Re-examining rumination: An investigation into the relative contributions of reflective and brooding ruminative processes to problem solving

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Thesis Abstract

Rumination has classically been associated with depressive symptoms and is often used as a clinical indicator for depression; however, a re-evaluation has recently suggested rumination may comprise of two sub-components: adaptive reflection, and maladaptive brooding. A separate line of enquiry has used evolutionary thinking to suggest that rumination is an adaptive process which facilitates problem solving. To date, there is little in the way of empirical support for these claims, nor have there been investigations into how the reflection/brooding dichotomy may fit into the adaptive framework. Moreover, no comment has been made with regard to the mechanisms through which rumination may influence problem solving. Four experiments sought to address these issues and better understand rumination in non-clinical populations. The results from study one indicate that reflection and brooding are both associated with improved problem solving in social-type and risk-reward problem solving, but not in abstract problem solving. In study two, reflective rumination was found to be positively associated with working memory capacity, whereas brooding and analytical ruminations were associated with slowed responses in a Posner attention task and stop signal reaction time task respectively. Study three explored the novel observation that brooding was useful in risk-reward scenarios, with results indicating that the availability of risk information did not moderate the effects of brooding. Finally, study four explores whether differences exist between trait and state rumination and if these differences may account for inconsistencies between studies. From these results, it is clear that rumination can no longer be treated as a unitary construct. More critically, the notion of brooding as a maladaptive force must be reconsidered by the wider literature, and it is advised that future research consider the relative balance between reflection and brooding in their samples.

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Statement of Copyright

Declaration

I, Yan Kristian Birch, declare that none of the work contained in this thesis has been submitted for consideration as part of a degree programme previously, either here elsewhere.

All work presented here is my own, and where information has been derived from other sources this has been indicated.

This thesis was prepared in accordance with the guidelines outlined by Durham University's Graduate School and in the Department of Psychology's Postgraduate Handbook. References have been amalgamated at the end of the thesis for ease of reading.

Yan Kristian Birch

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I dedicate this thesis to you all. This is yours, as much as it is mine now.

Thesis Aims and Chapter Summaries

This thesis aims to investigate a novel hypothesis derived from applying evolutionary theory to the development of depression which states that rumination is the critical component responsible for depression's persistence due to its potential role as an adaptive mechanism in complex problem solving. In doing so we aim to better understand rumination's role in non-clinical populations, adopting the view that depression is one extreme on an adaptive continuum. Thus, depression persists as those affected negatively (i.e. through maladaptive rumination) are rarer than those who experience the benefits of adaptive rumination associated with normal levels of low mood, and so in terms of genetic fitness, the overall benefits of the many outweigh the negative effects of the few. Furthermore, while it has been hypothesised that rumination facilitates more effective problem solving, there has been no suggestion to our knowledge of the potential mechanisms through which this effect occurs. Consequently, we aim to investigate rumination's association with specific aspects of cognition, namely those considered executive functions, as these cognitive processes are thought to play some role in problem solving and so are natural candidates through which rumination may impact problem solving. As will be discussed, unipolar depression presents a serious and growing problem to both individuals and society at large, placing a greater burden on health care services as the number of reported cases increases. Beyond the need for improving the treatments available to patients in light of evidence suggesting that as little as 50% of patients enjoy any benefit from medication (Berman, Narasimhan, & Charney, 1997) and many experiencing relapse following behavioural treatments (Paykel et al., 2005), it is critical that we begin to understand why such a disorder persists within the larger population.

Chapter One first presents the rationale behind applying evolutionary thinking to clinical disorder, before detailing how depression may be approached using evolutionary

theory in order to explain depressive symptoms and generate novel, testable hypotheses. The chapter concludes with details of alternative, though not necessarily conflicting, hypotheses which are beyond the scope of investigation in the present thesis, and a discussion of the clinical implications of approaching depression from an evolutionary perspective. Chapter Two provides an overview of the trait measures used throughout the thesis. Chapter Three details an empirical study investigating the relationship between rumination, low mood, and problem solving ability as measured by three different problem solving tasks. Ability in social-style and risk-reward, but not abstract problem solving tasks, was found to be positively related to the adaptive (reflection) and maladaptive (brooding) components of rumination. As such, this chapter gives the first indication that 'maladaptive' rumination may not, in fact, be as maladaptive as initially thought. The potential cognitive mechanisms behind these associated improvements are explored in Chapter Four by examining associations between rumination and several aspects of executive function which are thought to be involved in problem solving, namely working memory capacity, response inhibition, and attentional control. Individuals who engaged more frequently in adaptive rumination had an associated increase in working memory capacity. Moreover, individuals who engaged more frequently in 'maladaptive' rumination were found to have slower reaction times in a response inhibition task, while individuals engaging more frequently in analytical ruminations (a type of adaptive rumination) were slower at endogenously deploying attention to invalidly cued trials. For both of these observations, no differences in accuracy were found, suggesting that in these individuals adopt a more cautious approach to the task in order assure accuracy which complies with the potential hesitation account of brooding rumination detailed in Chapter Three. Chapter Five investigates the novel relationship between 'maladaptive' rumination risk-reward problem solving in greater detail, utilising risk-based tasks that vary in the availability of information regarding the risks. Here, no

differences were observed in decision making between the tasks as a function of the frequency of rumination, suggesting that the effects of rumination in these types of task are not dependent on the availability of risk information. Moreover, nuances in the data point to a potential gender difference in the effects of 'maladaptive' rumination on risk-reward problem solving. Chapter Six presents the final empirical study, detailing a pilot investigation of potential differences in the effects of state versus trait rumination. Though preliminary, the results suggest that the involvement of state or trait rumination may vary as a function of the short or long-term nature of a given problem. Finally, Chapter Seven concludes the thesis, discussing the wider implications of rumination reconsidered as a broadly adaptive construct. Critically, this challenges currently held conceptions that rumination, with particular reference to brooding, is a universally maladaptive construct.

Chapter One: Introduction

The integration of evolutionary principles into the study of psychological mechanisms and behaviours has steadily increased over the past three decades. Indeed, it is now common to offer not only *proximate* (immediate) explanations for a given behaviour but also *ultimate* (evolutionary) explanations on the persistence of a given behaviour or mechanism within the population. However, while such explanations have been applied to a broad range of behaviours such as language (e.g. Christiansen & Kirby, 2003; Hauser, Chomsky, & Fitch, 2002; Nowak & Krakauer, 1999) mate selection (e.g. Buss, 1988; Gangestad & Simpson, 2000) and aggression (e.g. Archer, 2009; Campbell, 1999), attention has only recently been brought to the domain of psychiatry. At first, it appears paradoxical to consider any form of psychopathology as adaptive, or indeed having adaptive origins; however, the persistence of disorders such as unipolar depression, bipolar disorder, schizophrenia and generalised anxiety requires explanation. In spite of the detrimental effects of these disorders on both sufferers and their families, they remain within the population and are observed across cultures (Draguns & Tanaka-Matsumi, 2003). As such, it is important to ask why the capability to develop these disorders remains and why evolution has not selected against this capacity, as this may ultimately lead to the development of new research questions which may, in turn, inform future treatments (Nesse, 1984).

1.1 Evolution and Psychopathology

In recent years, evolutionary explanations for psychopathology have become more prevalent. For instance, hypotheses on the adaptive nature of bipolar depression (Sherman, 2001, 2006, 2012), obsessive compulsive disorder (Abed & de Pauw, 1998; for a review, see Feygin, Swain, & Leckman, 2006) and eating disorders (Abed, 1998) have been offered; although few have received widespread attention or acceptance. By contrast, unipolar depression, generalised anxiety, and schizophrenia have been the subject of extensive

theorising and debate with regards to their evolutionary origins. Schizophrenia, for example, is a highly heritable condition commonly characterised by auditory hallucinations, inappropriate affective response and delusions (Andreasen, 1995), in addition to a broad range of neurocognitive deficits (Heinrichs & Zakzanis, 1998), including attentional (e.g. Braff, 1993; Cornblatt & Keilp, 1994; Orellana, Slachevsky, Peña, & Pena, 2012; Urbanek et al., 2009), working memory (e.g. Lee & Park, 2005; Silver, Feldman, Bilker, & Gur, 2003; Stone, Gabrieli, Stebbins, & Sullivan, 1998), language processing (e.g. Bagner, Melinder, & Barch, 2003; DeLisi et al., 1997; Faber & Reichstein, 1981; Marini et al., 2008), and motor deficits (e.g. Manschreck, Maher, Rucklos, & Vereen, 1982; Sullivan, Shear, Zipursky, Sagar, & Pfefferbaum, 1994; Tigges et al., 2000). In spite of this symptom profile, a number of theories have been offered on the evolutionary origins of the disorder. Functional theories have made associations between schizophrenia and increased creativity, such that schizophrenia is the extreme result of sexual selection for creativity in schizotypy (Nettle & Clegg, 2006), or have linked schizophrenia with cultural shamanism with schizophrenia linked genes propagating as a result of schizophrenic individuals being valued as spiritual leaders (Polimeni & Reiss, 2002). Additionally, genetic evidence suggests that schizophrenia-linked genes have in fact undergone positive selection and accelerated the evolution of schizophrenia (Crespi, Summers, & Dorus, 2007). An evolutionary model of schizophrenia is still, however, far from comprehensive and it is, as yet, unclear how such a model may inform clinical practice.

The application of evolutionary thinking to generalised anxiety has more immediate implications for clinical practice. It has been hypothesised that anxiety has developed from a need for enhanced vigilance in the evolutionary environment (M. Bateson, Brilot, & Nettle, 2011; Marks & Nesse, 1994), where predators were more abundant, mortality was higher, and survival was dependant on proper recognition of potential threats. In such a scenario, it

would be better to be more vigilant and perceive more threats where there were none (i.e. false alarms) than to become lax and fail to recognise a potentially fatal threat. This 'smoke detector principle' (Nesse, 2001) suggests that the energetic costs of false alarms are outweighed by the energetic costs of fatal encounters; thus in such an environment, it is more advantageous to flee in any scenario than face the possible consequences. Over successive generations, the perceptual bias for danger would become more extreme as individuals in possession of this genotype successfully reproduce. Moreover, as our environment has changed, predators are no longer a prominent threat, and therefore high levels of vigilance are no longer required and where it remains, it manifests as anxiety. Such a model may give insight into when anxiety may be adaptive and, as such, may help to shape treatment plans on a patient-by-patient basis (Nesse, 2001).

The evolutionary approach advocates the view of psychopathology as a continuum, such that a given psychopathology is the manifestation of the extreme upper tail of a normal distribution of a given trait, in line with genetic variation and expression within the population (Crow, 1997). Not only does adopting this view go some way towards explaining why any given psychopathology persists in the population by suggesting that psychopathological expression follows a normal distribution (and does not, therefore, impact fitness in the majority), it also challenges current clinical practices. For example, it is common for patients to be prescribed medication in response to seeking psychological help, with as many as one-in-five adults receiving psychiatric medication in the United States in 2010 (World Health Organization, 2011). However, under the continuum view, it is possible that a significant proportion of these prescriptions are in fact for adaptive levels of a given trait. For example, some individuals receiving medical treatment for anxiety may, in fact, be experiencing an adaptive response to their environment, such that there is a tangible threat to them within their environment. Indeed, one may then predict that levels

of anxiety vary as a function of threat probability, which is supported by epidemiological data examining levels of anxiety in relation to mortality threats (e.g. Breslau, Schultz, & Peterson, 1995; Lahti et al., 2010; Najman et al., 2010). Further support for the continuum approach stems from observations that mortality is lower in individuals who experience moderate levels of anxiety compared to those who experience low levels of anxiety (Lee, Wadsworth, & Hotopf, 2006). Moreover, in patient samples, individuals with comorbid anxiety disorders have lower mortality rates than patients without a comorbid anxiety diagnosis (Mykletun et al., 2009), indicating that anxiety may have some protective properties, even at the clinical level. It is important to note that while at some level a psychopathology may be adaptive from an evolutionary perspective, the experienced distress in and of itself warrants some form of address. What is currently unknown, however, is the long term consequence of suppressing a potentially adaptive response with medication (Nesse & Berridge, 1997), although evolutionary analyses suggest some medications negatively impact upon other adaptive processes over time (Andrews, Thomson, Amstadter, & Neale, 2012). Prolonged elevation of post-synaptic serotonin levels as a result of chronic antidepressant use, for example, can revert neurons to a functionally immature state, thereby impacting neural processing (Kobayashi et al., 2010). Thus, it is plausible that suppressing potentially adaptive responses in the short term may lead to greater and more enduring negative consequences because the causes of the adaptive response are not addressed.

In sum, as has been shown in the field of anxiety, applying evolutionary principles to the study of psychopathology allows for the development of novel hypotheses in the investigation of psychopathology. Moreover, in advocating a continuum approach to psychopathology, evolutionary hypotheses may be investigated at the sub-clinical level, with a view to assessing whether a given characteristic is adaptive at low levels of expression or

whether it is detrimental to some degree at all levels of expression. In adopting this approach, it is possible to apply an empirical framework in which to test these hypotheses. By assessing individuals who fall on different points of a continuum, it is possible to identify common characteristics between the clinical and non-clinical manifestations of a given disorder and in turn, assess the qualitative differences between them. Ultimately, it may then be possible to discern the potential adaptive value of a psychopathology, relative to the level of expression, which is not traditionally possible when assessing differences using an extreme groups approach (Preacher, Rucker, MacCallum, & Nicewander, 2005). As noted, evidence associating schizotypy, creativity, and mating success (Nettle & Clegg, 2006), in addition to evidence of enhanced threat detection in elevated levels of anxiety (Doty, Japee, Ingvar, & Ungerleider, 2013; Muris et al., 2000; Richards, Hadwin, Benson, Wenger, & Donnelly, 2011; for a review, see Richards, Benson, Donnelly, & Hadwin, 2014) demonstrate how evolutionary theory can generate empirical hypotheses and move beyond 'just so' stories, an approach the studies delineated here will take.

In spite of moving toward a more rigorous empirical framework, the study of evolutionary psychopathology remains largely populated by theoretical debate, particularly when considering unipolar depression. Given the potential benefits of adopting an evolutionary approach to psychopathology, this is especially concerning as recent estimates of disease burden rank depression second behind ischaemic heart disease in terms of Disability-Adjusted Life Years (DALYs), a measure of life years lost and years spent living with disability as a result of disease (Murray & Lopez, 1997). Moreover, epidemiological data from the United States suggests that the prevalence of depression is increasing year on year (Conway, Compton, Stinson, & Grant, 2006). Thus, it is clear that depression represents a persistent and growing problem that requires immediate address. The remainder of this chapter will outline evidence for the evolutionary basis of depression before presenting

evidence for an evolutionary model of depression emphasising rumination as a critical component of adaptation by facilitating enhanced analytical abilities. Finally, alternative theories will be discussed before highlighting the potential clinical impact of investigating evolutionary hypotheses of depression.

1.2 Unipolar Depression: Neurochemistry and Rumination

Unipolar depression is an affective mood disorder characterized by low mood, changes to both eating and sleeping patterns, anhedonia (the inability to enjoy pleasurable activities) and recurring thoughts of death or suicide (American Psychiatric Association, 2013). Changes in neurochemistry have been implicated in the genesis and maintenance of depressive episodes (e.g. Coppen, 1967), with such changes informing pharmacological treatments of depression. One mechanism of action for such treatments is primarily focussed on inhibition of serotonin reuptake at synapses throughout the brain (Vaswani, Linda, & Ramesh, 2003), with a view to enhancing serotonin's mood enhancing properties through prolonged exposure to elevated post-synaptic serotonin levels. Critically, however, alleviation of symptoms is not immediate (Katz, Koslow, & Frazer, 1996; Stassen, Angst, & Delini-Stula, 1999), taking six weeks on average for neurochemical changes to take effect (Frazer & Benmansour, 2001). This suggests that acute levels of serotonin may not play a causal role in the manifestation of depression, but may instead serve as a clinical indicator. This assumption is further supported by evidence of associations between selective serotonin reuptake inhibitors (SSRIs) and attempted suicide (Fergusson et al., 2005; Healy & Whitaker, 2003; Möller et al., 2008), in addition to evidence of medication-resistant depression affecting as much as 50% of those receiving treatment for depression (Berman et al., 1997). Indeed, SSRIs have been shown to up-regulate neurogenesis within the atrophied hippocampi of depression patients (Schmidt & Duman, 2007; Warner-Schmidt & Duman, 2006), and it is this process which explains the lag between beginning antidepressant

treatment and symptom alleviation. It is, therefore, apparent that other factors are involved in the onset and continuation of depressive episodes.

Stressful life events (SLEs) are often reported as preceding episodes of depression (e.g. Brown, 1998; Horesh, Klomek, & Apter, 2008; Pine, Cohen, Johnson, & Brook, 2002) and are widely accepted as causal factors, having been shown to interact with epigenetics in predicting vulnerability to, and development of, depression (Caspi et al., 2003). Specifically, chronic exposure to the stress hormone cortisol is thought to inhibit serotonin transport by decreasing serotonin receptor sensitivity; however, polymorphism in the serotonin transport gene 5-HTT moderates the impact of cortisol, resulting in variability in susceptibility to depression within the population (Caspi et al., 2003). It is of note that while SLEs are strong predictors of depression onset, they are not as strongly associated with duration and maintenance of a given episode (Horesh et al., 2008), nor to our knowledge are polymorphisms; thus, while an SLE may trigger a depressive episode, its duration is subject to a further factor: rumination.

Rumination has been defined as a thought-style characterised by repetitive and passive thinking on negative emotions and is a core symptom of depression, predicting episode severity, duration, and subsequent onset of new depressive episodes (Martin & Tesser, 1996; Nolen-Hoeksema, 2000), and has been found to be elevated in both partially and fully remitted depression patients (Riso et al., 2003). Moreover, rumination is associated with treatment-resistant variants of depression, with higher levels of rumination associated with a reduced probability of achieving remission (Jones, Siegle, & Thase, 2008) and more residual symptoms following treatment (Schmaling, Dimidjian, Katon, & Sullivan, 2002). As such, it is clear that rumination is a critical factor when considering a patient's long-term outcome and response to treatment; however, current practice often overlooks the impact of rumination and instead focuses on biological interventions, coping strategies, or a

combination of both. Before examining rumination itself in more detail, the development of the rumination hypothesis of the evolution of depression will be discussed.

1.3 The Evolution of Depression and the Rumination Hypothesis

Depression and its associated disorders have classically been approached as purely pathological under the disease model of medicine, despite a growing body of evidence to suggest the contrary. Again, it is important to state from the outset that in arguing for an adaptive function of depression, it is in no way argued that the suffering experienced by such patients is diminished or trivialised. Rather, the suffering in and of itself warrants treatment. The adaptive significance of bodily responses that are commonly viewed as unpleasant is now well documented. For example, fever is an immunological response to bacterial pathogens, intended to elevate body temperature to a point in which pathogens cannot survive (Blatteis, 2003). Another example concerns pregnancy sickness, which is thought to be a means of preventing ingestion of potentially toxic foods that may harm or prove fatal to an unborn child (Cardwell, 2012; Profet, 1992). Though these examples concern physiological responses, it is not unreasonable to assume that psychological mechanisms may have developed in a similar manner.

Further evidence for a potential evolutionary origin for depression comes from research into genetics that may underpin psychological disorder. Links between polymorphism in serotonin transporter gene 5-HTT and vulnerability to depression are now well supported (e.g. Caspi et al., 2003; Wilhelm et al., 2006; for meta-analyses, see Clarke, Flint, Attwood, & Munafo, 2010; Karg, Burmeister, Shedden, & Sen, 2011; however, for alternative views, see Risch et al., 2009) with evidence from twin and familial studies also supporting a strong genetic component (Sullivan, Neale, & Kendler, 2000). From an evolutionary perspective, it is difficult to reconcile the heritability of depression (approximately 40%-66%; de Geus & Middeldorp, 2013) with the consistent observations

of negative outcomes in patients, without considering a possible adaptive mechanism. Specifically, evolutionary theory predicts that common genetic polymorphisms that negatively impact fitness are likely candidates for elimination through natural selection (Homberg & Lesch, 2011). Thus, over the course of our evolutionary history, natural selection should have acted against 5-HTT polymorphism were it purely disease-linked and conveyed no adaptive advantage. A recent study examining fecundity of patients with a variety of psychiatric disorders (including depression) and their unaffected siblings found that only male depression patients suffered from a reduction in fecundity, with female patients remaining unaffected. Further to this, siblings of patients were found to have *increased* fecundity, which suggests the genes associated with depression are not negatively impacting reproductive success, and may, in fact, be facilitating reproduction in siblings (Power et al., 2013). Moreover, the prevalence rate of depression in the population exceeds the minimum 1% which would suggest that a disorder is attributable to a genetic mutation (Huxley, Mayr, Osmond, & Hoffer, 1964). Indeed, conservative estimates of prevalence and mutation rates in depression suggest that depression is observed in the population at 100 times the spontaneous mutation rate estimated for humans (Edwards, 1974; Longley, 2001). Thus, it is argued that depression, or the genetic material associated with depression, must have undergone some form of selection, otherwise, it would be observed at far lower rates in the general population.

Finally, it is also important to consider epigenetics, a phenomenon by which gene expression is modified through exposure to and interaction with the environment. Zhao, Goldberg, Bremner, and Vaccarino (2013) demonstrated a link between DNA methylation (an epigenetic biomarker) variation and variation in depressive symptoms in monozygotic twins. Crucially, this finding was independent of both shared genetic and environmental factors, demonstrating that unique, individual-environmental interactions contributed to

depressive symptoms at the genetic level. Moreover, 5-HTT polymorphism was found not to influence the association between DNA methylation and depressive symptoms. This and previous studies (e.g. Mill & Petronis, 2007; Schroeder, Krebs, Bleich, & Frieling, 2010) suggest that individuals are capable of developing depression irrespective of their genotype. As such, the *capacity* to develop depression under certain environmental conditions may also be indicative of adaptation. It is worth noting that epigenetic changes are heritable (Petronis, 2010) and may propagate depression in environments where it may be adaptive. Heritable epigenetic changes result in adaptation by increasing phenotypic variability in response to fluctuating environments, rather than directly influencing the average phenotype. Specifically, it is not the trait itself that is affected, but rather the propensity to vary phenotypically, such that a given genotype may result in a variety of phenotypes depending on environmental input (Feinberg & Irizarry, 2010).

