the present data underestimate the average age-related difference in reasoning and potentially overestimate the typical benefit that switching to an objective perspective provides. However, it is also the most optimistic view we can give of age-related differences in reasoning performance. The number of tasks given to the older adults in a single session may have also been quite taxing. One way to ensure that the data are a result of difference and not fatigue, would be to replicate these results by testing participants in multiple sessions or by examining some of these effects between subjects.

Also, whereas other studies have included multiple measures of working memory (e.g. Levitt, Fugelsang, & Crossley, 2006; Salthouse, 2005) to create a single composite score that might be a more reliable measure of capacity, in the current study we chose take only a single measure of working memory capacity. First, working memory tasks are taxing for participants, especially for older adults, and as above, we were already concerned about fatigue effects. Second, we were able to use the List Span Task (Daneman & Carpenter, 1980; De Beni,

Palladino, Pazzaglia, & Cornoldi, 1998), which has been argued to be a comprehensive and reliable measure (Morrison, 2005). However, to ensure the generalizability of our findings, it may be beneficial to measure working memory in this manner to provide further support for the current conclusions.

5.2. Future directions. There is still residual age-related variance that needs to be explained. One avenue would be to explore the relationship between the availability of mindware and the ability to successfully override the intuitive response with a Type 2-based response (Stanovich, 2009). As defined by Stanovich (see 2009 for review), mindware is the "rules, procedures, and strategies that can be retrieved by the analytic system and used to transform decoupled representation" (p. 71).

Further examination of this concept may also provide information for the marginal effect of AOT scores on the syllogistic task. In particular, reasoners may demonstrate a preference for analytic thinking (high scores on AOT) and have high capacity scores, but lack the mindware to execute successful Type 2 engagement. Thus, while these reasoners may have perceived the need for additional analytic thought, they may not have knowledge necessary to execute the appropriate rules and procedures. In other words, the fact that reasoners have high AOT scores does not mean that they have good mindware. Examination of the relationship between AOT scores and mindware will provide a test of this hypothesis.

To examine the null relationship between the CRT and the AOT scores, one could test the hypothesis that the questions on the CRT have a strong feeling of rightness, thus not providing reasoners with a cue to rethink the initial response. By employing a two response paradigm (Thompson et al., 2011; 2012), where reasoners are instructed to provide an initial response along with a feeling of rightness, before they are allowed as much time necessary to reconsider the response, we will get a better picture of the degree to which these problems are compelling, and why, this compelling response is a stronger cue than preference for analytic thinking.

5.3. Conclusions. The present findings advanced the literature of reasoning and aging in several ways: 1) by providing an integrative model to account for the current findings in multiple research domains, 2) by demonstrating that the age related differences in reasoning is restricted to problems that require analytic engagement, 3) by demonstrating that detection of the conflict between belief and logic differs by task, 4) by providing evidence that the difference is related to a combination of individual difference factors (algorithmic and reflective processes), and

strategy choice, 5) by demonstrating that age-related differences cannot, at this time, be explained by metacognitive differences between young and older adults, and 6) by identifying a simple intervention that may reduce the effects of this difference.

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Appendix A

Problems in the Syllogistic Task

Conflict Problems	
No addictive things are ramadions Some cigarettes are ramadions Therefore, some cigarettes are not addictive things *(Valid-Unbelievable)*	Some vitamin tablets are opprobines No nutritional things are opprobines Therefore, some nutritional things are not vitamin tablets *(Invalid-Believable)*
Some astronauts are Lapitars No healthy people are Lapitars Therefore, some astronauts are not healthy people *(Valid-Unbelievable)*	No well-educated people are Pennes Some judges are Pennes Therefore, some well-educated people are not judges *(Invalid-Believable)*

No-Conflict Problems	
No police dogs are argonelles Some highly trained dogs are argonelles Therefore, some highly trained dogs are not police dogs *(Valid-Believable)*	Some rich people are Hudons No millionaires are Hudons Therefore, some millionaires are not rich people *(Invalid-Unbelievable)*
Some religious people are Selaciens No priests are Selaciens Therefore, some religious people are not priests *(Valid-Believable)*	No deep sea divers are Sylvians Some good swimmers are Sylvians Therefore, some deep sea divers are not good swimmers *(Invalid-Unbelievable)*

Neutral Problems	
No Welps are lawyers Some Abens are lawyers Therefore, some Abens are not Welps *(Valid-Neutral)*	Some Delpads are bird watchers No Furels are bird watchers Therefore, some Furels are not Delpads *(Invalid-Neutral)*
Some Rewons are bus drivers No Likels are bus drivers Therefore, some Rewons are not Likels *(Valid-Neutral)*	No Mobbes are teachers Some Plicks are teachers Therefore, some Mobbes are not Plicks *(Invalid-Neutral)*

Example Base Rate Problems

Conflict Problem

(a) In a study 1000 people were tested. Among the participants there were 4 men and 996 women. Jo is a randomly chosen participant of this study. Jo is 23 years old and is finishing a degree in engineering. On Friday nights, Jo likes to go out cruising with friends while listening to loud music and drinking beer.