Evolutionary accounts of depression have undergone numerous iterations in the last three decades and have ranged from mechanisms of population regulation via goal disengagement (Klinger, 1975) to plea-for-help mechanisms like those observed in crying infants (Lummaa, Vuorisalo, Barr, & Lehtonen, 1998). Critically, these theories have either failed to account for how such a trait may be inherited (disengagement theory) or have failed to explain the adaptive function of all symptoms of depression (plea-for-help theories). More recently, it has been suggested that depression is an adaptive response to significant environmental changes that may render previously safe behaviours dangerous to the individual (Welling, 2003). Under this framework, it is argued that depressive symptoms represent valid reactions to sudden changes in circumstances. For example, loss of appetite may serve as a protective factor when the environmental change results in uncertain food sources, such that new food sources may be potentially harmful. Similarly, a reduction in libido results in a decline in sexual activity, which may reduce the risk of predation and

nutritional demands associated with increased metabolic activity. Such examples provide clear short-term solutions to problems posed by a changing environment; however, behaviours such as avoiding reproduction do not benefit evolutionary fitness in the long-term. Thus, behaviours such as these must serve to facilitate the development of a long-term solution.

The analytical rumination hypothesis (Andrews & Thomson, 2009) posits that the withdrawal from behaviours such as reproduction and regular feeding allows for focussing solely on the immediate environmental challenges, with resources dedicated to cognitive processing ultimately manifesting in prolonged rumination. It is thought that, through rumination, previously safe behaviours are analysed with respect to the new environment in order to assess their viability. Once new behavioural strategies are developed, rumination discontinues and the depressive episode alleviates. Therefore, the rumination hypothesis predicts that individuals experiencing lower levels of mood will benefit from enhanced analytical abilities as a consequence of elevated levels of rumination.

1.4 Depression in the Modern Environment: Testing the Rumination Hypothesis

One common problem with evolutionary theories pertains to their empirical investigation. Indeed, the modern environment is quite different to that of our evolutionary ancestors, such that many of the environmental problems they were confronted with do not necessarily apply today. Thus, it becomes difficult to assess a potential adaptation because the current environment may be incongruent with that in which the mechanism evolved. For example, as noted, it has been hypothesised that anxiety disorders stem from a need for elevated vigilance due to constant predatory threat (Bateson et al., 2011; Marks & Nesse, 1994); however, predators no longer pose the threat they once did. As such, it is challenging to test hypervigilance to predatory threat in the modern environment. With reference to depression, the changes in environment experienced by our ancestors may be incongruent with what is

considered an environmental change now. Competition for food sources, for example, has dramatically reduced, such that food availability rarely fluctuates and thus, assessing food source viability is no longer required. By contrast, modern examples of environmental change may include voluntary immigration to a new culture, or acculturation (Lassetter & Callister, 2009; Rasmussen, Crager, Baser, Chu, & Gany, 2012) or even winning the lottery (Nisslé & Bschor, 2002); all of which have been associated with depression onset.

It is evident that modern environmental challenges differ from those of our evolutionary ancestors; however, the rumination hypothesis generates testable predictions outside of the evolutionary environment. Specifically, though the environmental triggers may differ, an improvement in analytical ability should be observable in individuals experiencing a depressive episode when given problem solving tasks unrelated to the environmental trigger. To date, however, there have been few empirical studies examining this prediction. Early evidence in support of the hypothesis is derived from Hokanson, Sacco, Blumberg, and Landrum's (1980) investigation into interpersonal behaviours of depressed individuals when participating in a modified Prisoner's Dilemma paradigm. Under the modified paradigm, participants were placed into either a 'high power' or 'low power' position, such that participants in the high power position would be able to view the low power position participant's decision prior to making their own. As such, participants in the high power position were given the opportunity to maximise their points total on each trial by calculating which decision would benefit them most based on their partner's decision. It was found that depressed participants scored significantly more than their healthy counterparts in each condition, suggesting that depressed participants were better able to analyse the current scenario in order to maximise goal-related output. More recently, Surbey (2011) reports similar findings, and though these are interpreted in terms of self-deception and co-operation, the pattern of behaviour remains the same.

The relationship between problem solving and depression has now begun to be detailed more extensively (e.g. Donaldson & Lam, 2004; Marx, Williams, & Claridge, 1992; Watkins & Baracaia, 2002), and lends further support to the rumination hypothesis. For instance, Anderson, Goddard, and Powell (2011) examined the predictive power of problem solving ability on subsequent episodes of depression. Over a three-month period, Anderson and colleagues found that problem solving ability significantly predicted the onset of depressive episodes, such that those who were less able to effectively solve problems were more likely to subsequently experience a depressive episode. Critically, this association held not only for abstract problem solving but also for real-life problem solving, suggesting that an inability to successfully navigate individual environmental challenges is associated with depression onset. With regard to the rumination hypothesis, it follows that being unable to solve a particular problem initially results in increased demand for cognitive resources. Rumination should, therefore, increase in order to address the problem, with the increasing cognitive demand resulting in behavioural changes manifesting as depressive symptoms. These symptoms then persist because individuals who are still unable to solve the immediate problem continue to dedicate resources to solution generation. This contrasts with participants who were better able to solve problems, thereby requiring fewer resources dedicated to cognitive processing and thus having no adaptive need for depressive episodes.

Empirical studies that explicitly investigate the relationship between rumination, mood, and problem solving outside of a social context are few, and so, at present, generalisations based on the available data are difficult. Nevertheless, preliminary evidence would appear to support a model in which depression facilitates rumination for the purposes of solving complex problems. In spite of sparse empirical data, contradictory evidence has been offered that challenges the notion of rumination, and therefore depression, being adaptive at all. A number of studies have begun to report negative relationships between

rumination and problem solving ability, particularly in dysphoric and clinically depressed individuals (e.g. Donaldson & Lam, 2004; Kao, Dritschel, & Astell, 2006; Raes et al., 2005). However, there is now a growing body of evidence that suggests that these results are not incompatible with the evolutionary model and may themselves be explained in terms of evolutionary principles, namely that of cliff-edged fitness.

1.5 Cliff-Edged Fitness and the Manifestation of Rumination

The principle of cliff-edged fitness purports that expression of a particular trait increases fitness exponentially until a point, after which, increased expression is in fact associated with decreases in fitness (Nesse, 2004). For example, uric acid has been shown to protect against oxidative tissue damage in humans (Ames, Cathcart, Schwiers, & Hochstein, 1981; Becker, 1993). Thus, increased levels of uric acid result in decreased oxidative stress, which may ultimately decrease the likelihood of developing cancer (Dröge, 2002; Valko et al., 2007) and cardiovascular diseases (Cai & Harrison, 2000; Stocker & Keaney, 2004). However, elevated levels of uric acid have been linked with the development of gout through uric acid crystallisation around joints (Choi, Mount, & Reginato, 2005; Terkeltaub, 2003). While the evolutionary advantages of resistance to developing cancer and cardiovascular disease are clear, the consequences of supernormal uric acid levels are as important. Considering that the precipitation of uric acid crystals around joints results in acute arthritis, this consequently inhibits movement. With a reduction in movement comes an increased risk of predation due to an inability to evade threats as effectively. Moreover, limited movement may impact upon male mating strategies, with males being unable to maintain larger territories and thus access to more resources and potential mates. As such, increasing longevity through resistance to life-threatening illnesses increases fitness by extending the reproductive lifespan; however, fitness is then inhibited when levels of uric acid become excessive and potentially result in fewer mating opportunities and increased risk of predation.

Cliff-edged fitness may help explain the somewhat contradictory findings of rumination having negative associations with problem solving abilities. Indeed, the notion of two forms of rumination, adaptive and maladaptive, has begun to be explored in the literature. Specifically, adaptive rumination has been defined as more reflective in nature (Joormann, Dkane, & Gotlib, 2006; Treynor, Gonzalez, & Nolen-Hoeksema, 2003) and is rooted in a concrete and experiential style of thinking (e.g. Watkins, 2008; Watkins & Moulds, 2005) which is associated with better problem solving ability. Moreover, these improvements occur when rumination is goal-oriented (Ciarocco, Vohs, & Baumeister, 2010). Maladaptive rumination, by contrast, is characterised by a brooding thought style (Joormann et al., 2006; Treynor et al., 2003) which focuses on abstract thoughts (Watkins, 2008) and is not as goal-oriented as adaptive rumination (that is, rumination which in some way benefits an individual's evolutionary fitness). For example, Watkins and Moulds (2005) demonstrated in a depressed sample that realigning rumination to a more concrete and experiential mode resulted in enhanced performance on a social problem solving task. However, participants who maintained abstract ruminative styles were significantly worse at solving social problems. Similarly, Ciarocco et al. (2010) found performance improvements in a creativity task when ruminative thoughts were goal-oriented, especially following a perceived failure. Although evidence is only preliminary at present, these studies suggest that there is a point at which rumination changes from being adaptive to being maladaptive (see Table 1.1) for a summary of differences between these concepts); however, the nature of this transition has yet to be investigated. Henceforth, adaptive and maladaptive rumination shall be referred to as reflection and brooding respectively.

Table 1.1*: Characteristics of adaptive (reflection) and maladpative (brooding) rumination as described by the literature*

Adaptive Rumination (Reflection)	***Maladaptive Rumination (Brooding)***
- *Goal oriented*	- *Self-focussed*
- *Concrete thoughts*	- *Abstract*
- *Experiential*	- *Perseverative*
- *Solution generation*	- *Self-critical*
- *Active*	- *Negative*
	- *Passive*

One potential mechanism of action for rumination's impact on problem solving is through inner speech. Indeed, rumination is thought to have some verbal quality (Nolen-Hoeksema, 2004), and the use of inner speech has been implicated in the problem solving process (e.g. Rohrkemper, 1986; Williams, Bowler, & Jarrold, 2012; Winsler & Naglieri, 2003), with problem solving itself being dependent on language ability to some extent (Baldo et al., 2005). Moreover, inner speech has been associated with increased self-awareness (Morin & Michaud, 2007), which Morin (2005) suggests is also associated with increased self-reflection, and may assist with personal problem solving. The link between rumination and inner speech has received little attention in the literature thus far; however, there is evidence which suggests that rumination is highly correlated with hallucination proneness in both healthy (Jones & Fernyhough, 2009) and clinical populations (Hartley, Haddock, Vasconcelos e Sa, Emsley, & Barrowclough, 2014). Moreover, Jones and Fernyhough (2009) purport that ruminations may form the raw material for auditory verbal hallucinations (AVHs) given their verbal nature, conforming with models of AVHs which propose that they are the result of errors in source-monitoring of inner speech, as well as

abnormalities in the transition from condensed to expanded inner speech (Jones & Fernyhough, 2007). Whether condensed and expanded inner speech relate differentially to reflective and brooding rumination, and whether they have differential impacts on problem solving is currently unknown; however, this issue is beyond the scope of this thesis.

Of particular note is the relative dearth of empirical studies examining the apparent dichotomous nature of rumination. Indeed as discussed, rumination is largely viewed of as a negative construct; however, this is predominantly derived from studies with clinical populations, whose ruminations may be dysfunctional as a result of their disorder. Moreover, and perhaps more critically, these studies have all assumed rumination to be a unitary construct and have investigated it as such. Thus, any negative effects which may be associated with a specific type of rumination may be attributed to rumination overall. Without fully understanding the individual effects of each ruminative sub-type, it is premature to assume that all rumination is maladaptive, and so it is imperative that the relative contributions of each ruminative sub-type are accounted for, as this may have important clinical ramifications.

1.6 Clinical Implications

As noted, there are concerns over the clinical efficacy of SSRIs for the majority of depression patients in the long term, but also due to the lag between the beginning of this treatment and experiencing any potential symptom release. Moreover, brooding processes may impede behavioural treatments for depression. Rumination has been associated with poorer outcomes following treatment, including the reduced probability of achieving remission (Jones et al., 2008) and more post-treatment residual symptoms (Schmaling et al., 2002). Additionally, high levels of rumination have been found to interact with treatment measures, diminishing the effectiveness of treatment. For example, Ciesla and Roberts (2002) found in a clinical sample that levels of rumination predicted change in depressive symptoms over

the course of treatment, such that higher levels of rumination predicted smaller changes in symptoms and thus, lower treatment effectiveness. Moreover, high levels of rumination have been found to impede the effectiveness of neurostimulation interventions (Loo, 2014). Aside from pharmacological interventions, one common treatment for depression is cognitive behavioural therapy (CBT), which typically seeks to address negative thoughts in depression, although delivery is highly heterogeneous. While CBT has achieved some success in the acute treatment of depression (Hollon & Ponniah, 2010), its long-term efficacy has been questioned. For instance, of patients receiving CBT, one third experience relapse within 68 weeks (Paykel et al., 1999), with the beneficial effects of CBT diminishing for all patients within three and a half years (Paykel et al., 2005). While it is true that CBT as a treatment approach has undergone substantial changes in recent years, there are still questions as to whether it is effective for long-term remission, with follow-up studies reporting mixed results (e.g. Andersson et al., 2013; Wagner, Horn, & Maercker, 2014) Brooding may play a key role in these diminishing effects, such that traditional CBT may be unable to modify the *content* of thought due to the dysfunctional thought *process* of rumination.

The distinction between thought content and process is subtle but important. Specifically, content refers to the subject of the thought itself, which is typically negative in depression. In CBT, it is thought that by replacing negative thought content with positive thought content, symptoms may be reduced. By contrast, thought processes refer to styles of thinking (e.g. abstract analytical). Here, we postulate that maladaptive rumination maintains negative thought content (e.g. depressogenic problems) at the forefront of consciousness by framing current negative thoughts in an abstract manner. As maladaptive rumination is not as goal-oriented (i.e. focussed on solution generation), this creates a feedback loop in which the triggering problem remains salient due to failure to generate and implement a solution.

Thus, the triggering problem persists and rumination continues. Traditional CBT is consequently impeded from accessing the content of thought as cognitive resources are increasingly dedicated to the triggering problem, creating resistance to changes in thought content as attention is concentrated solely on the triggering problem.

From this model, it is possible to derive hypotheses grounded in evolutionary theory that are empirically testable. First, in assuming that rumination is adaptive at certain levels of expression for *all* individuals, beyond which rumination becomes destructive, it is predicted that in severe clinical depression attenuation of rumination will result in greater CBT adherence and improved long-term efficacy. This would be achieved by reducing the allocation of cognitive resources to depressogenic content and, therefore, allowing CBT to address the content directly and effectively. Preliminary evidence provides support for this hypothesis. For example, clinical trials of rumination-focussed CBT (RF-CBT), a form of CBT which seeks to address ruminative thought processes specifically, have shown significant improvement on outcome measures in depressed patients (Watkins et al., 2007), in addition to similar improvements when compared to treatment as usual (Watkins et al., 2011). Although sample sizes are small, these studies provide promising evidence that treating rumination is critical to long-term recovery and relapse prevention. Second, in assuming that rumination results in increasing dedication of cognitive resources to a given problem, it is predicted that with increasing levels of depression, and therefore rumination, is an associated increased difficulty in attentional shifting from task-relevant information. Additionally, as attentional shifting becomes more difficult, distraction-based treatment strategies will become less effective. Again, preliminary evidence has been shown to support this hypothesis, with increases in depressed affect associated with increased attentional demands and reduced distractibility (Andrews et al., 2007; Whitmer & Gotlib, 2013) in

addition to evidence of associations between rumination and negative information bias in attentional shifts (Donaldson, Lam, & Mathews, 2007).

Aside from highlighting the importance of rumination in depression and its impact on treatment, evolutionary theory still has much to contribute to clinical practice. As noted, the distinction between adaptive and maladaptive rumination in depression has only just begun to be investigated and as such, further research should seek to affirm this distinction. Moreover, in doing so, efforts should be made to profile the transition from adaptive to maladaptive rumination. By understanding the transition between adaptive and maladaptive rumination in depression, clinicians may then be better able to assess their patients with regard to treatment viability on a case-by-case basis. Specifically, based on a patient's level of expression with regards to rumination, a clinician may determine whether a patient should first undergo treatment to attenuate rumination or is able to start standard treatment protocols. It is hoped that in adopting such a strategy, more patients will experience long-term benefits of treatment and that delivery of treatment will be made more efficient, as only suitable candidates will be assigned to appropriate treatments.

Finally, it is hoped that research in to the adaptive, goal oriented nature of rumination and depression will stimulate the development of new treatment paradigms. For treatment-resistant depression, the use of neurostimulation techniques, such as transcranial magnetic stimulation (TMS) and transcranial direct current stimulation (tDCS), has become more commonplace; however, results remain mixed with regard to patient outcome (Kalu, Sexton, Loo, & Ebmeier, 2012; Wani, Trevino, Marnell, & Husain, 2013; Wassermann & Lisanby, 2001) and the evidence base with respect to its efficacy remains unclear (Miniussi et al., 2008). This, however, may be due to the interactive effects of rumination. As noted, higher levels of rumination (though no distinction was made between reflection and brooding) have been associated with the diminished effectiveness of tDCS in depression (Loo, 2014), thus

negative results reported elsewhere may also be related to higher levels of rumination. Evidence that rumination may interact with treatments at the neural level suggests that neural activity in high ruminators differs from that of low ruminators. As such, a potential avenue for investigation is discerning the neural activity associated with varying levels of rumination. Further to this, it may be possible to characterise activity profiles of adaptive and maladaptive ruminators. In identifying differences in neural activity between adaptive and maladaptive ruminators, it may then be possible to modulate activity specific to maladaptive rumination in an attempt to revert to a more adaptive form. In doing so, neurostimulation may form an effective adjunctive therapy alongside CBT. Further to this, activity profiles may be of diagnostic use in determining how well a patient may respond to given treatment program. As a result, patients may be prescribed different treatment programs on the basis of their neural activity.

1.7 Alternative Hypotheses

Although we argue that there is substantial evidence in support of the analytical rumination hypothesis, it is important to consider and evaluate alternative explanations for the persistence of depression. In recent years, alternative explanations have broadly fallen into two categories: immunological enhancement and social risk aversion. Both approaches will be considered in turn. Moreover, it is important to remember that although these offer alternative viewpoints on the evolutionary adaptiveness of depression, they are not necessarily incompatible with the rumination hypothesis. Indeed, given the complexities of evolution, it is likely that any one adaptation will exhibit benefits across multiple domains.

1.7.1 Immunological Enhancement Hypothesis

The most recent formulation of potential fitness benefits in depression concerns alterations in immunological responses. Specifically, it is argued that depression not only facilitates the combating of new and existing infections at the cellular level, but also halts the spread of

disease at the behavioural level through mechanisms such as social withdrawal (Anders, Tanaka, & Kinney, 2013). The development of this explanation originates in the observation of a persistent inflammatory response in depression (Dowlati et al., 2010) in conjunction with evidence that suggests the risk of developing depression increases following sickness (Dantzer, 2009; Wichers et al., 2006). It is hypothesised that the link between the immune response and depression is mediated by proinflammatory cytokines, which have been shown to modulate serotonin and dopamine levels (Capuron et al., 2003). This hypothesis serves as an extension of the Pathogen Host Defense hypothesis (Raison & Miller, 2013), which posits many of the same fitness benefits as the immunological enhancement hypothesis, but also suggests that depressive alleles did not co-evolve with immunological alleles, but are in fact one in the same with those alleles. To date, the immunological hypothesis is the only hypothesis that tries to account for the novel observations of persistent inflammatory responses in individuals with depression. What is not clear, however, is how these hypotheses can account for the development of depressive episodes following non-immunological events. As noted, the rumination hypothesis may be compatible with this hypothesis, such that ruminative states emerged from aversion behaviours in response to potential contamination, given the potential role of the immune system in depression. Here, it may be hypothesised that higher levels of rumination are associated with an enhanced disgust response to contamination stimuli; a hypothesis that, to the authors' knowledge, has yet to be investigated.

1.7.2 Social Risk Hypothesis

The Social Risk Hypothesis (SRH) posits that depressive episodes, in fact, serve to reduce the likelihood of exclusion from the social group (Dunn, Whelton, & Sharpe, 2012). As such, the withdrawal behaviours exhibited in depression are thought to represent the adoption of a risk-averse social strategy in order to avoid ostracism from the social group. Specifically,

when entering a depressive episode, depressed individuals become cognitively hypersensitive in social situations which reduce socially risky (i.e. confident, acquisitive) behaviours. Moreover, expression of submissive behaviours that diminish threat increases, in addition to comfort-seeking behaviours that elicit social support from close and caring others. At present, there is limited evidence in support of the theory. Badcock and Allen (2003, 2007) investigated risk-aversion strategies in depressed individuals, anxious individuals, and healthy controls and found some support for the theory. However, in their series of small studies, Badcock and Allen (2007) were unable to identify distinct differences in aversion strategies between depressed and anxious individuals. Moreover, clinically depressed individuals did not act as predicted. Specifically, depressed participants were more likely to be averse to attachment situations when the hypothesis suggests they will be *less* averse due to seeking social aid. Maladaptive brooding rumination may account for depressed participants' aversion to, rather than seeking of, attachment, as rumination was not measured. Indeed, reflection and brooding may moderate the relationship between depression and social-risk aversion; however, this association has yet to be investigated. Social-risk may in fact pose a unique social problem that requires careful navigation, and thus, rumination, particularly reflection may aid in analysing the scenario. As such, social-risk may be thought of as a specific complex problem to be solved, and may be explained more broadly by the analytical rumination hypothesis.

1.8 Conclusion

In sum, although the precise adaptive benefit afforded by depression and low mood is still a matter of debate, there is mounting evidence in support of the adaptive origin of depression. Indeed, evidence from studies examining the change in the prevalence of depression in Western cultures (Compton, Conway, Stinson, & Grant, 2006; Jorm, Patten, Brugha, Mojtabi, 2017; Kessler et al., 2005) suggest a pattern of exponential growth in prevalence

rates above the mutation rate which, combined with a multitude of gene-association studies, evidence of high heritability, and a greater understanding of epigenetic transmission, indicate a role for depression beyond the purely pathological. At present, it would appear that the analytical rumination hypothesis provides the most comprehensive account of depression in an evolutionary context and details how depression may progress to a pathological state. Although the rumination hypothesis does not account for observations of immunological enhancement in depressed individuals, it is not incompatible with hypotheses seeking to explain this phenomenon and serves to highlight that the rumination hypothesis may in fact permeate other purported adaptations, such as risk aversion. Indeed, it is likely that a complex disorder such as depression manifests multiple, interrelated adaptations.

As noted, there is some experimental support for the analytical rumination hypothesis; however, there are few studies that directly examine the link between problem solving and rumination, and those that have rarely make reference to the proposed sub-components of brooding and reflection. Thus, Chapter Three seeks to investigate the association between rumination, both broadly as a unified concept and as a function of its sub-components, and problem solving using tasks from multiple problem solving domains. In assuming that the principle of cliff-edged fitness applies to rumination, it is likely that the ruminations observed in patients are predominantly of the brooding-type, contributing to their inability to solve problems effectively. By contrast, goal oriented instances of rumination may occur more frequently in healthy non-clinical populations who do not exhibit difficulties with problem solving, and so the proceeding empirical chapters detail investigations in such populations. Critically, in treating rumination as a dichotomous construct, it is not assumed that reflection or brooding are unique to a specific population. Indeed, it is possible that the relative expression of both reflection and brooding differs

between patient groups and healthy controls. Although other adaptive theories of low mood and depression have been discussed, they are beyond the scope of the present thesis.

Chapter Two: Brief introduction to trait measures used throughout the thesis

In the following sections, the trait measures used throughout the thesis shall be detailed. Internal consistencies for each measure is detailed in each empirical chapter respectively. Additional measures whose use are restricted to single chapters are detailed in the appropriate chapter. Unless otherwise stated, all measures were administered pre- and post-testing and were completed in pen-and-paper format.

2.1 Beck depression inventory (BDI)

The BDI (Beck, Steer, & Brown, 1996) is a 21-item self-report measure designed to assess levels of depression and has been used extensively in mood research, often as the standard by which other depression measures are evaluated (Spielberger, Ritterband, Reheiser, & Brunner, 2003). The measure itself has repeatedly shown high concurrent validities with other clinician and self-report measures (r = .7; Beck, Steer, & Carbin, 1988) and moderate to high test-retest reliability (r = .48-.86). The version used throughout the thesis differed only in the removal of one item (item nine, Suicidal Thoughts) as the measure was not used for diagnostic purposes and it was thought the content might cause undue distress in some participants. For each item, participants could give one of four responses associated with a score of 0-3, with higher scores corresponding to increasing symptom severity. As one item had been removed, the maximum possible score was 60. The following values are proposed as different specifiers of severity (adjusted for the removal of one item): 0-10 to indicate minimal or no depression; 11-16, mild depression; 17-25, moderate depression; and 26-60, severe depression.

2.2 Ruminative response scale (RRS)

The RRS is a 22-item self-report measure which forms part of the larger Response Styles Questionnaire (Nolen-Hoeksema & Morrow, 1991), and measures ruminative responses to low or depressed mood. Given the theorised link between rumination and low mood based on the evolutionary literature (see Chapter One), and given that the majority of the rumination literature utilise the measure, the RRS was deemed the most appropriate measure of rumination, both from a theoretical perspective and as a means to maximise comparability with the larger literature. Example items include "*How frequently do you think about how alone you feel*" and "*How frequently do you think 'What am I doing to deserve this?"*". The RRS reports moderate test-retest reliability (r = .67; Treynor et al., 2003). Additionally, the RRS is comprised of two sub-scales which measure the frequency of reflective and brooding ruminations respectively. The reflection sub-scale is comprised of items 7, 11, 12, 20, and 21 from the overall RRS. The brooding sub-scale is comprised of items 5, 10, 13, 15, and 16 of the overall RRS. Test-retest reliability for these subscales has been reported to be moderate to high (r = .35 - .74; Hasegawa, Koda, Hattori, Kondo, & Kawaguchi, 2013). For all scales, participants gave responses on a Likert scale ranging in scores from 1 (*Almost never*) to 4 (*Almost always*), corresponding to the increasing frequency of which participants experienced the thought detailed by each statement. For the overall RRS, the maximum possible score is 88. For the two sub-scales, the maximum possible score is 20 for each.

2.3 Analytical rumination questionnaire (ARQ)

The ARQ (Barbic, Durisko, & Andrews, 2014) is a 20-item questionnaire designed to measure the frequency of analytical type ruminations. Example items include '*I tried to figure out the best option for dealing with my dilemma*' and '*I tried to find a goal or purpose that was meaningful to me*'. Participants gave responses on a Likert scale ranging

in scores from 1 (*None of the time*) to 5 (*All of the time*). The maximum score for the ARQ is 100, with larger scores being indicative of individuals being more analytical in their ruminations. Given its relative infancy, the ARQ has yet to undergo rigorous test-retest validation through use in other studies; however, the authors' initial analysis seems to suggest the measure has high test-retest reliability (r = .81). The ARQ was chosen as it is purported to measure analytical ruminations specifically, and so, given the theoretical background presented in Chapter One, it would appear to be most appropriate for the aims of the thesis. Furthermore, it is critical that new measures be assessed for their validity, and thus, where appropriate, associations between the ARQ and other measures are made with reference to the original paper

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Chapter Three: Rumination is positively associated with problem solving in social and risk-based tasks, but not in abstract problem-solving tasks.

3.1 Introduction

As discussed in Chapter One, the construct of rumination has begun to be reconceptualised in terms of reflective (adaptive) and brooding (maladaptive) processes, although many studies continue to treat rumination as a unitary construct. To date, studies investigating these proposed sub-components specifically are far from conclusive; however, the available evidence supports their existence. For example, Siegle and colleagues, (Siegle, Moore, & Thase, 2004), using the RRS, found in a community clinical sample that both reflection and brooding sub-scales positively correlated with depression severity; however, brooding showed much stronger correlations than reflection in patients as compared to healthy controls. Similarly, Whitmer & Gotlib (2011), subjecting the RRS to factor analysis, demonstrated this distinction in never depressed and formerly depressed individuals; although in their sample, currently depressed individuals failed to show a clear distinction between reflection and brooding (see also, Joormann et al., 2006). Importantly, such evidence allows for two inferences to be made: 1) rumination may not be a unitary process as originally thought, and 2) rumination may comprise a continuum within an individual, with rumination becoming maladaptive at extreme levels as brooding exerts a greater influence over reflection. Here it is suggested that elevated levels of rumination (as measured by the RRS) comprise a balance between reflective and brooding ruminations. In non-clinical populations reflective rumination, relative to brooding rumination, is more apparent; however, as rumination approaches pathological levels, the balance between reflection and brooding shifts, such that brooding becomes more apparent.

In spite of evidence suggesting the existence of reflective and brooding ruminations, the specific adaptive benefits of rumination remain debated. Indeed, reflection has been associated with greater chance of recovery from depressive episodes (Arditte & Joormann, 2011), lower levels of depression longitudinally (Eisma et al., 2015; Treynor et al., 2003), and as a potentially protective factor against addictive relapse in individuals with substance use problems (Adrian, McCarty, King, McCauley, & Stoep, 2014; Willem, Bijttebier, Claes, & Raes, 2011); yet the potential behavioural benefits remain poorly understood. The analytical rumination hypothesis (Andrews & Thomson, 2009) posits that rumination is the core process responsible for the evolution of depression, such that depression evolved as a mechanism to facilitate ruminative states. Under this framework, rumination allows for the focussing of cognitive resources on problems in the individual's environment with a view to generating solutions to these problems. As such, it has been hypothesised that individuals who engage in more frequent ruminations will, in turn, perform better in problem solving tasks than those who ruminate less frequently. To date, direct evidence for this hypothesis is limited, with only one study demonstrating that low mood induced by task feedback improves performance (Au, Chan, Wang, & Vertinsky, 2003). Indirect evidence has been taken from experiments examining the effects of mood on social interactions (Hertel, Neuhof, Theuer, & Kerr, 2000; Hokanson et al., 1980). Critically, however, these studies took no measure of rumination, and so the validity of these findings with respect to the analytical rumination hypothesis is diminished. Incorporating the reflection and brooding dichotomy, it is hypothesised that analytical rumination is associated with reflective rumination, and thus, is more adaptive in nature.

Previous research has predominantly examined clinical populations with respect to rumination, resulting in the maladaptive profile of rumination. However, by relying solely on clinical data, the possibility that rumination manifests as a continuum and may have

distinct qualities in healthy individuals as compared to patients is ignored. Indeed, the medical dichotomy model (i.e. the presence or absence of a given disorder) has begun to be eschewed in favour of a continuum model in the field of psychosis research (Berna et al., 2017; Garrison et al., 2017; Oestreich et al., 2015, 2016; Shevlin, McElroy, Bentall, Reininghaus, & Murphy, 2017) , with a view to elucidating the aetiology of psychosis. In adopting a continuum approach, one may begin to investigate the existence of a transition from non-pathological to pathological levels of a given trait. With respect to rumination, adopting a continuum approach allows for the examination of the relative balance of reflective (i.e. adaptive) and brooding (i.e. maladaptive) rumination within an individual. Moreover, the relative balance of these ruminations and their associations with mood levels can be examined. Documenting changes in this relative balance may have potential clinical benefits, such that early recognition of maladaptive ruminations may lead to earlier interventions.

In the present study, therefore, it was hypothesised that individuals with higher levels of low mood, but without diagnoses of depression or other psychological disorders, would engage more frequently in reflective rumination and therefore benefit from enhanced performance in problem solving tasks. As predicted the relationship between low mood and task performance would be mediated by levels of reflective rumination. Additionally, it was predicted that reflection and brooding would be related to task performance differentially, such that reflection would correlate positively while brooding would correlate negatively. Finally, given the high co-morbidity of mood and anxiety disorders (Kessler et al., 2003; Wittchen & Jacobi, 2005), levels of anxiety were assessed in order to investigate the relationship between anxiety and problem solving ability. Anxious ruminations were also measured in order to investigate whether these have a unique relationship with problem solving ability. Typically, anxious ruminations (often

conceptualised as worry) are comprised of thoughts which are pertinent to the self and others and may impact upon the ability to function (e.g. health; Wright, Hurt, Gorniak, & Brown, 2015), and as such, the position in the adaptive-maladaptive dichotomy is as yet unclear.

As problem solving may encompass a large variety of tasks, three were selected, each assessing problem solving in distinct domains. The modified prisoner's dilemma procedure (Hokanson et al., 1980) was chosen as a means for examining social problem solving ability. The modified Iowa gambling task (Cauffman et al., 2010) was selected in order to assess problem solving under conditions of ambiguous risks and rewards with implicit probability learning. These two tasks together also simulate evolutionarily relevant problems: social negotiation and resource gathering under uncertainty respectively. As the final task, Raven's advanced progressive matrices were administered. In contrast to the other two tasks, Raven's assesses abstract, non-verbal reasoning ability. Thus, if reflective rumination correlates positively with performance across all tasks, it may then be inferred that increases in reflective rumination are associated with general increases in problem solving ability. However, if differential relationships are observed, then reflective rumination may be only positively related to problem solving in specific domains. Additionally, if negative correlations are observed between problem solving ability and brooding rumination, then this suggests that brooding rumination may inhibit problem solving ability.

3.2 Methods

3.2.1 Participants

Participants were recruited from the student and staff bodies of Durham University. All participants identified as native English speakers through self-report and were included in

the study if they self-reported no personal or familial history of psychological or neurological disorder, in addition to not currently taking medications of any kind. The final sample comprised of 11 males and 30 females with a mean age of 21.2 years (*S.D.*: 5.3 years). Participants were reimbursed with either course credit or a £5 voucher for an online retailer. The study protocol was approved by the Durham University Department of Psychology Ethics Committee.

3.2.2 Measures

3.2.2.1 Beck depression inventory (BDI)

The 20-item BDI (as reported in Chapter Two, p. 43) reported acceptable internal consistency at both T1 and T2 (Cronbach's α: .771 and .780 respectively).

3.2.2.2 Ruminative response scale (RRS)

The full 22-item RRS (as reported in Chapter Two, p. 44) reported an acceptable internal consistency at T1 and T2 (Cronbach's α: .941 and .918 respectively). Internal consistencies for both brooding and reflection subscales were acceptable at T1 (Cronbach's α: .862 and .861, respectively) and T2 (Cronbach's α: .861 and .872 respectively).

3.2.2.3 Hospital anxiety and depression scale – anxiety subscale (HADS-A)

The HADS-A is a seven-item subscale of the 14-item HADS (Zigmond & Snaith, 1983) which measures levels of anxiety experienced by the participant. Participants gave responses on a Likert scale ranging in scores from 0 to 3, with larger numbers associated with a greater intensity of anxiety associated with a given statement. Participants scoring 0-7 are considered normal; 8-10, borderline abnormal; 11-21, abnormal. The maximum possible score for the scale was 21. The HADS-A reported acceptable internal consistency at T1 and T2 (Cronbach's α: .803 and .764, respectively).

3.2.2.4 Distressing thoughts questionnaire ruminative thoughts subscale (DTQ-R)

The DTQ-R is a five-item subscale of the DTQ (D. A. Clark & de Silva, 1985) designed to assess the frequency with which participants experience anxious ruminative thoughts using a nine-point Likert scale ranging from 1 (*Never*) to 9 (*Daily*). The maximum possible score for the scale was 45. Internal consistency was acceptable for the DTQ-R at T1 (Cronbach's α: .718), however at T2 internal consistency was noticeably lower (Cronbach's α: .305).

3.2.3 Tasks

All tasks were presented on a 15.6 inch monitor at 1920x1080 resolution, with a refresh rate of 60Hz, with screen brightness set to maximum. The monitor was placed at a distance of 57cm, such that 1cm equates to one degree visual angle. Participants were also asked to use a chin rest during the course of the task battery. All tasks were programmed in Matlab version 2012b using the Psychophysics Toolbox version 3 extensions (Brainard, 1997; Pelli, 1997). Participants completed the task battery in a darkened room.

3.2.3.1 Modified prisoner's dilemma procedure (mPDP)

A computerized version of the mPDP, as described by Hokanson et al. (1980), was developed and administered. The modified procedure requires participants to compete with an opponent over a number of trials in a series of defect/co-operate decisions in an effort to accumulate the largest number of points. Additionally, unlike the classic paradigm in which both participants simultaneously make their decision, the modified paradigm assigns each participant to either a 'high' or 'low' power position. Participants in the 'low' power position make their decision as in the classic paradigm before moving on to the next trial. In contrast, participants in the 'high' power position are informed of their opponent's decision before making their own, thus providing them with greater control over the outcome of the interaction. For the present study, participants were always competing

against the computer and were always assigned to the ‘high’ power position. Individual participant score, opponent (computer) score, and overall task score (computed as participant score minus computer score) were recorded.

3.2.3.2 Modified Iowa gambling task (mIGT)

The mIGT administered to participants was exactly the same as that described by Cauffman et al. (2010). In the classic IGT (Bechara, Damasio, Damasio, & Anderson, 1994), participants are informed that they are to try and accumulate as much money as possible. To do so, they are required to draw cards from one of four decks of cards on each trial which will result in them either gaining or losing money, or neither. Critically, each deck of cards has a different probability of paying out or punishing the player, such that two decks overall are associated with net losses and two decks are associated with net gains. Thus, the game assesses the ability of participants to learn implicit rules associated with each deck and therefore make risk-reward decisions. In the classic version, participants are allowed to freely choose which deck to take cards from on each trial, and as such it is possible for them to ignore any given deck. By contrast, the mIGT preselects the deck in play for a given trial. By removing the free choice element, it is possible to remove potential confounding effects that may be imparted by individual differences in search strategy. Additionally, this allows for the analysis of play/pass patterns across each deck, thereby removing the possibility that participants may differentially ignore certain decks (Peters & Slovic, 2000). For each trial participants were given four seconds to make a decision to either play the selected deck or pass and move on to the next trial. Decks A and B were considered ‘bad’ decks, such that their average payout would result in a net loss overall. For deck A, payouts and losses were equally likely to occur; however losses were always much greater than payouts. For deck B, payouts occurred more frequently than losses (e.g. nine out of ten trials would be a payout); however, losses would be so

large that there would again be a net loss. Decks C and D were conceptualized as 'good' decks, such that their average payout would result in a net gain overall. For deck C, payouts would occur 50% of the time, with losses occurring 25% of the time and no changes in score occurring the remaining 25% of the time. With this deck, the losses, though still fairly high, occur infrequently enough to outweigh the value of the payouts. Finally, deck D follows the same payout and loss frequency pattern as deck B; however, the losses have been reduced in size, such that overall, deck D results in a net gain overall. In contrast to Cauffman et al. (2010), participants completed only one block of trials in order to limit the effect of prolonged learning and maximise novelty. Total number of plays (by deck and overall), total number of passes (by deck and overall), final monetary total, and response time were recorded. Play counts were then used to compute percentage good plays (that is, percentage of plays which occurred on 'good' decks) and percentage bad plays (percentage of play decisions on 'bad' decks) for each participant. Finally, a net performance measures was calculated by subtracting percentage bad plays from percentage good plays.

3.2.3.3 Raven's advanced progressive matrices (RAPM)

The RAPM (Raven, Court, & Raven, 1994) is a measure of nonverbal analytical reasoning which has been used extensively with a variety of target populations. Participants are presented with a series of spatial patterns in which each item in a sequence changes according to a particular rule. In each sequence of spatial patterns one item is missing and participants are required to select one item from a selection of eight possible answers to complete the sequence. Participants were presented with the 12-item set in order to familiarise themselves with the task before being presented with the full 36-item set. Completion time and number of correctly completed sequences were recorded.

3.2.4 Procedure

Recruitment was conducted primarily through the use of online advertisements within the University and through word of mouth. Prior to arrival, participants were contacted to confirm that they did not meet any of the exclusion criteria. Testing was conducted in two labs across two campuses of the University. Before beginning the testing session, all participants were provided with written and verbal explanations of what would happen during the testing session and given assurances regarding confidentiality of participation. Finally, all participants gave full written consent.

Participants first completed the initial set of questionnaires before completing either the mPDP followed by the mIGT, or the mIGT followed by the mPDP. Half of the participants completed the first order, while the other half completed the second order. Participants were allocated to these initial task orders randomly. For all participants, the final task of the test battery was always the RAPM. This precaution was taken due to evidence suggesting that completion of the RAPM may result in a reduction in mood (Andrews et al., 2007) which may, therefore, confound interpretation of the results of the other tasks. Following completion of the task battery, participants completed a second set of questionnaires before being debriefed and compensated for their time.

3.2.5 Data analysis

Statistical analyses were conducted using the Statistical Package for Social Sciences (SPSS version 20.0). All responses given to self-report measures at T1 and T2 were subjected to paired samples t-tests to validate the robustness of the self-report measures in addition to investigating whether completing the task battery resulted in observable changes in mood, anxiety, and rumination. Descriptive statistics for the questionnaire measures are given in Table 3.1.

Table 3.1: *Descriptive statistics for each questionnaire variable under investigation*

	Mean	**S.D.**
BDI	7.7	4.6
RRS	42.01	12.91
RRS-R	9.74	4
RRS-B	9.35	3.9
DTQ-R	19.09	7.37
HADS-A	6.35	3.61

Note: BDI = Beck Depression Inventory, RRS = Ruminative Response Scale, RRS-R = Reflection subscale of the Ruminative Response Scale, RRS-B = Brooding subscale of the Ruminative Response Scale, DTQ-R = Rumination subscale of the Distressing Thoughts Questionnaire, HADS-A = Anxiety subscale of the Hospital Anxiety and Depression Scale

For the mPDP, self, computer, and overall task score were correlated with each questionnaire measure and associated subscales. For the mIGT, initial analysis concerned correlations between these same questionnaire measures and play and pass percentages for each deck within the game. Following Cauffman and colleagues (Cauffman et al., 2010), play counts within high-risk decks (A and B) and low-risk decks (C and D) were then summed. These values were used to calculate a play percentage for both high and low-risk decks, defined as the percentage of good plays (e.g. how often a participant chose to play when presented with a low-risk deck) and percentage bad plays (e.g. how often a participant chose to play when presented with a high risk deck). A net task score was then calculated by subtracting the percentage of bad plays from the percentage of good plays. These variables were then correlated with the questionnaire measures. Finally, total RAPM score and response time were correlated with questionnaire measures.

In order to further investigate the effects of low mood and rumination on problem solving abilities as predicted by the analytical rumination hypothesis, simple mediation analyses were conducted using ordinary least squares path analysis. Regression models were computed for each model using mediator variables as predictors for the outcome variable, controlling for BDI scores, as suggested by (Baron & Kenny, 1986). For each task, the effect of BDI scores on each outcome measure was investigated using rumination scores as a mediator. The PROCESS macro, as detailed by Hayes (2013), was implemented to conduct this analysis.

3.3. Results

3.3.1 Comparison of T1 and T2 self-report measures

No comparison reached significance, all $t(40)<1.847$, $p>.072$. For subsequent analyses, T1 and T2 scores on each self-report measure were averaged to give an overall score for each participant.

3.3.2 mPDP analysis

3.3.2.1 Relationship between mPDP scores and self-report measures

Descriptive statistics for each outcome variable are given in Table 3.2. Significant positive correlations were observed between individual participant scores with BDI ($r(41) = .308$, $p = .025$) and RRS ($r(41) = .345$, $p = .0135$) scores as predicted. This relationship extended to both the reflective ($r_S(41) = .296$, $p = .03$) and brooding ($r_S(41) = .309$, $p = .025$) rumination subscales. Overall task score was also significantly and positively associated with both BDI ($r(41) = .368$, $p = .009$) and DTQ-R ($r(41) = .288$, $p = .034$) scores. Additionally, opponent (computer) scores were significantly and negatively associated with DTQ-R scores only, $r(41) = -.273$, $p = .0425$,. Scores from the HADS-A showed no significant associations with any task measure (see Table 3.3 for correlation values).