What is most likely?

a. Jo is a man   b. Jo is a woman

No-Conflict Problem

(a) In a study 1000 people were tested. Among the participants there were 995 who buy their clothes at high-end retailers and five who buy their clothes at Wal-Mart. Karen is a randomly chosen participant of this study. Karen is a 33-year-old female. She works in a business office and drives a Porsche. She lives in a fancy penthouse with her boyfriend.

What is most likely?

a. Karen buys her clothes at high end retailers b. Karen buys her clothes at Wal-Mart

Neutral problem

(a) In a study 1000 people were tested. Among the participants there were five who campaigned for George W. Bush and 995 who campaigned for John Kerry. Jim is a randomly chosen participant of this study. Jim is 5 ft and 8 in. tall, has black hair, and is the father of two young girls. He drives a yellow van that is completely covered with posters.

What is most likely?

a. Jim campaigned for George W. Bush   b. Jim campaigned for John Kerry

Appendix C

The Cognitive Reflection Test (CRT)

(1) A bat and a ball cost $1.10 in total. The bat costs a dollar more than the ball. How much does the ball cost?   _____ cents

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

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

Appendix D

Perspective Stimuli

Set 1 Premises	Set 2 Premises	Conclusions
All things with gebbers are flowers. Roses have gebbers.	All flowers are things with gebbers. Roses have gebbers.	a) Roses are flowers b) Roses are not flowers c) Roses may or may not be flowers
A writer states that: All gottuses are alive. Televisions are not gottuses.	All things that are alive are gottuses. Televisions are not gottuses.	a) Televisions are alive b) Televisions are not alive c) Televisions may or may not be alive
All things that have emblers are animals. Cats do not have emblers.	All animals have emblers. Cats do not have emblers.	a) Cats are animals b) Cats are not animals c) Cats may or may not be animals
All things that have zabs can walk. Whales have zabs.	All things that can walk have zabs. Whales have zabs.	a) Whales can walk b) Whales can not walk c) Whales may or may not be able to walk
All communist countries have a nima. Canada does not have a nima.	All countries that have a nima are communist countries. Canada does not have a nima.	a) Canada is a communist country b) Canada is not a communist country c) Canada may or may not be a communist country
All things that have motors have a frimjam. Automobiles have a frimjam.	All things that have a frimjam have motors. Automobiles have a frimjam.	a) Automobiles have motors b) Automobiles do not have motors c) Automobiles may or may not have motors
All large mammals metabolize mimus. Mice metabolize mimus.	All things that metabolize mimus are large things. Mice metabolize mimus.	a) Mice are large mammals b) Mice are not large mammals c) Mice may or may not be large mammals
All animals with four legs have the protein brox in their blood. Poodles do not have the protein brox in their blood.	All things that have the protein brox in their blood are animals with four legs. Poodles do not have the protein brox in their blood.	a) Poodles have four legs b) Poodles do not have four legs c) Poodles may or may not have four legs

METAMEMORY IN ADULTHOOD
Metamemory in Adulthood used with permission Dixon, R. A. & Hultsch, D. F. ©1983

Date: _____ / _____ / _____   Participant # _____
         d   m   y

Scorer's Initials: _____

MEMORY QUESTIONNAIRE

Directions

       Different people use their memory in different ways in their everyday lives. For example, some people make shopping lists, whereas others do not. Some people are good at remembering names, whereas others are not.

       In this questionnaire, we would like you to tell us how you use your memory and how you feel about it. There are no right or wrong answers to these questions because people are different. Please take your time and answer each of these questions to the best of your ability.

       Each question is followed by five choices. Draw a circle around the letter corresponding to your choice. Mark <u>only</u> one letter for each statement.