Table 3.2: *Descriptive statistics for each mPDP outcome variable*

	Mean	S.D.	Range
Individual score	159.6	25.2	110 – 218
Opponent score	26.49	115.49	-198 – 254
Task score	133.17	120.31	-130 - 352

3.3.3 mIGT analysis

3.3.3.1 Relationship between individual play/pass patterns and self-report measures

Correlations for pass percentage are identical to those reported for play percentages, save for inversion of the relationship (i.e. positive to negative, negative to positive. See Table 3.5 for full correlation values). Descriptive statistics are presented in Table 3.4. As predicted, BDI scores were significantly negatively related to the frequency with which participants took cards from deck B (infrequent, but high losses; $r(41) = -.471$, $p = .001$), suggesting that individuals with lower mood were more sensitive to the risks of Deck B. This relationship was also observed for both overall RRS scores ($r(41) = -.319$, $p = .0225$) and RRS-B scores ($r_S(41) = -.289$, $p = .035$), but not RRS-R scores. Finally, HADS-A scores were also significantly negatively related to the frequency of which participants took cards from Deck B ($r(40) = -.293$, $p = .033$), suggesting that highly anxious individuals were more sensitive to the risks of deck B. Additionally, a significant positive relationship was observed between HADS-A scores and the frequency of which participants took cards from deck C (payout 50% of the time, overall net profit; $r_S(40) = .311$, $p = .0255$), such that individuals with higher levels of anxiety took cards more often from Deck C. This relationship was not observed with any other measure.

Table 3.3: *Zero-order correlations between each mPDP outcome and scores on self-report measures*

	1.	2.	3.	4.	5.	6.	7.	8.	9.
1. Individual score	-								
2. Opponent score	-.086	-							
3. Task score	.292*	-.978^	-						
4. BDI	.308*	-.317	.368**	-					
5. RRS	.345*	-.110	.178	.472**	-				
6. RRS-R†	.296*†	-.061	.129	.246	.902^†	-			
7. RRS-B†	.309*†	-.028	.075	.377**†	.874^†	.749^	-		
8. DTQ-R	.125	-.273*	.288*	.295*	.501^	.359*†	.389**†	-	
9. HADS-A	.188	-.132	.167	.529^	.481^	.126†	.392**†	.557^	-

† *= Non-parametric,* ******* *= p<.05,* ******** *= p<.01, ^ = p<.005*

Table 3.4: *Descriptive statistics for play and pass percentages of each deck from the mIGT*

	Mean	S.D.
Deck A Play	64.02	19.26
Deck A Pass	35.98	
Deck B Play	76.11	15.86
Deck B Pass	23.89	
Deck C Play	71.59	22.09
Deck C Pass	28.41	
Deck D Play	84.76	14.04
Deck D Pass	15.24	

Note: Standard deviations are given for play and pass pairs for each deck

3.3.3.2 Task percentage analysis

3.3.3.2.1 Relationship between task percentage measures and self-report measures

Descriptive statistics for each task percentage variable are given in Table 3.6. As predicted, both BDI ($r(40) = -.299$, $p = .0305$) and rumination scores ($r(40) = -.301$, $p = .0295$) were significantly negatively correlated with percentage of bad plays, suggesting that individuals lower in mood or who more frequently engaged in rumination are less likely to accept cards from decks A or B. Moreover, both scores were significantly positively correlated with net task score (BDI: $r(40) = .401$, $p = .005$; RRS: $r(40) = .265$, $p = .049$), suggesting that individuals who were lower in mood or more frequently ruminated were also better at the task. Examining both the reflection and brooding subscales also revealed significant negative correlations (reflection: $r_S(40) = -.285$, $p = .0375$; brooding: $r_S(40) = -.27$, $p = .046$) with percentage of bad plays.

Table 3.6: *Descriptive statistics for task percentage variables calculated for the mIGT*

	Mean	**S.D.**	**Range**
Percentage good plays	77.42	14.41	38 – 100
Percentage bad plays	71.06	12.44	42.03 – 92.75
Net task score	6.36	19.27	-53.17 – 53.97

Contrary to predictions, the percentage of good plays did not correlate significantly with any rumination measure. However, as predicted, BDI scores correlated significantly positively with percentage of good plays ($r_S(40) = .293$, $p = .0385$), suggesting that those experiencing lower levels of mood were more likely to accept cards from decks C or D. See Table 3.6 for a full list of correlation values.

Table 3.5: *Zero-order correlations between play percentages for each mIGT deck and scores on self-report measures*

	1.	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**	**8.**	**9.**	**10.**
1. Deck A Play	-									
2. Deck B Play	.049	-								
3. Deck C Play†	.406^†	-.378**†	-							
4. Deck D Play†	-.106	.067	.044	-						
5. BDI	.071	-.471^	.229	.149	-					
6. RRS	-.099	-.319*	-.067	.046	.472^	-				
7. RRS-R†	-.237	-.174	-.206	-.006	.246	.902^†	-			
8. RRS-B†	-.099	-.289*†	-.033	.002	.377**†	.874^†	.749^†	-		
9. DTQ-R	.126	-.009	-.002	.160	.295*	.501^	.359*†	.389**†	-	
10. HADS-A	.083	-.293*	.311*	.041	.529^	.481^	.126	.392**†	.557^	-

† *= Non-parametric,* ******* *= p<.05,* ******** *= p<.01,* ***^*** *= p<.005*

Table 3.7: *Zero-order correlations between each mIGT task percentage outcome and scores on self-report measures*

	1.	2.	3.	4.	5.	6.	7.	8.	9.
1. Percentage good plays†	-								
2. Percentage bad plays	.074	-							
3. Net task score	.74^†	-.664^	-						
4. BDI	.293*†	-.299*	.401^	-					
5. RRS	-.012	-.301*	.265*	.472^	-				
6. RRS-R†	-.171	-.285*†	.028	.246	.902^†	-			
7. RRS-B†	-.029	-.27*†	.162	.377**†	.874^†	.749^†	-		
8. DTQ-R	.06	.08	.043	.295*	.501^	.359*†	.389**†	-	
9. HADS-A	.364*†	-.16	.372**	.529	.481^	.126	.392**†	.557^	-

† *= Non-parametric,* ******* *= p<.05,* ******** *= p<.01,* ^ *= p<.005*

3.3.4 RAPM analysis

Descriptive statistics are given in Table 3.8. No significant correlations between performance and self-report measures were observed.

Table 3.8: *Descriptive statistics for RAPM outcome variables*

	Mean	**S.D.**	**Range**
Total items correct	20.07	6.34	3 – 32
Session time (minutes)	18.34	6.2	7 – 34

3.3.5 Mediation analyses

3.3.5.1 mPDP mediation analysis

As can be seen from Table 3.9 and Figure 3.1, levels of rumination positively predicted individual scores such that individuals who more frequently ruminated were predicted to achieve greater individual scores (b = 0.502); however, this term did not achieve significance (p = .138). A bias-corrected bootstrap confidence interval for the indirect effect of low mood on individual scores (ab = 0.665) based on 10,000 bootstrap samples was entirely above zero (0.006 to 1.93). However, the direct effect of low mood on individual scores was found to be non-significant (c' = 1.02, p = .281), suggesting that low mood can only have an effect on individual scores through rumination.

Table 3.9: *Model coefficients for the proposed mediation model for low mood, rumination and individual scores from the mPDP*

		Consequent						
		***M* (RRS)**				***Y* (Individual Score)**		
Antecedent		**Coeff.**	***SE***	***p***		**Coeff.**	***SE***	***p***
***X* (BDI)**	***a***	1.325	0.396	.0018	***c'***	1.02	0.93	.281
***M* (RRS)**		---	---	---	***b***	0.502	0.33	.138
Constant	i_1	31.818	3.54	<.001	i_2	130.722	12.855	<.001
		R^2 = .223 $F(1,39)$ = 11.187, p = .0018				R^2 = .382 $F(2,38)$ = 3.25, p = .0498		

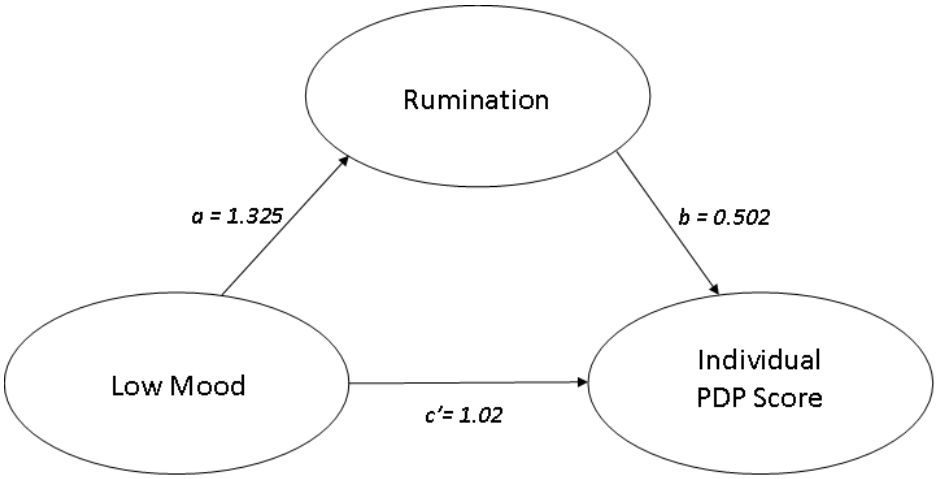

Figure 3.1: *Simple mediation model detailing the direct and indirect effects of low mood on individual PDP scores, using rumination as a mediator.*

Examining the effect of low mood on opponent (computer) scores using anxious ruminations as a mediator (see Table 3.10 and Figure 3.2), neither low mood (*c'* = -6.491, *p* = .11) or anxious ruminations (*b* = -3.075, *p* = .221) predicted opponent (computer)

scores. Additionally, calculating bootstrapped confidence intervals for the indirect effect of low mood on opponent's (computer) score (*ab* = -1.4524) revealed the inclusion of zero (-6.053 to 0.303), suggesting there is also no indirect effect of low mood on opponent (computer) scores.

Table 3.10: *Model coefficients for the proposed mediation model for low mood, anxious rumination and opponent (computer) scores from the mPDP*

		Consequent						
		***M* (DTQ-R)**				***Y* (Opponent Score)**		
Antecedent		**Coeff.**	***SE***	***p***		**Coeff.**	***SE***	***p***
***X* (BDI)**	***a***	0.472	0.472	.061	***c'***	-6.491	3.961	.11
***M* (DTQ-R)**		---	---	---	***b***	-3.075	2.473	.221
Constant	i_1	15.45	2.19	<.001	i_2	135.12	51.034	.012
		R^2 = .295 $F(1,39) = 3.716$, $p = .061$				R^2 = .368 $F(2,38) = 2.975$, $p = .063$		

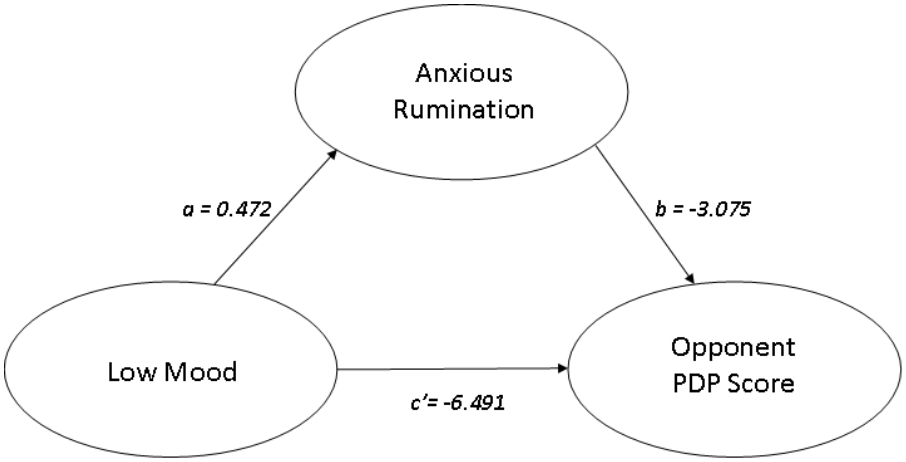

Figure 3.2: *Simple mediation model detailing the direct and indirect effects of low mood on opponent PDP scores, using anxious rumination as a mediator.*

Finally, examining the effect of low mood on overall task score using RRS scores as a mediator (see Table 3.11 and Figure 3.3), rumination did not significantly predict overall task score when accounting for level of low mood (b = 0.048, p = .976). Moreover, bias corrected bootstrap confidence intervals revealed no indirect effect of low mood on overall task score (ab = 0.0634, CIs = -4.144 to 3.875); however, the direct effect of low mood on overall task score returned significance (c' = 9.564), suggesting that low mood has a direct influence on overall task scores.

Table 3.11: *Model coefficients for the proposed mediation model for low mood, rumination and overall task scores from the mPDP*

		Consequent						
		***M* (RRS)**				***Y* (Overall Task Score)**		
Antecedent		**Coeff.**	***SE***	***p***		**Coeff.**	***SE***	***p***
***X* (BDI)**	***a***	1.325	0.396	.0018	***c'***	9.564	4.472	.039
***M* (RRS)**		---	---	---	***b***	0.048	1.594	.976
Constant	i_1	31.818	3.54	<.001	i_2	130.722	12.855	<.001
		R^2 = .223 $F(1,39)$ = 11.187, p = .0018				R^2 = .136 $F(2,38)$ = 2.983, p = .0626		

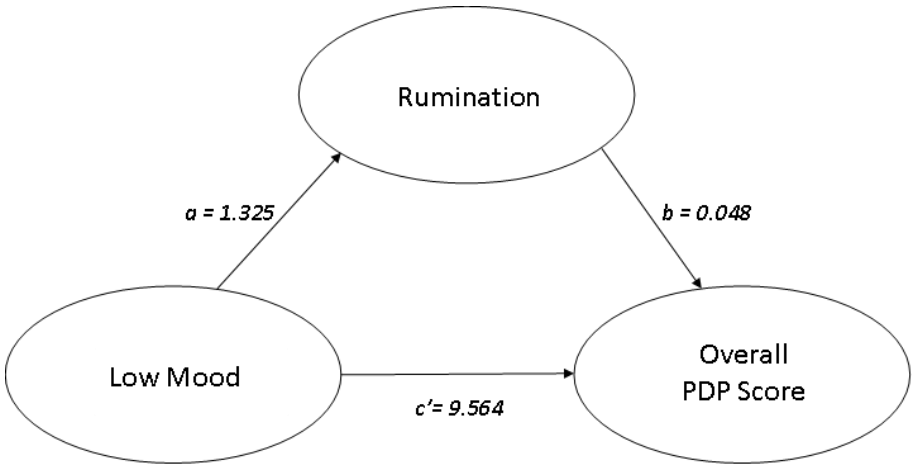

Figure 3.3: *Simple mediation model detailing the direct and indirect effects of low mood on overall PDP scores, using rumination as a mediator.*

3.3.5.2 mIGT mediation analysis

Across all mIGT measures, no significant mediation models were computed (all $p > .05$), suggesting that all previously observed mIGT correlations occur in the absence of a mediating variable.

3.4 Discussion

The present study aimed to investigate whether engaging more frequently in self-reported, trait reflective rumination was associated with improved problem solving ability in a group of individuals without diagnoses of depression or other psychological disorders. Our results suggest that there is indeed a positive relationship between the frequency of reflective trait rumination and the ability to effectively solve problems, as predicted. Moreover, the relationship between low mood and problem solving is mediated by a combination of both reflective and brooding rumination; however whether or not mediation occurs appears to be dependent on the task used. Finally, our results suggest that all different aspects of rumination may carry potential adaptive benefits under different circumstances at non-pathological levels.

First, as expected, individuals with lower levels of mood were found to engage more frequently in rumination, which is in line with reports from previous studies (Nolen-Hoeksema et al., 1999; Szasz, 2009; Treynor et al., 2003; Wenzlaff & Luxton, 2003), although these studies make no distinction between reflective (adaptive/constructive) and brooding (maladaptive/unconstructive) rumination. Within the mPDP, elevated levels of rumination were associated with increased individual scores on the task. This supports the literature suggesting that increased levels of depression are associated with more selfish strategies (e.g. defection) in social bargaining type games (Hokanson et al., 1980; Surbey, 2011). When considering the scoring system of the mPDP, low opponent (computer) scores are achieved by *subtracting* points from the opponent (computer). As such, in the

context of the game, these choices may be viewed as punishing the opponent. Decreased opponent (computer) scores were associated with anxious ruminations only, such that the more frequently one engages in anxious type ruminations, the lower the score of the opponent (computer) in the mPDP. Taken together, these findings suggest that different aspects of rumination facilitate different strategies for effectively completing mPDP. Specifically, reflective rumination is associated with better performance through actions taken on the self (e.g. giving oneself more points), whereas anxious ruminations are associated with better performance through actions taken against external sources (e.g. punishing an opponent).

Second, both low mood and rumination were associated with better overall performance on the mIGT. Individuals with lower mood were significantly more likely to make good plays (i.e. take cards from either deck C or D; plays which result in net monetary gains overall), significantly less likely to make bad plays (i.e. take cards from deck A or B; plays which result in net monetary losses overall), and had higher overall task scores, consistent with previous studies reporting associations between depression and risk-averse decision making (e.g. Chou, Lee, & Ho, 2007; González-Ortega, Echeburúa, Corral, Polo-López, & Alberich, 2013; Juhasz et al., 2010; Yuen & Lee, 2003). Extending previous studies, our results suggest that in addition to making fewer riskier decisions, individuals with lower levels of mood also made advantageous decisions more frequently. Moreover, to the authors' knowledge, this is the first study that documents a direct relationship between risk-aversion, rumination and improved performance on a gambling task. It is suggested that increases in the frequency of rumination correspond with increases in risk sensitivity, such that frequent ruminators detect risks more effectively as evidenced by a reduction in bad plays during the mIGT. Thus, frequent ruminators perform more ably as a result of experiencing fewer punishments.

These findings expand on Nettle's (2009) theoretical model of the adaptive function of low mood. In this model, low mood is hypothesized to attenuate risky decisions as the potential emotional rewards do not outweigh the potential emotional consequences of failure, whereas the reverse is true for those in elevated and severely depressed mood states. Indeed, the present study demonstrates that lower levels of mood are associated with fewer bad plays and an increased frequency of good plays, and thus better performance overall. Additionally, more frequent rumination (both reflective and brooding) is associated with decreased frequency of bad plays and better performance overall. As such, it would appear that rumination has an additional attenuating effect on risky decisions. Moreover, low mood, in addition to attenuating risky decisions, appears to promote good, safe decisions.

Multiple mediation analyses yielded mixed support for the analytical rumination hypothesis. For the mPDP, consistent with our predictions, the relationship between low mood and task performance was mediated by rumination; however this held for individual scores only; that is, points participants awarded themselves, separate from the opponent's (computer's) score and overall task score. Additionally, no significant mediation models were computed for any measure taken from the mIGT, suggesting that all observed effects of mood and rumination on performance in the mIGT are direct. One possible explanation for these findings may be that when the self is a critical factor in problem resolution, rumination mediates the effect of low mood on problem solving through reflective processes. As such, one would not observe mediation effects in tasks such as the mIGT, as the self has no conceptual component in the task. At present, however, this is speculative.

In line with our predictions, differential relationships were observed for both reflection and brooding sub-scales of the RRS with different task measures. Contrary to these initial predictions, however, was the observation that these sub-scales did not show

inverse relationships with various task measures. Indeed, across all correlations, brooding was not associated with poorer performance or poor decision making in the mIGT. Instead, brooding was in fact associated with better choices in the mIGT, negatively correlating with the frequency with which participants took cards from deck B (one of the 'bad' decks). Furthermore, this relationship was not observed with the reflection sub-scale. This particularly novel finding challenges the currently held belief that the brooding component of rumination is completely maladaptive, and may have particular benefits in non-clinical populations. It is possible that brooding in healthy populations may promote hesitation in the face of risky decisions, thereby promoting decision making which favours safer, more certain outcomes. Without replication, however, this remains speculative.

Of particular note is the absence of any observable effects within the RAPM, even when performance was shown to be enhanced in both the mPDP and mIGT for individuals who more frequently ruminate. Raven's matrices are considered to be one of the best measures of non-verbal analytical reasoning ability (Carroll, 1993), and so, following the analytical rumination hypothesis, one would anticipate improved performance for the RAPM in those with elevated levels of reflective rumination. One potential explanation for this absence may be due to the evolutionary relevance of the RAPM. Specifically, enhanced problem solving ability may only be detectable in tasks in which some element relates to a problem that may have been encountered in our evolutionary past. With respect to the present study, the mPDP and mIGT may conceivably possess such elements. Though completely computerised, the mPDP asks participants to monitor responses given by the opponent (computer) in response to their own decisions over time and serves as an analogue to social interactions. The mIGT requires participants to monitor risk and probabilities of reward, and though this task is conceptualised with respect to financial rewards and losses, the basic process of risk-reward analysis is similar to that used by

hunter-gatherers when obtaining resources. By contrast, the RAPM has no immediate real-world analogue given its abstract nature. Indeed, the concept of evolved relevance in tasks and the potential performance benefits they elicit has recently begun to be investigated, with studies demonstrating evolutionary relevance effects in visual processing (Jackson & Calvillo, 2013), memory (Nairne, Pandeirada, Gregory, & Van Arsdall, 2009) and attention (New, Cosmides, & Tooby, 2007). Thus, the present study contributes to this growing literature, highlighting the need to consider tasks carefully when investigating evolutionary hypotheses.

One potential limitation of the present study pertains to the power of the mediation analyses, such that the analyses themselves are underpowered based on the suggestions of Baron and Kenny (1986). Moreover, on the basis of their suggestions it may be argued that the analyses themselves are inappropriate due to the absence in two of the three models of a direct effect entirely. However, there are two objections to this critique. First, as described by MacKinnon, Fairchild, and Fritz (2007), Baron and Kenny's first requirement that a significant relationship between variable X (the independent variable) and variable Y (the outcome variable) exists results in a marked reduction in power, particularly when determining if complete mediation is taking place as one must confirm the complete absence of an effect without committing a Type II error. Indeed, as demonstrated by Fritz and Mackinnon (2007), the required sample size for calculating the mediation path of small effect size is approximately 21000 participants, which for most studies is unfeasible. While the theoretical value in many cases of the X-Y relationship is not disputed, the ability to evidence this relationship before conducting mediation analyses may prohibit the investigation of real mediation effects due to insufficient power. Further to this, the assumption that there must be an X-Y relationship to begin with may also be flawed. As Zhao, Lynch, and Chen (2010) suggest, mathematically the zero-order effect of X on Y is

equivalent to the combination of the indirect and direct path. This is particularly important if it is considered that the indirect and direct paths may exert different effects. For example, the direct effect of X on Y may be positive in nature, whereas the indirect effect of X on Y through mediator M may be negative. Thus, combining the two pathways to calculate the total effect results in zero, and so it may erroneously be concluded that effects do not exist. This highlights the importance of fully investigating mediation models in cases where zero-order effects would suggest there are none.

Finally, understanding the potential functional benefits of low mood and rumination may help inform clinical practice. By further clarifying the role of rumination in non-clinical populations, we gain an understanding of the effects of rumination when it is non-pathological. As such, it is possible to more effectively identify problem ruminations in patients. Additionally, under the analytical rumination hypothesis, by identifying rumination as the principal adaptation of low mood, clinicians can become more focussed in their treatment of depression. Specifically, if brooding rumination, at pathological levels, is responsible for the majority of depressive symptoms (see Joormann et al., 2006; Siegle et al., 2004; Treynor et al., 2003, for evidence of association) then clinicians should concentrate on addressing elevated levels of maladaptive rumination. Indeed, preliminary evidence suggests that targeting rumination specifically with behavioural therapies results in better prognosis and reduced probability of relapse at follow up (Watkins, Mullan et al., 2011; Watkins, Scott et al., 2007). Whether levels of adaptive rumination remain elevated post-treatment as compared to maladaptive rumination, or whether rumination more generally is attenuated is not clear. Moreover, how adaptive rumination may contribute to recovery remains unknown and should be addressed in future studies.

3.5 Conclusion

In sum, the present study is the first to the author's knowledge to document a direct relationship between rumination and problem solving ability in two different types of problem solving task. Furthermore, the results suggest that rumination is only adaptive in tasks that involve some form of real world analogues in contrast to abstract tasks. This contributes to an emerging literature on the concept of evolutionary relevance in task selection when investigating the adaptive nature of cognitive traits. Finally, it is suggested that determining the adaptive importance of rumination can help inform clinical practice, by allowing clinicians to become more focussed in their treatments. Considering the present study's findings, it is critical that future studies investigate how adaptive components of rumination can impact clinical outcome.

Chapter Four: Rumination and executive function: Associations between ruminative styles, working memory, attention, and response inhibition.

4.1 Introduction

The precise relationship between rumination, including its sub-components reflection and brooding, and problem solving ability in a non-clinical population was investigated in the study reported in Chapter Three. In conflict with previous findings, found that rumination was in fact positively related to problem solving ability in two types of problem solving task. Furthermore, each component of rumination contributed differentially to each type of task. Specifically, reflective rumination was positively associated with better performance in a modified prisoner's dilemma task (for emulating social interactions; see Hokanson, Sacco, Blumberg, & Landrum, 1980) and a modified Iowa gambling task (for assessing risk-reward problem solving; see Cauffman et al., 2010). Contrary to predictions, rather than exhibiting negative relationships with performance in these tasks, brooding rumination was in fact positively related to performance in these tasks, which has led us to suggest a re-evaluation of the adaptive/maladaptive dichotomy in favour of a balanced model of rumination.

In spite of evidence for the positive effects of rumination has begun to emerge (see Chapter Three; Hubbard, Faso, Krawczyk, & Rypma, 2015), the potential mechanisms through which rumination may improve problem solving remain largely unknown. Problem solving ability itself is not thought of as a unitary process but the result of an interaction of more fundamental processes (Kendler & Kendler, 1962). If this concept is accepted, likely candidates for these fundamental processes may be found within the domain of executive functioning. Executive function comprises a suite of general-purpose mechanisms which govern cognitive processes at the most fundamental level (A Miyake et

al., 2000) and is most commonly associated with prefrontal cortical structures (Banich, 2009; Funahashi, 2001; Miller & Cohen, 2001; however, see also Alvarez & Emory, 2006). Of these processes, three consistently emerge in the literature as critical components of executive function: inhibition and task switching (e.g. Burgess, 2000; Miyake et al., 2000; Sergeant, Geurts, & Oosterlaan, 2002), working memory (e.g. Baddeley, Sala, Robbins, & Baddeley, 1996; Lehto, Juujärvi, Kooistra, & Pulkkinen, 2003; McCabe, Roediger, McDaniel, Balota, & Hambrick, 2010), and attentional control (e.g. Diamond, 2013; Fassbender et al., 2004; Kane & Engle, 2002).

Though problem solving has been theorised to engage higher-order cognitive processes such as executive functions (Barbey & Barsalou, 2009), there have been few empirical studies investigating the potential relationship. Lv (2015), for example, reported an association between problem solving ability and both working memory capacity and inhibition. Specifically, working memory capacity was positively related to the ability to process problem information efficiently, whereas inhibition exhibited contradictory relationships over the course of two experiments, being both negatively and positively related to ability. Furthermore, Vandermorris, Sheldon, Winocur, and Moscovitch (2013) observed a positive relationship between composite executive function scores and ability to solve both well- and ill-defined problems; however, the specific components contributing to the association were not identified and as such, it is uncertain as to whether this association is driven by a single or multiple components. From these studies alone, it is clear that the relationship between executive function and problem solving ability is complex and may be subject to influence from other cognitive factors.

As with the rumination and problem solving literature, many of the inferences made regarding rumination and aspects of executive function are derived from clinical studies involving patient groups, or take no account of the independent effects of reflection

and brooding. Based on these studies, rumination has been thought to impair executive function (e.g. Connolly et al., 2014; Joormann, Levens, & Gotlib, 2011; Joormann & Gotlib, 2008; Philippot & Brutoux, 2008; Watkins & Brown, 2002; Whitmer & Banich, 2007), aligning with the maladaptive view of rumination. However, in addition to not considering the sub-components of rumination, these studies have commonly assumed that any change in a facet of executive function is detrimental, paying little attention to the idea that these changes may serve a functional purpose. For example, Altamirano, Miyake, and Whitmer (2010) suggest that ruminators exhibiting difficulties in task switching may, in fact, be demonstrating improvements in goal maintenance instead. As such, when given a task, they are more able to focus on the original goals, and may, in turn, be more resistant to task distracters.

In order to investigate whether there are differential relationships between the ruminative sub-components reflection and brooding, and the three commonly cited components of executive function (inhibition and task switching, working memory, and attentional control) in a clinically healthy sample, the present study administered three tasks, each designed to measure one of these components. Participants completed a forward digit span task, with a staircase procedure implemented, adapted from the Wechsler Adult Intelligence Scale (Wechsler, 2008), in order to measure working memory capacity; a variable stop signal reaction time (SSRT) task in order to measure response inhibition; and an exogenous/endogenous attentional cueing task (Posner, 1980) in order to assess attentional control. Based on the study reported in Chapter Three it is predicted that if problem solving ability is indeed related to executive functioning then the frequency of these ruminations should be associated with enhanced performance in these tasks. In addition to administering the RRS to measure rumination, the recently developed Analytical Rumination Questionnaire (ARQ; Barbic, Durisko, & Andrews, 2014) was also

completed by participants. This measure has been designed specifically to measure levels of analytical-type ruminations and is hypothesised to be most closely associated with problem solving. Furthermore, levels of analytical rumination are thought to be closely related to levels of reflective rumination and as such, the correlation between ARQ scores and reflective rumination scores will be investigated.

4.2 Methods

4.2.1 Participants

Participants were recruited from the student body of Durham University. All participants reported no personal history of psychological or neurological disorder and indicated that they had not been taking in the past six months any medications that may affect the central nervous system. The final sample comprised six males and 37 females, with a mean age of 23.14 years (*S.D.*: 7.09 years). Participants were reimbursed with either course credit or a £5 voucher for an online retailer. The study protocol was approved by the Durham University Department of Psychology Ethics Committee.

4.2.2 Measures

4.2.2.1 Beck depression inventory (BDI)

The 20-item BDI reported acceptable internal consistency at both T1 and T2 (Cronbach's α: .83 and .84 respectively).

4.2.2.2 Ruminative response scale (RRS)

The full RRS reported an acceptable internal consistency at T1 and T2 (Cronbach's α: .892 and .899 respectively). Internal consistencies for both brooding and reflection subscales were acceptable at T1 (Cronbach's α: .786 and .772, respectively) and T2 (Cronbach's α: .805 and .752 respectively).

4.2.2.3 Analytical rumination questionnaire

The full ARQ (as reported in Chapter Two, pp. 44-45) reported acceptable internal consistencies at T1 and T2 (Cronbach's α: .952 and .934 respectively).

4.2.3 Tasks

All tasks were presented on a 15.6 inch monitor at 1920x1080 resolution, with a refresh rate of 60Hz, with screen brightness set to maximum. The monitor was placed at a distance of 57cm, such that 1cm equates to one degree visual angle. Participants were also asked to use a chin rest during the course of the task battery. All tasks were programmed in Matlab version 2012b using the Psychophysics Toolbox version 3 extensions (Brainard, 1997; Pelli, 1997). Participants completed the task battery in a darkened room.

4.2.3.1 Digit span task

A computerized adaptation of the digit span task as detailed in the Wechsler Adult Intelligence Scale (Wechsler, 2008) was administered. For the present study, only the forward digit span procedure was used, requiring participants to remember a sequence of digits presented to them in the exact order they are presented. Additionally, a staircase function was implemented, such that the number of digits the participants were required to recall varied as a consequence of each individual participant's performance. For every three sequences of *n*-digits recalled correctly, the total number of digits in the sequence increased by one. Conversely, for every three sequences of *n*-digits participants did not recall correctly, the total number of digits in the sequence was reduced by one. Each time the number of digits changed, the correct/incorrect count returned to zero for the purposes of determining when the next change in the number of digits would occur. The task would continue until the participant had recorded five reversals in the change of the number of digits, with reversals defined as an increase then decrease in the number of digits, or a

decrease then increase in the number of digits. The total number of sequences recalled correctly and the total number of sequences recalled incorrectly were recorded. Using the raw data, digit span thresholds (where performance is estimated to remain at 50% accuracy) were calculated for each participant.

4.2.3.2 Posner attentional cuing task

The Posner attention task, as described by Posner (1980), was administered to participants. Three boxes were presented on a gray background (one central and one each on the left and right periphery, sized 2.5° x 2.5° visual angle), with participants being asked to fixate on the central box. Between the start of the trial and presentation of a cue, there was a variable delay between 250ms and 1000ms, followed immediately an endogenous cue or exogenous cue depending on which block of trials the participant was currently completing. Endogenous cues were presented as an arrow pointing to either the left or right periphery, whereas exogenous cues were presented as the outline of one of the peripheral boxes becoming thicker. Cues were presented for 200ms. Following the presentation of the cue, one of the peripheral boxes would fill in to become a solid square (see Figure 4.1 for an example sequence of events). All delays were determined at random on each trial, for both central and peripheral cues. Variable delays were also used in order to reduce the probability of habituation to a stable delay. Additionally, by using variable delays between cue onset *and* stimulus onset, participants must maintain attentional focus throughout the task. Moreover, the delay range was chosen in order to capture the range of values typically used in the Posner paradigm (e.g. Hayward & Ristic, 2015; Milliken, Lupianez, Roberts, & Stevanovski, 2003; Olk, Tsankova, Petca, & Wilhelm, 2014). Participants were then required to press one of two keys on a keyboard based on which of the peripheral boxes becomes a solid square (i.e., the target). On 80% of trials, the presented cues were indicative of which box would become the target (valid trials), with the remaining 20% of

trials being classified as invalid, such that the presented cue was not indicative of which of the peripheral boxes would become the target. Participants completed six blocks of 40 trials, with half of the blocks containing endogenous cues and the remaining half containing exogenous cues. Block order was determined randomly for each participant prior to beginning the task. Accuracy and response time to each type of trial was recorded.

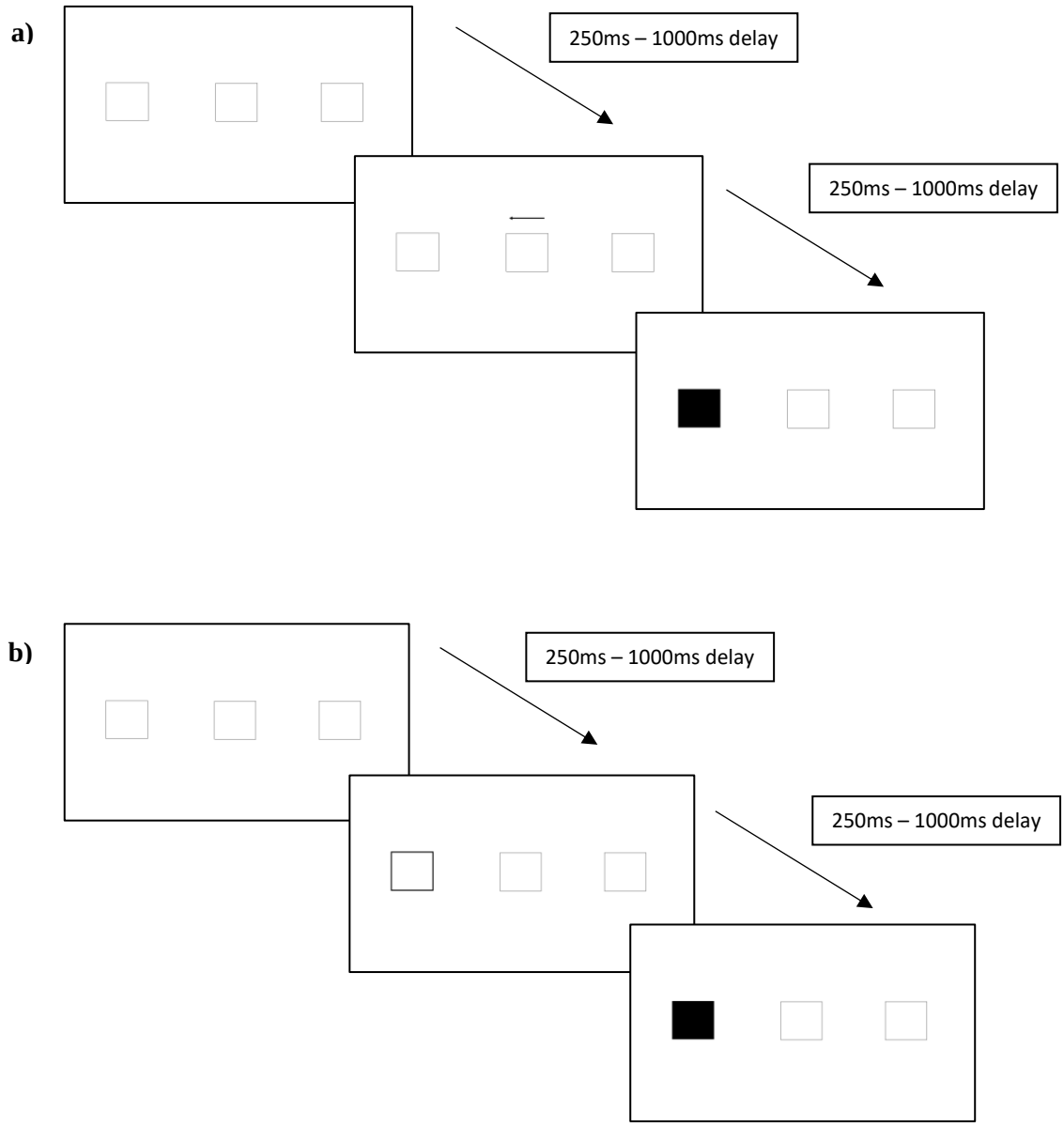

Figure 4.1: *Schematic of two example trials from the Posner attentional cueing task. Trial sequence* ***a)*** *details an endogenously cued trial, whereas trial sequence* ***b)*** *details an exogenously cued trial.*

4.2.3.3 Stop signal reaction time task (SSRT)

The SSRT task is designed to measure a participant's ability to inhibit a previously engaged motor response. At the beginning of each trial, participants were asked to fixate

on a central circle on a white background. After a variable delay (between 250ms and 500ms), a green square (rgb value: 0, 255, 0; sized 2.5° x 2.5° visual angle) was presented in the centre of the screen. On go trials, the square remained green, whereas on no-go trials the square became red (rgb value: 255, 0, 0; see Figure 4.2 for an example event sequence). Participants were instructed to press the spacebar as quickly as possible in response to the green square, and when the red square appeared they were to do nothing. Thus, on trials where the square changed colour, participants would have to inhibit their go response. The delay between the presentation of the stop signal after the go signal was adjusted dynamically based on the performance of the participant. On completion of successful stop trials, the stop signal delay (SSD) was increased by 50ms, and on unsuccessful stop trials, the SSD was reduced by 50ms. This tracking procedure, as detailed by Levitt (1971), is designed to promote a 50% inhibition failure rate which allows for the estimation of the SSRT. Participants completed six blocks of trials, each consisting of 48 trials. Half of the blocks had a distribution of 50% go trials and 50% no-go trials, with the remaining blocks of trials consisting of 75% go trials and 25% no-go trials. Block order was determined randomly prior the beginning of the task. Accuracy and response times were recorded and used to calculate the SSRT for each participant.

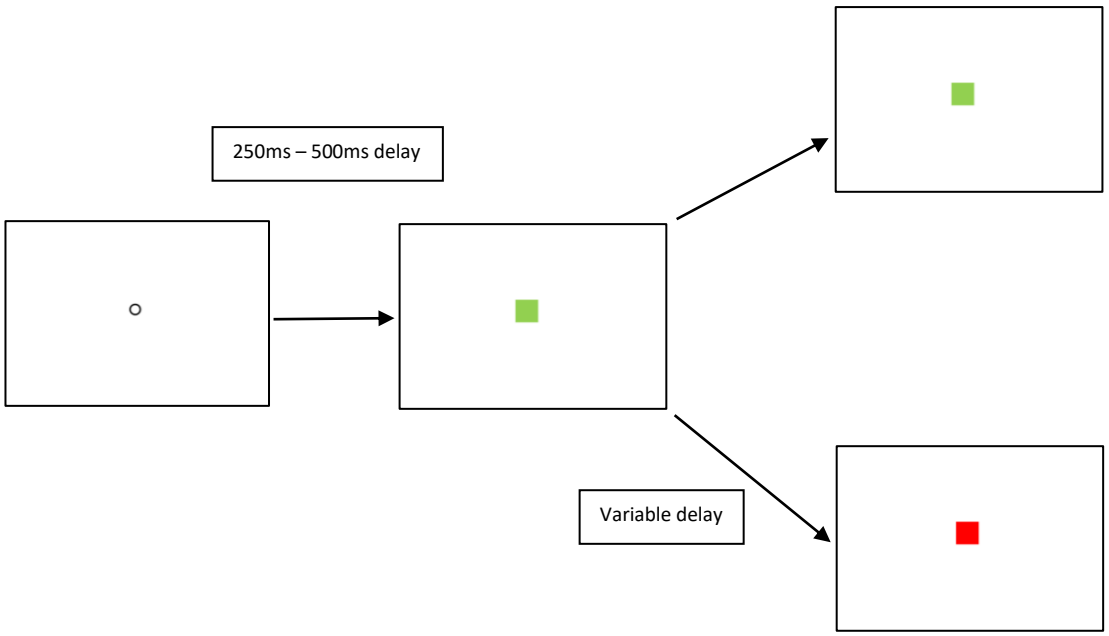

Figure 4.2: *Schematic of go (upper path) and no-go (lower path) trials for the stop signal reaction time task*

4.2.4 Procedure

Recruitment was conducted primarily through the use of online advertisements within the University and through word of mouth. Prior to arrival, participants were contacted to confirm that they did not meet any of the exclusion criteria. Testing was conducted in two labs across two campuses of the University. Before beginning the testing session, all participants were provided with written and verbal explanations of what would happen during the testing session and given assurances regarding confidentiality of participation. Finally, all participants gave full written consent.

Participants first completed the BDI, RRS, and ARQ, administered in a random order before completing the task battery. Tasks were administered in a random order to each participant. The order of tasks was determined prior to the experimental session. After

completing the task battery, participants completed the BDI, RRS, and ARQ for a second time, again in a random order, before being debriefed and compensated for their time.

4.2.5 Data analysis

All responses given to self-report measures at T1 and T2 were subjected to paired samples t-tests to validate the robustness of the self-report measures in addition to investigating whether completing the task battery resulted in observable changes in mood, anxiety, and rumination. Descriptive statistics for the questionnaire measures are given in Table 4.1.

Table 4.1: *Descriptive statistics for the questionnaire variables under investigation*

	Mean	**S.D.**
BDI	8.37	5.37
RRS	40.66	9.46
RRS-R	8.72	2.87
RRS-B	9.73	2.87
ARQ	63.76	15.85

Note: BDI = Beck Depression Inventory, RRS = Ruminative Response Scale, RRS-R = Reflection subscale of the Ruminative Response Scale, RRS-B = Brooding subscale of the Ruminative Response Scale, ARQ = Analytical Rumination Questionnaire

Results from each questionnaire measure were taken and correlated with each outcome variable for each task. Due to absent data (computer error), seven participants were excluded from all aspects of the digit span analysis. All analyses were conducted using the total number of digit sequences recalled correctly,

For the SSRT task analysis, two methods were used to calculate the SSRT for each participant. Method one used the mean go-signal reaction time for each participant whereas method two used the median go-signal reaction time (as suggested for use with staircase designs; Aron, Fletcher, Bullmore, Sahakian, & Robbins, 2003). The average delay in signal onset for each participant was then subtracted from these values to calculate an estimate of the SSRT.

4.3 Results

4.3.1 Comparison of T1 and T2 self-report measures

No comparison reached significance, all $t(40)<1.15$, $p>.257$. For subsequent analyses, T1 and T2 scores on each self-report measure were averaged to give an overall score for each participant.

4.3.2 Digit span analysis

4.3.2.1 Relationship between digit span outcome and self-report measures

Table 4.2: *Descriptive statistics for each outcome variable from the Digit Span task*

	Mean	**S.D.**	**Range**
Total Sequences Correct	27.61	5.62	19 – 40
Total Sequences Incorrect	16.22	3.67	8 – 26
Threshold Value	7.06	1.39	5 - 11

Descriptive statistics for each digit span measure are given in Table 4.2. No significant correlations were observed between any digit span outcome variable and overall RRS, BDI, or ARQ scores. Similarly, no significant correlations were observed with the brooding subscale of the RRS (RRS-B). Significant positive correlations were observed between the reflection subscale of the RRS (RRS-R) and the total number of digit sequences recalled correctly, $r(36)=.310$, $p = .0325$, and the calculated digit span threshold, $r_s(36)=.283$, $p = .047$, as predicted (see Figure 4.3a and 4.3b respectively).