       Some of the questions ask your opinion about memory-related statements; for example:

_____

My memory will get worse as I get older.   a. agree strongly
                                            b. agree
                                          c. undecided
                                          d. disagree
                                          e. disagree strongly

_____

In this example you could, of course, choose any <u>one</u> of the answers. If you agree strongly with the statement you would circle a. If you disagree strongly you would circle letter <u>e</u>. The <u>b</u> and <u>d</u> answers indicate less strong agreement or disagreement. The letter <u>c</u> answer gives you a middle choice, but don't use the <u>c</u> unless you really can't decide on any of the other responses.

       Some of the questions ask how often you do certain things that may be related to your memory. For example:

_____

Do you make a list of things to   a. never
be accomplished during the day?   b. rarely
                                            c. sometimes
                                          d. often
                                          e. always

_____

Again, you could choose any one of the answers. Choose the one that comes closest to what you <u>usually</u> do. Don't worry if the time estimate is not exact, or if there are some exceptions.

<u>Keep these points in mind:</u>
(a) Answer every question, even if it doesn't seem to apply to you very well.
(b) Answer as honestly as you can what is true for you. Please do not mark something because it seems like the "right thing to say."

1.	For most people, facts that are interesting are easier to remember than facts that are not.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
2.	I am good at remembering names.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
3.	Do you keep a list or otherwise note important dates, such as birthdays and anniversaries?	a. never b. rarely c. sometimes d. often e. always
4.	It is important to me to have a good memory.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
5.	I get upset when I cannot remember something.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
6.	When you are looking for something you have recently misplaced, do you try to retrace your steps in order to locate it?	a. never b. rarely c. sometimes d. often e. always
7.	I think a good memory is something of which to be proud.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly

8.	I find it harder to remember things when I am upset.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
9.	I am good at remembering birth dates.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
10.	I can remember things as well as always.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
11.	When you have not finished reading a book or magazine, do you somehow note the place where you have stopped?	a. never b. rarely c. sometimes d. often e. always
12.	I get anxious when I am asked to remember something.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
13.	It bothers me when others notice my memory failures.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
14.	I'm less efficient at remembering things now than I used to be.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly

15.	I have difficulty remembering things when I am anxious.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
16.	The older I get the harder it is to remember clearly.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
17.	Do you think about the day's activities at the beginning of the day so you can remember what you are supposed to do?	a. never b. rarely c. sometimes d. often e. always
18.	I am just as good at remembering as I ever was.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
19.	I have no trouble keeping track of my appointments.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
20.	For most people, it is easier to remember information they need to use immediately than information they will not use for a long time.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
21.	Most people find it easier to remember directions to places they want or need to go than to places they know they will never be going.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly

22.	I am usually uneasy when I attempt a problem that requires me to use my memory.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly

23.	I feel jittery if I have to introduce someone I just met.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly

24.	Having a better memory would be nice but it is not very important.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly

25.	Do you post reminders of things you need to do in a prominent place, such as bulletin boards or note boards?	a. never b. rarely c. sometimes d. often e. always

26.	It doesn't bother me when my memory fails.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly

27.	I am poor at remembering trivia.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly

28.	I am much worse now at remembering the content of news articles and broadcasts than I was 10 years ago.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly

29.	Do you routinely keep things in a familiar spot so you won't forget them when you need to locate them?	a. never b. rarely c. sometimes d. often e. always
30.	Compared to 10 years ago, I am much worse at remembering titles of books, films, or plays.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
31.	For most people it is easier to remember words they want to use than words they know they will never use.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
32.	I remember my dreams much less now than 10 years ago.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
33.	I can't expect to be good at remembering postal codes at my age.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
34.	Most people find it easier to remember the names of people they especially dislike than people they hardly notice.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
35.	I have little control over my memory ability.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly

36.	When you want to take something with you, do you leave it in an obvious, prominent place, such as putting your suitcase in front of the door?	a. never b. rarely c. sometimes d. often e. always
37.	I think it is important to work at sustaining my memory abilities.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
38.	I misplace things more frequently now than when I was younger.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
39.	As people get older they tend to forget where they put things more frequently.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
40.	I work hard at trying to improve my memory.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
41.	Compared to 10 years ago, I now forget many more appointments.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
42.	If I am put on the spot to remember names, I know I will have difficulty doing it.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly