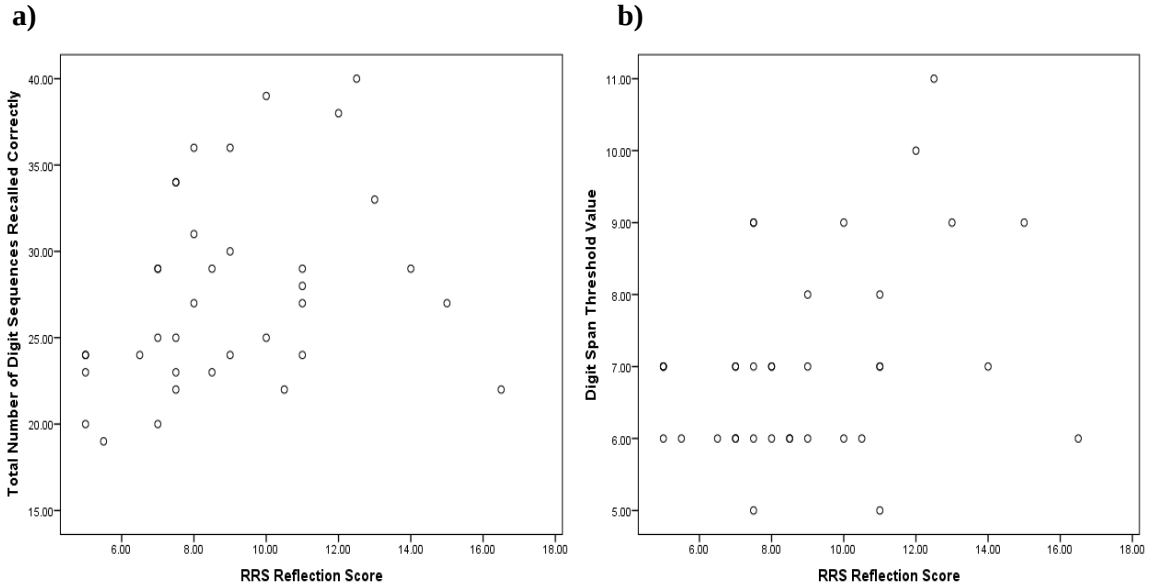

Figure 4.3: *Scatterplots depicting the relationship between reflective rumination scores and digit span outcome measures.* ***a)*** *Total number of sequences recalled correctly* ***b)*** *Individual digit span threshold values*

4.3.3 Posner attentional cueing task analysis

4.3.3.1 Relationship between cueing task outcome and self-report measures

Descriptive statistics for response times for each trial type is given in Table 4.3. As with the digit span analysis, BDI, ARQ, and overall RRS scores showed no significant associations were observed with any outcome variables from the Posner attentional cueing

task. However, there was a significant positive relationship between RRS-B scores and reaction times for correct responses on invalidly cued trials, $r_s(39)= .343$, $p = .016$, and within these trials specifically the relationship was observed for endogenously cued trials only, $r_s(39)= .365$, $p = .011$ (see Figure 4.4a and 4.4b for a comparison of the relationships between brooding, and endogenously and exogenously cued trials respectively).

Table 4.3: *Descriptive statistics for all reaction time variables taken from the Posner Attentional Cuing task*

	Mean	**S.D.**	**Range**
Correct Endogenous	.319	.739	.23 - .61
Incorrect Endogenous	.082	.140	0 - .75
Correct Exogenous	.324	.081	.23 - .64
Incorrect Exogenous	.076	.076	0 - .24
Correct Valid	.309	.072	.22 - .55
Incorrect Valid	.082	.156	0 - .75
Correct Invalid	.378	.086	.27 - .71
Incorrect Invalid	.076	.071	0 - .24
Correct Valid Endogenous	.307	.072	.21 - .58
Incorrect Valid Endogenous	.077	.160	0 - .75
Correct Invalid Endogenous	.371	.096	.26 - .73
Incorrect Invalid Endogenous	.043	.069	0 - .29
Correct Valid Exogenous	.311	.081	.20 - .62
Incorrect Valid Exogenous	.012	.042	0 - .19
Correct Invalid Exogenous	.386	.091	.26 - .75
Incorrect Invalid Exogenous	.073	.075	0 - .24

Note: All values given in milliseconds (ms).

In order to investigate whether the relationship between RRS-B scores and reaction times for correct responses to invalidly cued trials overall was driven by the relationship between RRS-B scores and reaction times for invalid endogenous trials, a partial correlation controlling for invalid endogenous reaction times was conducted. After controlling for invalid endogenous reaction times, the relationship between RRS-B scores and reaction times to invalidly cued trials returned non-signficance, $r_s(39)= -.095$, $p = .569$.

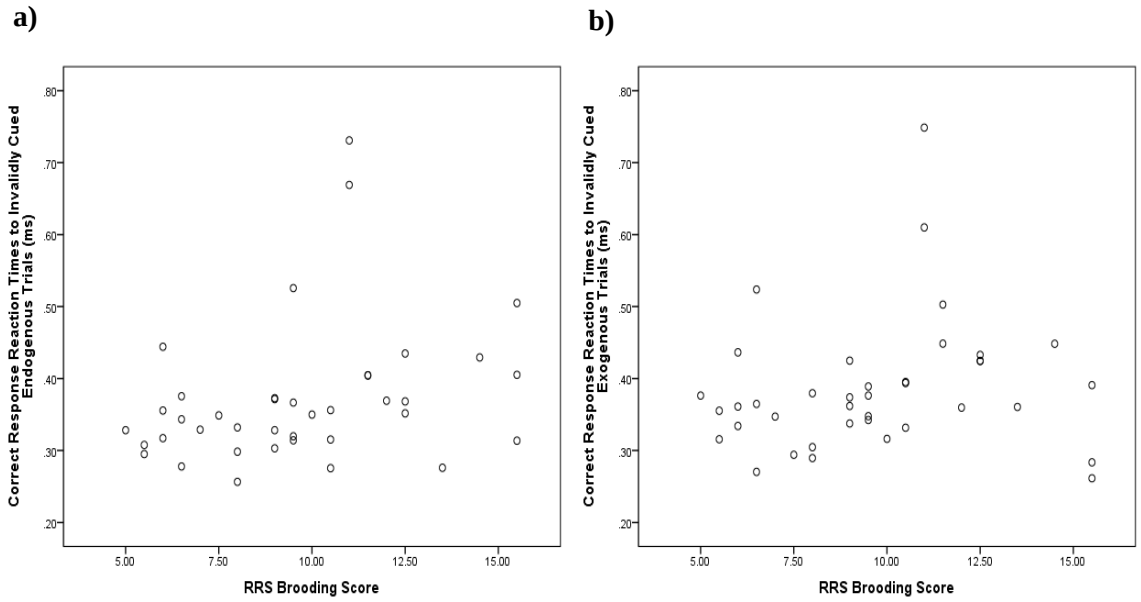

Figure 4.4: *Scatterplots depicting the relationship between brooding rumination scores and reaction times for correct responses to* ***a)*** *invalidly cued endogenous trials, and* ***b)*** *invalidly cued exogenous trials in the Posner attentional cueing task*

4.3.4 SSRT analysis

4.3.4.1 Relationship between SSRT and self-report measures

Table 4.4: *Descriptive statistics for both SSRT calculation methods*

	Mean	S.D.	Range
Mean Method 50/50	.129	.202	-.41 – .65
Mean Method 75/25	.175	.238	-.35 – 1.02
Median Method 50/50	.096	.217	-.47 – .61
Median Method 75/25	.138	.259	-.36 – 1.03

Note: All values given in milliseconds (ms)

No significant associations were observed between any calculated SSRT for either 50/50 trials (50% go signal, 50% no-go signal) or 75/25 trials (75% go signal, 25% no-go signal) and BDI scores, overall RRS scores, or the RRS sub-scales. ARQ scores were significantly positively associated with both mean and median calculation method SSRTs for 50/50 trials (mean method: $r(40)=.285$, $p = ..0375$; median method: $r(40)=.319$, $p = .0225$) and for 75/25 trials (mean method: $r_s(40)=.299$, $p = ..0305$; median method: $r_s(40)=.330$, $p = .019$).

4.4 Discussion

The present study aimed to investigate whether the frequency of rumination, and the nature of these ruminations, was related to any improvements in the executive functions working memory, attentional control, and response inhibition, in a group of individuals without diagnoses of depression or other psychological disorders. The results suggest that there is mixed evidence for rumination's relationship with executive functioning, and consistent

with the findings of Chapter Three, it appears that the subcomponents of rumination are differentially involved.

Although no relationship was observed with overall RRS scores and any digit span measure, a significant positive relationship emerged between RRS-R scores and both total number of sequences recalled correctly and the overall threshold value. As such, individuals who engaged more frequently in reflective ruminations recalled more digit sequences correctly and had higher thresholds at which their performance dropped to 50% accuracy. This suggests that highly reflective individuals have an associated increase in working memory capacity. As noted, working memory capacity has been associated with problem solving ability (Lv, 2015) and so the association between reflective rumination and working memory may go someway to explaining the relationship between reflective rumination and problem solving ability. Reflection has been shown to form a part of active problem solving (Hasegawa et al., 2016), with reflective ruminations typically concerning the analysis of an encountered problem. Such analysis normally requires the manipulation of multiple units of information, and so reflectors require greater working memory capacity in order to effectively process this information, given that they are more likely to engage in analytical thinking. What is unclear, however, is whether reflectors naturally possess greater working memory capacity, or whether working memory capacity increases as a result of repeated engagement in reflective rumination. Critically, the present sample was without any indication of clinical diagnoses, present or historical, and thus extends current knowledge on the nature of the relationship between rumination and working memory. Specifically, these results contrast with observations from healthy controls in clinical studies (Connolly et al., 2014; Joormann et al., 2011) which report no such associations, and highlights the importance of fully investigating each component of

rumiation individually given their apparent independent contributions to different cognitive functions (see Chapter Three).

Contrary to predictions, no association was observed between any measure of rumination and improved reaction times or accuracy on the Posner attentional cueing task. Rather, a significant positive association emerged between RRS-B scores and reaction times for correct responses on invalidly cued trials overall, with further analysis indicating that this was driven by a significant positive relationship between RRS-B scores and reaction times to invalid endogenous cues, indicating that on these trials individuals who engaged in more frequent brooding ruminations were slower in giving a correct response. To the author's knowledge, this finding is somewhat novel with respect to the attention literature and is the first to demonstrate slowed reaction times in association with brooding rumination. Returning to the data, brooding exhibited no associations with accuracy in the task (all *ps* > .214). Thus, differences in accuracy cannot explain any differences observed in reaction times.

There are two potential explanations for these observations. First, individuals who more frequently engage in brooding rumination may find it more difficult to disengage their attention from the initial cue on invalid trials. In the present version of the Posner attention task, across all blocks 80% of the cues presented were valid, such that the box indicated by the cue would become the target, with the remaining cues not being indicative of the eventual target. As such, invalid cues are relatively rare and so it is easier to assume that a presented cue will be indicative of the target, thus participants learn to associate the target with the presented cue. With respect to individuals who display high frequency brooding behaviours, it is possible that once they become reliant on the common valid cues, they find it difficult to disengage from the cued location on invalid trials and require extra time to make a correct response as a result. Prior research has alluded to potential

problems in task switching among high frequency ruminators (Altamirano et al., 2010; Whitmer & Banich, 2007) which may explain the delay in correct responses given to invalid cues by brooders. An alternative explanation concerns brooding's potential role as a hesitation mechanism in order to avoid making risky decisions (Chapter Three). As noted, valid trials are far more common than invalid trials; however, upon the discovery of invalid trials, brooders may become more hesitant to react as quickly as before, resulting in a delay in reaction times. Indeed, adaptive response switching may depend on hesitancy as a result of brooding, such that individuals who display high frequency brooding behaviours may be more hesitant to switch responses in the face of infrequent events (i.e. invalid trials) as these may be anomalous events and as such, there may be no adaptive benefit in changing a response, or response pattern.

The significant positive association between SSRTs and ARQ scores also ran contrary to our predictions. Larger SSRTs are indicative of participants requiring more time to inhibit an initiated response, and are therefore associated with poorer performance on the task. Thus, within the present sample, individuals who more frequently engaged in analytical-type ruminations were manifested poorer performance overall in the SSRT task. Given the relative infancy of the ARQ as a measure, explanations for this observation are speculative. Previous research has found associations between slowed SSRTs and levels of depression in patients (Bora, Harrison, Yücel, & Pantelis, 2013) and remitted individuals (Aker, Bø, Harmer, Stiles, & Landrø, 2016) and as such, given rumination's close association with depression, the present results may give an indication as to why some depressed individuals, specifically those who frequently engage in analytical-type ruminations, have difficulty in inhibiting responses in cognitive tasks. Difficulties in response inhibition in cognitive tasks may be indicative of more general inhibition difficulties impacting emotion regulation which may perpetuate depressive symtpoms and

thus, rumination (Joormann & Gotlib, 2010). As such, delays in inhibition may be a mechanism through which analytical ruminations perpetuate themselves following anomalous results of behaviour in order to dedicate cognitive resources to understanding why such an outcome occurred. The 'oddball effect' or orienting account of inhibitory control (Notebaert et al., 2009), states that, during response-inhibition tasks delays in response inhibition occur following either an infrequent error or an infrequent correct response. The infrequent nature of either the error or correct response (depending on the experimental set-up) is thought to capture attention, causing a deviation in attention from the task and ultimately resulting in inhibition delays as individuals reorient themselves to the task. Indeed, numerous studies have now detailed post-error slowing following rare errors in inhibition tasks (Houtman, Castellar, & Notebaert, 2012; Jonker, Seli, Cheyne, & Smilek, 2013; Notebaert & Verguts, 2011) which generalises across tasks (Wang, Pan, Tan, Liu, & Chen, 2016), suggesting that this may be a general rather than a task-specific mechanism.

A conflict monitoring account (Botvinick, Braver, Barch, Carter, & Cohen, 2001) offers an alternative explanation for delays in inhibition. Here, it is the errors which are important, as opposed to whether an error or correct response is infrequent, and as such delays occur following an error as the cognitive control systems adapt in order to reduce the frequency of errors. Thus, in the context of the stop-signal task, once an error occurs go-responses are delayed as participants try to ensure their response to the following trial is accurate. With respect to analytical ruminators, the positive relationship between levels of analytical rumination and SSRTs may be indicative of this more cautious approach to the task. This compliments previous work which suggests ruminators may be more hesitant in risk-reward scenarios (see Chapter Three) in order to mitigate the risk of potential negative consequences by effectively processing task-relevant information. Thus, there is a response

time tradeoff, such that analytical ruminators take longer to respond more accurately, thereby avoiding any risks. In the present study, the frequency of stop-signals was manipulated in such a way that infrequent correct responses were rare. As such, it is not possible to directly compare the orienting account and conflict monitoring accounts with the available data.

Finally. to the author's knowledge, this is the first study to utilise the ARQ to examine associations between scores on this questionnaire and behavioural measures. Consistent with Barbic et al. (2014), ARQ scores were strongly and positively associated with RRS-Reflection scores and showed no significant correlation with BDI scores. However, significant positive correlations were also observed with RRS-Brooding, which suggests that brooding may have a role in analytical ruminations consistent with evidence of brooding's association with improved performance in risk-based tasks. The absence of a relationship between ARQ and BDI scores suggest that the ARQ captures a unique aspect of rumination which is independent of depressive symptoms. Indeed whereas the RRS (and consequently RRS-R and RRS-B) asks individuals to report their ruminations in response to depressed mood, the ARQ is more general in its enquiry, asking participants to report their ruminations in response to problems more generally. Although the RRS-R and RRS-B measure some aspect of depressive response, the relationships with ARQ scores may indicate that they measure some shared aspect of analytical rumination which may be involved in depressive symptoms, although not with depression directly.

A potential limitation concerns the use of the Posner attentional cueing task. As noted, the results from this task ran contrary to predictions which may be a consequence of the relatively short nature of the task. When considering the role of attention in a problem solving framework, it is arguable that complex problems are not likely to be solved in a rapid fashion. Rather, effective solutions are more likely to be arrived at following

sustained analysis (Andrews & Thomson, 2009), and thus, differences between high and low frequency ruminators may become more apparent under conditions of sustained attention. As such, while the present results are not necessarily incompatible with this view, future work should investigate the association between rumination and ability to maintain sustained attention. Moreover, these studies should also vary working memory load where appropriate, due to the present data indicating a link between rumination and working memory ability in addition to a number of studies suggesting a link between working memory and attentional processes (e.g. Fruchtman-Steinbok & Kessler, 2016; Saito & Miyake, 2004; Shulman & Greenberg, 1971).

4.5 Conclusion

The present study indicates that both reflective and brooding rumination are related to executive functioning in ways which may explain the positive relationships with problem solving ability observed previously. Furthermore, analytical ruminations, as specifically measured by the ARQ, appear to be independent of depressive symptoms, further indicating the need to treat rumination as a multi-component construct. Taken together, the results suggest that the conclusion of the wider literature that rumination negatively impacts executive functioning is premature, and that such relationships must be considered with respect to potential function. Future studies should seek to employ paradigms requiring sustained attentional effort in order to determine whether rumination's relationship with attention varies as a function of the time spent on task.

Chapter Five: Rumination and risk-reward decision making: Associations in the face of explicit and implicit risks

5.1 Introduction

Rumination has classically been associated with a number of cognitive and behavioural deficits. As noted in Chapters Three and Four, several studies have linked rumination with both poorer problem solving abilities (e.g. Donaldson & Lam, 2004; Kao, Dritschel, & Astell, 2006; O'Mahen, Boyd, & Gashe, 2015; Sanders & Lam, 2010; Watkins & Baracaia, 2002; Yoon & Joormann, 2012) and executive dysfunction (Arditte & Joormann, 2011; Connolly et al., 2014; Joormann, Siemer, & Gotlib, 2007; Philippot & Brutoux, 2008; Watkins & Brown, 2002; Whitmer & Banich, 2007). Although these observations predominantly concern patient populations, evidence is now emerging that suggests that these relationships also exist in healthy populations but are more complex. As demonstrated in Chapters Three and Four, rumination has been associated with improved problem solving in social-style and risk-reward type tasks, with each sub-component of rumination contributing differentially to these tasks. Additionally, the relationship between rumination and core components of executive function (namely working memory, attentional control, and response inhibition) reflect the need to fully investigate healthy populations as the results run contrary to most clinical observations, indicating that rumination is associated with improvements (e.g. increased working memory capacity) or different behavioural strategies (delays in attentional control and response inhibition, with no impact on accuracy) as opposed to deficits in performance as seen in patients.

In light of the novel findings from Chapter Three that brooding is associated with risk-reward problem solving in non-clinical samples, one remaining question concerns the relationship between rumination and decision making under risk in the absence of disorder.

Current knowledge has been informed largely by investigations using atypical samples, as with the larger problem solving literature, and suggests that rumination negatively impacts the efficacy of decisions made under conditions of risk. Atlas and Peterson (1990), for example, found in problem gamblers that rumination was associated with an increase in the amount of money wagered following a loss. Moreover, rumination was also associated with less successful wagers overall. More recently, de Lisle, Dowling, and Sabura Allen (2014) found that rumination positively correlated with self-reported gambling severity such that individuals who ruminated more frequently reported greater levels of problem-gambling. However, as demonstrated in Chapter Three, individuals who are clinically healthy show no such deficits in risk-reward type tasks and, in fact, perform better at a modified Iowa gambling task when engaging more frequently in rumination. Furthermore, reflection and brooding were found to relate differentially to play and pass strategies on each deck (for a full description of the task see Chapter Three and Cauffman et al., 2010). Again, this not only emphasises the need to investigate beyond the scope of clinical populations but also indicates that rumination is not a unitary process and that each component may relate to behavioural performance differentially.

To date, the empirical and theoretical literature pertaining to the potential advantages of rumination under conditions of risk remains relatively sparse; however, the available empirical evidence complements existing theory on the adaptive nature of low mood in facilitating problem solving. The relationship between low mood and rumination, and how they may interact at a potentially adaptive level, is well established (see Chapter One) and as such, it is feasible that rumination may function as the adaptive mechanism in functional accounts of low mood. With respect to low mood and risk, only one theory has been formulated to the author's knowledge. Nettle (2009) proposes that low mood is an adaptation to limit risky decisions, reasoning that individuals who are moderately low in

mood should avoid risks because the emotional consequences of failure (e.g. gambling and losing) do not outweigh the potential benefits of success (e.g. gambling and winning). Conversely, individuals with 'normal' levels of mood and individuals who are depressed should take more risks than those who a low in mood. For individuals with 'normal' levels of mood, the consequences of failure are not as emotionally damaging compared to those with moderately low levels of mood. Importantly, individuals with 'normal' levels of mood are more emotionally resilient, and thus they are able to experience failure and continue as normal. Depressed individuals, on the other hand, are able to endure failure due to their conception that their situation cannot deteriorate further. As such, the consequences of failure are diminished resulting in the rewards outweighing the risks. In this model ascending the low mood continuum from non-depressed through low mood to depression, a U-shaped curve should emerge with respect to the frequency of risks taken.

At present, there is a dearth of direct empirical evidence supporting Nettle's (2009) model with only one study explicitly examining the relationship between depression, risky decision making, and attitudes towards risk to our knowledge. Garcia-Retamero, Okan, and Maldonado (2015) found that individuals classified as depressed (though they did not carry a formal clinical diagnosis) were less likely to make risky decisions than their non-depressed counterparts. Moreover, depressed individuals were less likely to recommend risky decisions to others, indicating a general risk aversion as opposed to self-focussed aversion. Furthermore, as demonstrated by in Chapter Three, levels of depression as measured by the Beck Depression Inventory (BDI; Beck, Ward, Mendelson, Mock, & Erbaugh, 1961) in a non-clinical sample were associated with avoiding high risk decisions in a modified Iowa Gambling Task (mIGT, see Chapter Three for a full description), further supporting the model. It is important to note that neither of these studies included patients in their samples, and as such, the most extreme manifestations of low mood were

excluded. Consequently, it is unclear as to whether the pattern of risk-related decisions follows the U-shaped distribution as suggested by Nettle (2009).

As noted in Chapter Three, rumination may serve as the mechanism by which risky decisions are attenuated in individuals with low mood. Indeed, the association between increased frequency of rumination and fewer risky decisions made in a gambling task parallels that of the association with low mood. Moreover, the relationship between rumination and risky decision making may be delineated further by examining the reflection and brooding sub-components individually. As predicted reflection correlated negatively with risky decision making, but, contrary to predictions, so did brooding. Further to this, brooding exhibited a unique relationship with decision making associated with one of the 'bad' decks in the modified Iowa gambling task. Recall that one of the two 'bad' decks produces infrequent-yet-large losses, whereas the other produces frequent-yet-small losses. In spite of both decks resulting in the same net loss over a period of ten trials, only high frequency of brooding rumination was associated with avoiding cards from the frequent-yet-small deck. One potential explanation for this finding may be that increases in the frequency of brooding rumination are associated with an increased sensitivity to negative outcomes, thereby allowing frequent brooding ruminators to discern the negative nature of the frequent-yet-small losses deck which may not be as apparent as the infrequent-yet-large losses deck. At present, however, this remains speculative owing to an absence of studies investigating this.

One final factor that must be considered concerns the availability of information regarding the probability of a positive or negative outcome when engaging in risky decision making. Indeed, when making real world decisions there are often times where the probabilities of success and failure are not explicitly known and as such, they must be inferred. Specifically, with respect to the mIGT, participants are required to calculate the

relative risks of each deck for themselves based on their experiences with each deck. As such, one may engage in implicit learning in order to determine which decks are more favourable, a phenomenon which has been observed in the classic IGT (e.g. Bechara, Damasio, Tranel, & Damasio, 1997; Bechara, Damasio, Damasio, & Anderson, 1994; Brand, Recknor, Grabenhorst, & Bechara, 2007; Jollant et al., 2016). Conversely, there are some scenarios in which the risks are known and as such the probabilities of positive and negative outcomes are explicit. Whether rumination affects decision making with implicit and explicit risks differentially is currently unknown. Moreover, the literature on rumination and learning is currently sparse and so it is difficult to formulate predictions with respect to these effects.

The aims of the present study are twofold. First, to extend the findings of Chapter Three by investigating the relationship between rumination and decision making under conditions of risk by using two different gambling tasks in which the available information regarding the consequences of a decision differ. Specifically, in one task (the mIGT) the probability of winning or losing on each trial must be learnt implicitly, whereas in a second task (Game of Dice Task, GoDT; Brand et al., 2005) the probabilities of winning or losing on each trial are explicitly given. Second, to determine the specificity of the association between rumination and variations in risk-based decision making. As noted in Chapter Three, there is a growing literature that suggests that when investigating evolutionarily relevant hypotheses, it is important to employ tasks that are in some way analogous to evolutionary problems encountered by our ancestors. Gambling tasks are appropriate in a modern context as they typically concern the accumulation of currency (either hypothetical or real), which may be considered a modern equivalent of resource gathering. Thus, by also administering a task that does not have an evolutionary equivalent, one may determine the specificity of the adaptive mechanism in question. Here, the Stoplight task (Chein et

al., 2011) will also be administered as a measure of risk-based decision making that critically does not have an analogous evolutionary component. Moreover, the Stoplight task has no explicit or implicit rules regarding the probabilities of positive or negative outcomes and therefore measures an individual's propensity to engage in risky decisions. From an adaptive/goal directed perspective, two predictions can be made depending on the specificity of rumination's potential effect. First, if rumination is associated with making fewer risky decisions generally, then this association should be observed across all tasks. However, if the mechanism is domain specific, associations may only be observed in tasks with potential evolutionary relevance (e.g. the gambling tasks).

5.2 Methods

5.2.1 Participants

Participants were recruited from the student body of Durham University. All participants reported no personal history of psychological or neurological disorder and indicated that they had not been taking any medications in the past six months that may affect the central nervous system. Three participants were removed from the analysis owing to BDI scores falling three standard deviations away from the mean. In accordance with the recommendation of the Ethics Committee, all participants were provided with materials detailing the services available both within the University and from independent organisations which provide support to individuals experiencing distress, with participants encouraged to contact them and their General Practitioner if appropriate. The final sample comprised 12 males and 28 females, with a mean age of 21.08 years (*S.D.*: 2.67 years). Participants were reimbursed with either course credit or a £5 voucher for an online retailer. The study protocol was approved by the Durham University Department of Psychology Ethics Committee.

5.2.2 Measures

5.2.2.1 Beck depression inventory (BDI)

The 20-item BDI reported acceptable internal consistency at both T1 and T2 (Cronbach's α: .922 and .891 respectively).

5.2.2.2 Ruminative response scale (RRS)

The full RRS reported an acceptable internal consistency at T1 and T2 (Cronbach's α: ..896 and .89 respectively). Internal consistencies for both brooding and reflection subscales were acceptable at T1 (Cronbach's α: .711 and .8, respectively) and T2 (Cronbach's α: .718 and .831 respectively).

5.2.2.3 Analytical rumination questionnaire

Internal consistencies for the ARQ at T1 and T2 were acceptable (Cronbach's α: .922 and .853 respectively).

5.2.3 Tasks

5.2.3.1 Modified Iowa gambling task (mIGT)

The mIGT, as described by Cauffman et al. (2010), was administered. Please see Chapter Three (pp. 52-53), for a full description of the task and calculation of outcome measures.

5.2.3.2 Game of dice task

The GoDT (Brand et al., 2005) is a computerised gambling task in which participants are asked to attempt to win as much money as possible by betting on the possible outcomes of a single die roll. On each trial, participants may choose the total number of outcomes they wish to bet on and the combination of numbers for that bet (see Figure 5.1 for combinations). The potential gains and losses are determined by the number of outcomes wagered on, such that the fewer numbers selected the larger the gain or loss will be.

Conversely, by betting on more numbers, the gains and losses become smaller. This reflects the probability of success and failure and emulates situations of high risk plus high reward and low risk plus low reward. Unlike the mIGT, the probability of each outcome can be reasoned easily based on the ratio of occurrence (1:6, 2:6, 3:6, and 4:6), resulting in explicitly known risks that are quantifiable. Participants are informed of how much money they have won or lost after each trial. For the purposes of analysis, trials where participants bet on only one or two numbers were classified as risky and disadvantageous. Trials where participants bet on three or four numbers were classified as non-risky and advantageous. The task was administered using the default settings, resulting in 12 trials overall. Given that no implicit rules regarding advantageous versus disadvantageous strategies must be learnt over a series of trials (as in the mIGT), a lower number of trials is acceptable.

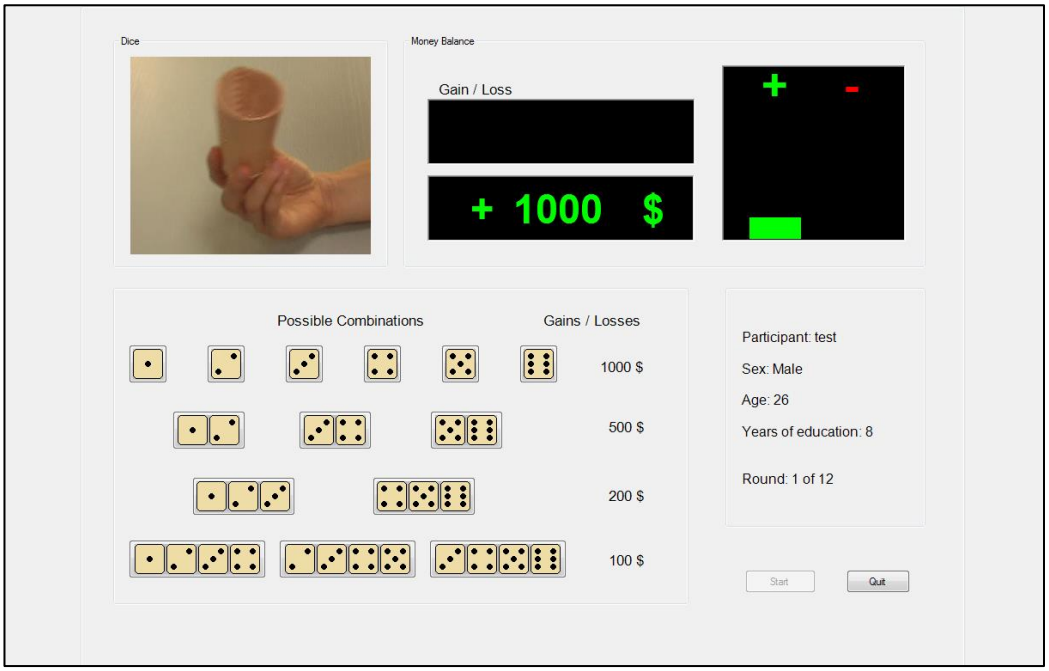

Figure 5.1: *Example trial screen from the Game of Dice task. Participants are asked to choose from the betting options on the left, at which point the result of the dice roll is revealed. Earnings/losses for that round are indicated at the top of the screen. Current monetary total is also displayed.*

5.2.3.3 Stoplight task

The Stoplight task developed by Chein et al. (2011) is a measure of risk taking in the absence of any discernible rules regarding the probability of positive or negative outcomes. The task itself comprises a simple driving simulation of a journey from the participant's home to a party being hosted in the mountains. During the task, participants are informed that they are to reach their destination within five minutes and along the way must make decisions at each intersection as to whether they will stop at a set of traffic lights, or continue through the traffic lights and risk crashing with traffic. Continuing through the traffic lights without incident resulted in time being saved, whereas stopping at the traffic lights resulted in a slight delay. Should participants choose not to stop and become involved in an accident then the delay incurred here is greater than if they had chosen to stop. Critically, the timing of the traffic signals at each intersection, and the probability of crashing were varied randomly. As such, there are no rules that the participant can learn, either implicitly or explicitly, which will help them to take more successful risks. Participants engaged the brake by pressing the space key on a keyboard. The total time spent driving (in seconds), the time taken to engage the break (in milliseconds) and the number of risky and non-risky decisions made were recorded.

5.2.4 Procedure

Recruitment was conducted primarily through the use of online advertisements within the University and through word of mouth. Prior to arrival, participants were contacted to confirm that they did not meet any of the exclusion criteria. Testing was conducted in two labs across two campuses of the University. Before beginning the testing session, all participants were provided with written and verbal explanations of what would happen during the testing session and given assurances regarding confidentiality of participation. Finally, all participants gave full written consent.

Participants first completed the BDI, RRS, and ARQ, administered in a random order before completing the task battery. Tasks were administered in a random order to each participant. The order of tasks was determined prior to the experimental session. After completing the task battery, participants completed the BDI, RRS, and ARQ for a second time, again in a random order, before being debriefed and compensated for their time.

All tasks were presented on a 15.6 inch monitor at 1920x1080 resolution, with a refresh rate of 60Hz, placed 57cm away from the participant. Participants' head position was maintained with the use of a chin rest.

5.2.5 Data analysis

Descriptive statistics for each questionnaire measure are given in Table 5.1. All responses given to self-report measures at T1 and T2 were compared to validate the robustness of the self-report measures.

Table 5.1: *Descriptive statistics for the questionnaire variables under investigation*

	Mean	**S.D.**
BDI	9.80	8.65
RRS	41.4	9.91
RRS-R	9.52	3.41
RRS-B	9.58	2.86
ARQ	66.6	13.5

Note: BDI = Beck Depression Inventory, RRS = Ruminative Response Scale, RRS-R = Reflection subscale of the Ruminative Response Scale, RRS-B = Brooding subscale of the Ruminative Response Scale, ARQ = Analytical Rumination Questionnaire

Scores on each questionnaire measure were correlated with outcome variables from each task. Percentage of good plays (e.g. how often a participant chose to play when

presented with a low-risk deck), percentage of bad plays (e.g. how often a participant chose to play when presented with a high risk deck), and net task score were computed for the mIGT, as described in Chapter Three, (pp. 52-53). For the GoDT, net task score was calculated by subtracting the number of risky decisions from the number of non-risky decisions. Furthermore, differences in the frequency of which different dice combinations were selected were investigated using a simple repeated measures ANOVA. To investigate potential interactions between high/low frequency of rumination (reflection or brooding) and the number of dice selected in the GoDT, multiple mixed model ANOVAs were computed. A median split procedure was conducted using reflection and brooding scores to create high and low frequency reflection groups, and high and low frequency brooding groups respectively. Median scores were calculated for reflection and brooding independently with participants assigned to high or low groups depending on whether their score fell above or below this value. Participants whose score fell on the median were excluded from the analysis. Finally, in order to assess differences in performance across all tasks directly, the number of good and bad decisions (i.e. non-risky and risky decisions respectively) were converted to percentages and initially subjected to repeated measures ANOVAs.

5.3 Results

5.3.1 Comparison of T1 and T2 self-report measures

Only comparisons for BDI scores reached significance, $Z = -2.826$, $p = .005$, such that scores at T2 (BDI: $M = 9.16$, $S.D. = 8.49$) were significantly lower than at T1 (BDI: $M = 10.44$, $S.D. = 9.05$). All other comparisons returned non-significance, all $p > .51$. All subsequent analyses were conducted using an average score calculated from T1 and T2 scores. However, due to the significant difference between T1 and T2 scores for the BDI, analyses using BDI scores were restricted to those collected at T1.

5.3.2 Modified Iowa gambling task

5.3.2.1 Relationship between overall task measures and self-report measures

Descriptive statistics for the mIGT are given in Table 5.2. No associations achieved significance (all *n.s.* > .079).

Table 5.2: *Descriptive statistics for the task percentage variables calculated for the mIGT*

	Mean	**S.D.**	**Range**
Percentage good plays	79.1	14.5	50 – 100
Percentage bad plays	70.1	17.4	16.7 – 100
Net task score	9.1	19.3	-35.7 – 73.3

5.3.3 Game of dice task

5.3.3.1 Relationship between overall task measures and self-report measures

Descriptive statistics for all GoDT variables are given in Table 5.3. Correlations conducted to test the relationship between each self-report measure and net GoDT score and final monetary total revealed only one significant relationship: ARQ scores were significantly negatively associated with final monetary total, $r_s(35)= -.408$, $p = .015$. No other correlation achieved significance, all *ps* > .071.

Table 5.3: *Descriptive statistics for each of the GoDT outcome variables*

	Mean	S.D.	Range
One Die Selected	.57	1.21	0 – 5
Two Dice Selected	2.52	2.33	0 – 8
Three Dice Selected	4.86	2.83	0 – 12
Four Dice Selected	4.05	3.22	0 – 12
Risky Decisions Made	3.10	2.88	0 – 11
Non-Risky Decisions Made	8.90	2.88	1 – 12
Net Score	5.81	5.76	-10 – 12
Total Money Won (£)	323.81	1924.40	-5400 – 3900

5.3.3.2 Differences in relative risk selection

A simple repeated measures ANOVA conducted to investigate differences between each betting option (e.g. one die, two dice etc.) revealed a significant effect of die number, $F(1.986, 75.483) = 17.529$, $p < .001$, $\eta^2 = .316$, Greenhouse-Geisser corrected. Significant differences were observed between the number of times one die was chosen and the number of times each of the other betting options was chosen, all *ps* < .001, such that the one die option was chosen significantly less frequently (*M* = .54, *S.D.* =.19) than the two dice (*M* = 2.67, *S.E.* = 2.34), three dice (*M* = 4.59, *S.E.* =2.35), and four dice (*M* = .4.21, *S.E.* =3.19) options. Furthermore, two dice were selected significantly less often the three dice, $p = .011$. The frequency of selection did not differ significantly between three and four dice options, $p = 1$. Furthermore, Initial analysis of the potential interactions between high/low rumination groups and the number of dice selected revealed no significant interactions across all grouping variables, all *ps* > .349.

5.3.4 Stoplight task

5.3.4.1 Relationship between overall task measures and self-report measures

Descriptive statistics for the Stoplight task are given in Table 5.4. As in the GoDT analysis, only ARQ scores were found to correlate with any outcome measure from the Stoplight task. Specifically, ARQ scores significantly negatively correlated with the average time taken to engage the brake following the presentation of a yellow light. $r_s(35) = -.476$, $p = .004$, No other comparison achieved significance, all $p > .09$.

Table 5.4: *Descriptive statistics for each of the Stoplight task variables*

	Mean	S.D.	Range
Risky Decisions Made	7.33	2.87	2 – 15
Non-Risky Decisions Made	10.78	3.02	2 – 17
Successful Risky Decisions	3.95	1.78	1 – 9
Unsuccessful Risky Decisions	3.17	1.40	0 – 6
Brake Engagement Delay (ms)	1622.48	292.07	710 – 2167.68
Total Task Time (secs)	274.57	10.52	245.12 – 289.57

5.3.5 Cross task analysis

In order to assess differences in performance across all tasks directly, the number of good and bad decisions (i.e. non-risky and risky decisions respectively) were converted to percentages and initially subjected to repeated measures ANOVAs. Taking the percentage of good decisions made first, a significant main effect of task was observed, $F(2, 74) = 9.810$, $p < .001$, $\eta^2 = .21$. Pairwise comparisons indicate that in the Stoplight task, participants made significantly fewer good decisions ($M = 59.23$, $S.D. = 17.14$) than in the

GoDT (*M* = 72.59, *S.D*, = 23.96, *p* = .016) and mIGT (*M* = 78.19, *S.D*, = 14.58, *p* < .001). The percentage of good decision made did not differ between the GoDT and mIGT (*p* = .788). Repeating the same analysis using percentage of bad decisions made as the dependent variable returned a significant main effect of task $F(2, 74) = 51.753$, $p < .001$, $\eta^2 = .583$. Pairwise comparisons indicate that participants made significantly fewer bad decisions in the GoDT (*M* = 27.41, *S.D.* = 23.96) than in the Stoplight task (*M* = 40.78, *S.D.* = 17.14, *p* =.016) and the mIGT (*M* = 68.35, *S.D.* = 17.48, *p* < .001). Similarly, participants made significantly fewer bad decisions in the Stoplight task as compared to the mIGT (*p* < .001).

Multiple mixed model ANOVAs were then computed to investigate potential group interactions with differences in the types of decision made across the tasks. Across all analyses for both percentage of good and percentage of bad decisions made, no significant model was computed, all *ps* > .207.

5.4 Interim Discussion

The present study sought to further clarify the role of rumination and its sub-components in decision making when faced with conditions of risk. Moreover, following the work presented in Chapter Three, three tasks were used in which the available information regarding whether the outcome may or may not be favourably varied, thereby allowing for the investigation of whether rumination's involvement in the decision-making process differs as a function of information availability.

First, no significant associations were observed between any measure of rumination and performance on the modified Iowa gambling task (mIGT), nor were there group differences in play and pass patterns between the decks, irrespective of whether they are considered 'good' or 'bad', unlike the results presented in Chapter Three using the same

task. This contradiction cannot be explained by differences between the two samples, as pooling the relevant data from the present study and that detailed in Chapter Three revealed no differences between the samples in age, gender distribution, or on any of the shared self-report measures, and as such, demographic differences between the samples are unlikely to account for the disparity.

Gender differences in rumination may provide a potential explanation for the inconsistency between the results presented here and those reported previously. Although there were no differences between men and women in each self-report measure, there are nuances in the data that may indicate a moderating effect of gender and as such, further analyses were carried out in order to account for the effect of gender.

5.5 Post-hoc gender analysis

In order to investigate the potential effect of gender, the mIGT data were submitted to multiple two-way ANOVAs. Examining percentage of bad plays revealed a marginally non-significant interaction between gender and low/high rumination group membership (as calculated by conducting median splits on overall RRS scores), $F(1, 34) = 3.891$, $p = .057$, $\eta^2 = .103$. Investigation of this interaction revealed a significant effect in men only, $t(9) = 3.602$, $p = .006$, such that those men who engage more frequently in rumination made fewer bad decisions ($M = 52.05\%$, $S.D. = 13.04\%$) than those who do not frequently engage in rumination ($M = 73.59\%$, $S.D. = 6.28\%$).

For net IGT performance, analysis revealed a marginally non-significant interaction between gender and brooding group, $F(1, 30) = 3.701$, $p = .063$, $\eta^2 = .11$. Investigating this interaction revealed no significant differences however, all $ps > .106$.

Finally examining potential interactions between deck play frequencies, high/low group membership, and gender using mixed model ANOVA revealed a significant three-

way interaction between deck, low/high RRS group membership, and gender, $F(3, 102) = 2.715$, $p = .049$, $\eta^2 = .074$. Further investigation revealed a significant interaction between gender and deck play frequencies in high frequency ruminators only, $F(3, 48) = 3.595$, $p = .02$, $\eta^2 = .183$. A significant difference was observed between high frequency male ruminators and high frequency female ruminators in the frequency of which they took cards from deck B (one of the bad decks, see Chapter Two), $t(16) = 3.933$, $p = .001$. Specifically, men took significantly fewer cards from deck B ($M = 47.93\%$, *S.D.* = 14.24%) than women ($M = 78.04\%$, *S.D.* = 14.65%).

5.6 General Discussion

Statistically, a reduction in power is necessarily observed with the inclusion of an additional factor and as such, the following conclusions are speculative. Post-hoc analyses revealed a marginally non-significant interaction between gender and low/high RRS group membership when examining the percentage of bad plays made. Exploring this interaction revealed that men with more frequent ruminations showed a reduction in the percentage of bad plays made compared to men with less frequent ruminations. Conversely, women with more frequent ruminations showed an *increase* in the percentage of bad plays made compared to women with less frequent ruminations, however, this comparison did not achieve significance. Similarly, for the net mIGT score, more frequent brooding-type ruminations resulted in an increase in net performance in men, whereas for women these resulted in a decrease in net performance. Results from the mixed model ANOVAs examining each deck corroborated these findings, suggesting that increasing the frequency of rumination (potentially driven by brooding-type ruminations) may be beneficial for men but detrimental to women. There is now an extensive literature documenting gender differences in the presentation of depression and depressive symptoms, such that females generally suffer more frequently from depression and present more symptoms than men

(Akhtar-Danesh & Landeen, 2007; Kessler, Mcgonagle, Swartz, Blazer, & Nelson, 1993; Kessler et al., 1994, 2003; Weissman, Bland, Joyce, Wells, & Wittchen, 1993). As noted, a number of studies have linked depression and rumination, many of which have also detailed gender differences in the presentation of rumination which mirror those observed in depression (Johnson & Whisman, 2013; Jose & Brown, 2008; Nolen-Hoeksema et al., 1999; Strauss, Muday, McNall, & Wong, 1997). In the context of the mIGT, good and bad plays may be conceptualised as non-risky and risky decisions respectively. Thus, the gender specific effects of rumination and their implications for adaptive theory may be interpreted with regard to the risk-taking literature and may offer an explanation for the inconsistency between the results presented here and those reported previously.