43.	For most people, it is easier to remember the names of people they especially like than people that don't make much of an impression on them.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
44.	Most people find it easier to remember words they understand than words that don't mean very much to them.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
45.	My memory for important events has improved over the last 10 years.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
46.	I admire people who have good memories.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
47.	My friends often notice my memory ability.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
48.	When you try to remember people you have met, do you associate names and faces?	a. never b. rarely c. sometimes d. often e. always
49.	I am good at remembering the order that events occurred.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly

50.	For most people, words they have seen or heard before are easier to remember than words that are totally new to them.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
51.	Familiar things are easier to remember than unfamiliar things.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
52.	I am good at remembering conversations I have had.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
53.	I would feel on edge right now if I had to take a memory test or something similar.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
54.	My memory for phone numbers will decline as I get older.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
55.	I often notice my friends' memory ability.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
56.	My memory for dates has declined greatly in the last 10 years.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly

57.	When you have trouble remembering something, do you try to remember something similar in order to help you remember?	a. never b. rarely c. sometimes d. often e. always
58.	My memory for names has declined greatly in the last 10 years.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
59.	I often forget who was with me at events I have attended.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
60.	Do you consciously attempt to reconstruct the day's events in order to remember something?	a. never b. rarely c. sometimes d. often e. always
61.	As long as I exercise my memory it will not decline.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
62.	I am good at remembering the places I have been.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
63.	I know if I keep using my memory I will never lose it.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly

64.	Do you try to relate something you want to remember to something else hoping that this will increase the likelihood of your remembering later?	a. never b. rarely c. sometimes d. often e. always
65.	It's important that I am very accurate when remembering names of people.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
66.	When I am tense and uneasy at a social gathering I cannot remember names very well.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
67.	Do you try to concentrate hard on something you want to remember?	a. never b. rarely c. sometimes d. often e. always
68.	It's important that I am very accurate when remembering significant dates.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
69.	It's up to me to keep my remembering abilities from deteriorating.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
70.	When someone I don't know very well asks me to remember something I get nervous.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly

71.	I have no trouble remembering where I have put things.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
72.	It is easier for most people to remember things that are unrelated to each other than things that are related.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
73.	Even if I work on it, my memory ability will go downhill.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
74.	Most people find it easier to remember concrete things than abstract things.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
75.	Do you make mental images or pictures to help you remember?	a. never b. rarely c. sometimes d. often e. always
76.	I know of someone in my family whose memory improved significantly in old age.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
77.	I am good at remembering things like recipes.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly

78.	I get anxious when I have to do something I haven't done for a long time.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
79.	It bothers me when I forget an appointment.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
80.	Most people find it easier to remember things that happen to them than things that happen to others.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
81.	Do you mentally repeat something you are trying to remember?	a. never b. rarely c. sometimes d. often e. always
82.	My memory has improved greatly in the last 10 years.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
83.	I like to remember things on my own, without relying on other people to remind me.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
84.	I get tense and anxious when I feel my memory is not as good as other peoples'.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly

85.	Do you ask other people to remind you of something?	a. never b. rarely c. sometimes d. often e. always
86.	I'm highly motivated to remember new things I learn.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
87.	I do not get flustered when I am put on the spot to remember new things.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
88.	I am good at remembering titles of books, films, or plays.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
89.	My memory has declined greatly in the last 10 years.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
90.	For most people it is easier to remember things in which they are most interested than things in which they are less interested.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
91.	I have no trouble remembering lyrics of songs.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly

92.	My memory will get better as I get older.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
93.	It is easier for most people to remember bizarre things than usual things.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
94.	Do you write yourself reminder notes?	a. never b. rarely c. sometimes d. often e. always
95.	I am good at remembering names of musical selections.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
96.	Most people find it easier to remember visual things than verbal things.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
97.	After I have read a book I have no difficulty remembering factual information from it.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
98.	Do you write appointments on a calendar to help you remember them?	a. never b. rarely c. sometimes d. often e. always

99.	I would feel very anxious if I visited a new place and had to remember how to find my way back.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
100.	I am good at remembering the content of news articles and broadcasts.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
101.	No matter how hard a person works on his memory, it cannot be improved very much.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
102.	If I were to work on my memory I could improve it.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
103.	It gives me great satisfaction to remember things I thought I had forgotten.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
104.	Remembering the plots of stories and novels is easy for me.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
105.	I am usually able to remember exactly where I read or heard a specific thing.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly

106.	I think a good memory comes mostly from working at it.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
107.	Most people find it easier to remember unorganized things than organized things.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
108.	Do you write shopping lists?	a. never b. rarely c. sometimes d. often e. always