There now exists a wealth of studies indicating that generally men take more risks than women (see Byrnes, Miller, & Schafer, 1999 & Cross, Copping, & Campbell, 2011 for meta-analyses) which may be in part due to differences in punishment sensitivity (Moeller & Robinson, 2009) or reward sensitivity (Li, Huang, Lin, & Sun, 2007). To date, only one study to our knowledge has been conducted to investigate the relationship between punishment and reward sensitivity, and rumination (Whitmer, Frank, & Gotlib, 2012); the results of this study suggested that ruminative states increase reward sensitivity while simultaneously decreasing punishment sensitivity. Although Whitmer et al. (2012) were also interested in the concurrent effects of major depression, and as such also studied patient populations, their findings are partially corroborated and extended by the results of the present study. Specifically, decreases in punishment sensitivity in tandem with increases in reward sensitivity may explain the pattern of behaviour exhibited by female participants who experience more frequent ruminations. This explanation, however, cannot account for the pattern of results observed for male participants. By contrast, male participants who frequently ruminate show a marked decrease in the number of risky

decisions made which would suggest that punishment sensitivity *increases* and reward sensitivity *decreases* in male participants. Without further data, however, this remains speculative.

Initial analysis of the game of dice task (GoDT) revealed a significant negative association between analytical rumination scores and participants' final monetary total indicating that the more frequent analytical-type ruminators tended to lose more money during the game. Analytical ruminations, as described by Barbic et al. (2014), consist of a focus on the problem at hand, potential solutions, and a cost-benefit analysis of these potential solutions. As such, one would anticipate that individuals who frequently engage in analytical ruminations to outperform their low frequency counterparts in tasks requiring an element of cost-benefit analysis such as the GoDT where one can explicitly calculate the risks of each betting option. As noted, rumination may increase sensitivity to reward while decreasing sensitivity to punishment (Whitmer et al., 2012) and so while analytical rumination may improve cost-benefit analyses, it is possible that these analyses are conducted on biased information. Specifically, if an individual's sensitivity to punishment is diminished, then the perceived risk of the decision is also reduced and as such may facilitate riskier decision making.

Within the Stoplight task, one significant association emerged from the initial analysis such that the more frequent analytical-type ruminators had correspondingly shorter delays in engaging the brake of the car following the presentation of a yellow light. Furthermore, the median split analysis revealed a significant difference in brake application times between high and low frequency analytical ruminators, such that high frequency analytical ruminators were faster to apply the brake. Thus, once high frequency analytical ruminators had decided on a non-risky course of action they were faster at implementing their decision. The rapid nature at which a response is initiated may be

interpreted as a form of confidence, such that analytical ruminators are more confident in their decisions and so do not hesitate to implement them. To date several studies have linked elevated levels of rumination with indecision and decreased levels of confidence (Lyubomirsky, Tucker, Caldwell, & Berg, 1999; van Randenborgh, de Jong-Meyer, & Huffmeier, 2010; Ward, Lyubomirsky, Sousa, & Nolen-Hoeksema, 2003); however these studies have examined rumination related to dysphoria which is characterised as maladaptive rather than adaptive. More recently, Kingston, Watkins, and Nolen-Hoeksema (2014) demonstrated that relative to depressive rumination, engaging in concrete-thinking (that is, *how* to deal with a problem, rather than *why* a problem exists) resulted in greater confidence and assertiveness. Although concrete thinking is not explicitly described as a form of rumination, it shares many similarities with analytical-type ruminations, in that it is solution-focussed and takes account of all the details of a given scenario, presumably to undergo predictive processing.

Predictive processing models refer to the process by which we are able to simulate reality in order to prepare for potential future events (Bendixen, SanMiguel, & Schröger, 2012). Consequently, it is thought to play a key role in problem solving, as one may simulate the potential outcomes of any given solution to a problem and assess which outcome is most favourable to the individual. Early iterations of these models concerned with perception suggest that incoming sensory information is subject to top-down processing and combined with previous knowledge in order to make predictions about the world (Friston, 2005, 2009). More recently, Clark (2015) has suggested that such predictive processing is more radical than conservative; that is, the individual is more action-oriented in their predictions in order to reduce future prediction error by assimilating the consequences of their actions with previously held knowledge. Assuming concrete thinking and analytical rumination to be somewhat analogous, analytical

rumination may improve problem solving and decision making by not only focussing resources on solution generation but also by improving an individual's confidence in their solutions, thereby increasing the likelihood of implementation. Following implementation, the individual may then process the outcomes of their solution in order to improve future predictive processing by confirming the effectiveness of the solution, or by preventing the recurrence of ineffective solutions. As such, ruminative processing may then become more efficient in the face of similar problems, either by being able to call upon a known effective solution or by being able to ignore previously ineffective solutions and dedicate cognitive resources more effectively to solution generation. To date, there has been no investigation of the link between predictive processing and rumination, however, and so this remains speculative.

Although rumination is not explicitly discussed by Nettle (2009), the observations involving brooding, presented here and previously (see Chapter Three) compliment the theoretical model of the adaptiveness of low mood. Given the strong association between low mood and brooding, we suggest based on the present data that brooding may be the mechanism through which low mood may be considered adaptive in the model. As discussed previously, the model argues that as mood changes from normal to low levels, the number of risks taken diminishes as a function of the potential emotional costs of failure. Within the present data, transitioning from low levels of brooding to high levels resulted in a significant reduction in the number of risks taken in each task. Thus, it is possible that a reduction in the level of mood may facilitate increased frequency of brooding-type ruminations culminating in risk-averse behaviours. Unfortunately, however, the present data may only partially be applied to the model due to the absence of a depression group, and as such, it is impossible to tell whether increasing brooding to levels

such as those seen in patients, for example, would result in a reversion to risk-prone behaviours as predicted by the model.

Finally, the cross task analysis revealed no significant differences between groups (i.e. low/high brooding, reflection etc.) in overall task performance in the mIGT, GoDT and Stoplight task, suggesting that any observed effects of rumination in each task are associated with risk in general and are not modulated by risk information availability. To the author's knowledge, this is the first study to investigate differences in risky decision making between tasks where information regarding risk must either be learnt implicitly, is given explicitly, or is completely absent. When examining the percentage of good decisions made, participants made fewer good decisions in the Stoplight task (where information on the probability of a positive *or* negative outcome is completely absent) than in both the GoDT and mIGT which did not differ from each other, which suggests that even when information is not explicitly given regarding the risks, participants are still able to use this information to their advantage as opposed to making potentially random decisions. By contrast, when examining the percentage of bad decisions, participants made the fewest in the GoDT, followed by the Stoplight task and finally the mIGT. At first, this may appear to contradict the apparent effect of information availability observed with good decisions; however, as the mIGT requires implicit learning, it is necessary to make a number of bad decisions in order to determine which decks are 'good' decks to take cards from. Critically, rumination or low mood did not interact with any of these measures, suggesting that the effects of rumination and low mood do not vary with the availability of information regarding risk. Moreover, this also suggests that these effects are not domain specific and may represent a more general adaptive mechanism.

The present study was subject to a number of limitations, however. Notably, BDI scores significantly differed from pre- to post-testing, such that scores were lower at post-

test (indicating improvements in mood) than at pre-test, suggesting that state, rather than trait level low mood was being assessed. Whether state and trait low mood affect problem solving differentially is currently unknown, and as such it is difficult to determine in the present study whether the beneficial effects may be attributable to either state or trait mood. In both Chapters Three and Four, mood did not differ between pre- and post-testing and the results presented here support the effects reported in those studies, thus the differences between state and trait low mood, with respect to problem solving, may be negligible. Conversely, the effects of state and trait rumination remain largely unknown, and so further studies are required to systematically document potential differences between them. A second limitation pertains to the sample collected, specifically the gender imbalance. As discussed, there is a disparity in the presentation of depression and rumination, such that women more frequently experience depression and rumination than men; however, to our knowledge, no study to date has indicated that rumination may affect men and women differently. Though the present study provides an indication that rumination may have gender-specific effects, the relatively small number of men in the current sample makes it difficult to draw any firm conclusions. As such, it is important for future studies to pursue this potential difference using adequate gender sampling, as this may have important clinical ramifications for patients and potential treatment plans. Critically, if rumination does indeed affect men and women differently, then it cannot be assumed that any treatment designed to alleviate distressing ruminations can be applied universally.

One final consideration pertains to the relationship between performance on a laboratory-based gambling task and performance on a real-world gambling task, and whether performance in one is necessarily analogous to the other. Indeed, in laboratory-based tasks, participants may potentially react to risk-based tasks differently as the

consequences of failed risk-taking are not as serious as in real-world gambling tasks, where a participant may potentially lose money. As such, behaviour in the laboratory could reflect a more relaxed approach to risk on behalf of the participant if they believe there are no tenable consequences to failure (Tierney & Hart, 2016). Studies that have incentivised performance by implying that a participant's performance on a given gambling task (for example, the IGT) is linked to their compensation have found improved decision-making in these participants (Oswald et al., 2015; Vadhan, Hart, Haney, van Gorp, & Foltin, 2009). Future replications of this study should investigate the role of incentivising performance in order to determine its impact, and whether potential effects are dependent the prospect of incentive.

5.7 Conclusion

It has become increasingly clear that rumination's involvement in risky decision making is still poorly understood; however the present study has provided evidence to suggest that again, contrary to the position of the wider literature, brooding rumination may indeed have a potential beneficial effect in regulating risky decisions. Furthermore, brooding rumination may down-regulate risky decisions in men, but up-regulate risky decisions in women. Why brooding rumination may affect men and women differentially is unclear from an adaptionist perspective, and as such requires further investigation to ensure this difference is a true difference; however, based on the present data, it appears the beneficial effects of rumination in risky decision making are not domain specific and does not differ based on the availability of risk information.

Chapter Six: An experimental investigation into the effects of mood induction on state rumination and problem solving ability

6.1 Introduction

It is now clear that rumination's relationship with problem solving is increasingly complex, and as Chapters Three, Four, and Five have shown, rumination is not unilaterally negative for problem solving ability, or for executive functioning. One remaining question, however, pertains to potential differences in the effects exerted by state versus trait rumination. As noted in Chapter Five, the inconsistencies between the observations reported there and in Chapter Three may be attributed to this, although at present, there is limited evidence examining this issue. Until now, the studies detailed in this thesis have been concerned with trait rumination, that is, the propensity for an individual ruminate following a stressor. State rumination, on the other hand, is the act of ruminating itself in response to a stressor (Key, Campbell, Bacon, & Gerin, 2008). As such, it is possible at any time for low trait ruminators to have high levels of state rumination and similarly, high trait ruminators may have low levels of state rumination.

More broadly the issue of state versus trait rumination has begun to receive a greater focus in recent years. LeMoult, Arditte, D'Avanzato, and Joormann (2013), for example, investigated the association between state rumination and emotional stress reactivity, finding that state rumination was uniquely related to difficulties in recovering from emotionally stressful events as compared to trait rumination. Additionally, state and not trait rumination predicted difficulty in disengaging from negative stimuli in dysphoric individuals. Similarly, Lewis, Taubitz, Duke, Steuer, and Larson (2015) found that state rumination was uniquely associated with elaborative processing (that is, enhanced and sustained processing) of negative material (e.g. negative-valence images) with trait rumination demonstrating no such relationship. These examples, along with a growing

number of other studies (e.g. Ciarocco, Vohs, & Baumeister, 2010; Key, Campbell, Bacon, & Gerin, 2008; Sanders & Lam, 2010) have begun to demonstrate differential effects of, and interactions between, state and trait rumination.

The majority of studies to date have largely employed trait measures of rumination designed to identify an individual's propensity to engage in rumination in a given situation; however one's propensity to engage in rumination does not necessarily indicate their current levels of rumination, nor does heightened levels of trait rumination necessarily indicate that one's state levels of rumination would be of a similar intensity. Indeed, as Moberly and Watkins (2008) note, measures such as the Response Styles Questionnaire (RSQ), commonly used to assess trait rumination, have been shown to vary in their test-retest reliability, with correlation values ranging from above .6 (Nolen-Hoeksema, 2000; Nolen-Hoeksema, Parker, & Larson, 1994) to as low as .36 (Kasch, Klein, & Lara, 2001), and it may, therefore, be difficult to determine whether it is trait or state rumination that is being measured, thereby reducing the ability to attribute effects to either accurately. A further criticism relates to the retrospective nature of such measures, such that participants are sometimes asked to recall their ruminative experiences from weeks prior to testing which may be subject to biases or recall error. It is clear, therefore, that in order not only to delineate the individual contributions of state and trait rumination but also to clarify previous research involving measurement of rumination more generally, studies must endeavour to investigate rumination as a more dynamic construct. Moreover, to our knowledge, no study to date has explicitly investigated to what extent state rumination may depend on trait rumination.

One potential method for investigating state rumination pertains to induction techniques designed to promote ruminative states in participants. Induction has seen widespread use in the affective literature as a means for dynamically altering a

participant's mood, with a number of robust and reliable techniques available (e.g. Picture presentation: Bauer, Jordan, Soares, & Meyer, 2015; Farach, Treat, & Jungé, 2014; autobiographical scripts: Liotti, Mayberg, McGinnis, Brannan, & Jerabek, 2002; Nixon, Liddle, Nixon, & Liotti, 2013; sad memory focus: Prossin et al., 2015); however, rumination induction techniques are still in an emergent state. Nolen-Hoeksema and Morrow (1993) originally investigated the effects of inducing a ruminative state versus a distracted state on levels of reported depression in moderately depressed and non-depressed participants. For the rumination induction, participants were asked to focus on the meanings and causes of their current negative mood for eight minutes, whereas for the distraction induction participants were asked to focus on a number of statements that were not personally relevant. Although increases in depressed mood were observed for moderately depressed individuals only, it is difficult to determine whether increases in rumination were observed in never depressed individuals in the absence of any observable mood effects due to levels of rumination not being quantifiably measured. Thus, it is critical to ensure that induction techniques have had the desired effect by measuring rumination immediately following the induction of a given mood. Additionally, what is also unknown is how effective induction techniques may be in the face of varying levels of trait rumination.

As noted, the literature examining the interaction between state rumination and problem solving ability is sparse with only one study to our knowledge having investigated this potential relationship. Watkins and Baracaia (2002) investigated whether inducing a ruminative state in never depressed, currently depressed, and recovered depressed participants would negatively impact social problem solving ability. Using a state induction procedure similar to Nolen-Hoeksema and Morrow (1993), depressed participants induced to ruminate were found to produce fewer solutions to the presented

problems and these solutions were rated as less effective compared to those generated by never depressed participants. Additionally, recovered depressed participants exhibited the same pattern of results as currently depressed participants. Thus it would appear that inducing a ruminative state may be detrimental to problem solving in those who are currently, or have been, depressed. However, like Nolen-Hoeksema and Morrow (1993), the levels of rumination experienced by participants post-induction were not measured, and so it is difficult to determine the precise effects of rumination at different levels, or whether different depressive states elicit different frequencies of rumination. Furthermore, without these measurements, there is no way of determining whether such an induction procedure promotes reflection or brooding differentially. As such, it is difficult to interpret the results of Watkins and Baracaia fully with respect to the adaptive rumination framework.

As rumination induction procedures are still not well established and little is known about these procedures with regard to how they may influence rumination's sub-components (i.e. do they favour reflective or brooding components), the present study attempts to induce state rumination were conducted using an alternative mood induction. This is because the rumination hypothesis (Andrews & Thomson, 2009) predicts that rumination aids problem solving ability and that rumination is facilitated by low levels of mood, and so, by inducing a low mood state, it is thought that a ruminative state will also be induced; however, the type of ruminative state induced is unknown beforehand. Unlike previous studies where induced rumination may interact with pre-existing low mood and affect problem solving, the present study allows for the examination of the causal pathway predicted by the analytical rumination hypothesis by investigating within a population of healthy, never depressed participants. Thus, the present study aimed to investigate whether mood induction may provide a viable technique for the induction of state rumination. Moreover, by measuring rumination explicitly, we may begin to address the gap the in

literature with respect to whether induction techniques favour reflection, brooding, or both, and whether this may depend on baseline levels of mood. Subsequent to this, should mood induction prove a viable method, the effects of state rumination on problem solving ability will be investigated. In doing so, we may contrast the results here with those reported in previous chapters based on the examination of trait rumination. Due to the limited available evidence, no specific hypotheses were made with regard to the effect of state rumination on problem solving.

6.2 Methods

6.2.1 Participants

Participants were recruited from the student body of Durham University. All participants reported no personal history of psychological or neurological disorder and indicated that they had not been taking any medications in the past six months that may affect the central nervous system. Three participants were removed from the analysis owing to BDI scores falling three standard deviations away from the mean. The final sample comprised 12 males and 28 females, with a mean age of 21.08 years (*S.D.*: 2.67 years). Participants were reimbursed with either course credit or a £5 voucher for an online retailer. The study protocol was approved by the Durham University Department of Psychology Ethics Committee.

6.2.2 Trait Measures

6.2.2.1 Beck depression inventory (BDI)

The 20-item BDI reported acceptable internal consistency (Cronbach's α: .905).

6.2.2.2 Ruminative response scale (RRS)

The full RRS reported an acceptable internal consistency at (Cronbach's α: .869). Internal consistency for the reflection subscale was also acceptable (Cronbach's α: .793); however, the brooding subscale reported poorer internal consistency (Cronbach's α: .556).

6.2.2.3 Analytical rumination questionnaire (ARQ)

The internal consistency of the ARQ was acceptable (Cronbach's α: .924).

6.2.3 State Measures

In order to assess state levels of rumination, the RRS and ARQ were modified to instruct participants to complete the measures with regard to how they were thinking about the statements *at that moment*. The state versions of the RRS and ARQ were administered pre- and post-mood induction and both reported acceptable internal consistencies at pre- (RRS: Cronbach's α: .952; ARQ: Cronbach's α: .965) and post-mood induction (RRS: Cronbach's α: .949; ARQ: Cronbach's α: .96). Brooding and reflection sub-scales also reported acceptable internal consistencies at pre- (Brooding: Cronbach's α: .806; Reflection: Cronbach's α: .893) and post-induction (Brooding: Cronbach's α: .788; Reflection: Cronbach's α: .905).

In order to assess state mood, the Positive and Negative Affect Scale (PANAS; Watson, Clark, & Tellegen, 1988) was also administered at pre- and post-induction. The PANAS consists of two 10-item scales designed to assess positive (PA) and negative affect (NA). Participants are required to rate the extent to which they have experienced an emotion within a given time frame on a 5-point scale, ranging from *1 (Slightly or not at all)* to *5* (V*ery much).* Both scales have a maximum score of 50 respectively. High PA

scores indicate that participants are experiencing high levels of positive mood, whereas high NA levels indicate that participants are experiencing highly negative mood. Reported internal consistencies were acceptable at both time points (Cronbach's α: .896 & .81, pre- and post- respectively).

6.2.4 Mood Induction

Negative mood was induced using a procedure similar to that described in study two of Pickett, Gardner, and Knowles (2004). As the present study was not concerned with differences between types of negative affect, only that negative affect was induced, only one type of negative induction was employed. Participants were randomly assigned to one of two induction groups: negative or neutral. In the neutral induction condition, participants were asked to recall and write down in as much detail as possible their journey to the testing session that day for between five and eight minutes. In the negative induction condition, participants were asked to recall and write down in as much detail as possible a memory in which they felt an intense sadness, for between five and eight minutes.

There are a number of ethical concerns with regard to the induction of a transient negative mood state. For instance, care should be taken not to include participants with a history of mental health disorder, as the stress and anxiety which may be induced along with the sad mood may persist or be more resistant to modification. As such, all participants were screened for pre-existing mental health conditions prior to taking part in the study and were excluded if they reported a pre-existing mental health condition. Furthermore, participants were encouraged to bring materials with them (either music or videos) which they use to improve their mood when they experience low mood in their daily lives. Following completion of the study, participants used these materials until they had returned to pre-induction levels of mood. As in previous studies, all participants were

provided with contact information for services both within the university and from external organisations who provide support for individuals experiencing emotional distress.

6.2.5 Tasks

6.2.5.1 Modified Iowa gambling task (mIGT)

The mIGT, as described by Cauffman et al. (2010), was administered. Please see Chapter Three (pp. 52-53), for a full description of the task and calculation of outcome measures.

6.2.5.2 Modified prisoner's dilemma procedure (mPDP)

The mPDP as described in Chapter Three was administered. Please see pages 51 and 52 for a full task description.

6.2.6 Procedure

Recruitment was conducted primarily through the use of online advertisements within the University and through word of mouth. Prior to arrival, participants were contacted to confirm that they did not meet any of the exclusion criteria. Testing was conducted in two labs across two campuses of the University. Before beginning the testing session, all participants were provided with written and verbal explanations of what would happen during the testing session and given assurances regarding confidentiality of participation. Finally, all participants gave full written consent.

Participants first completed the BDI and trait versions of the RRS and ARQ, all administered in a random order. Participants then completed state versions of the RRS and ARQ, in addition to the PANAS in order to measure baseline levels of rumination and mood. State measures were also administered in a random order. Following completion of the initial state measures, participants then completed the induction procedure. Participants were then asked to complete a second set of the state measures to assess whether the

induction procedure worked as anticipated. Finally, participants completed the mIGT and mPDP in a random order before being debriefed and compensated for their time.

6.2.6 Data analysis

Descriptive statistics are given in Table 6.1. Neutral and negative mood-induction groups were compared at baseline to determine whether there were any differences in mood and rumination prior to the induction procedure. Pre- and post-induction mood and rumination scores were compared within and between both groups to ensure the induction procedure had the desired effect, and that any observed changes in mood and rumination between groups were qualitatively different. Both groups were then compared on each outcome measure for the mPDP and the mIGT. Finally, in order to assess the direct and indirect effects of low mood on ability in the mPDP and mIGT, mediation models were computed using state reflection, brooding, and ARQ scores as mediators, state mood as an independent variable, task outcome as a dependent variable. For further details on the calculation of mediation models, please see Chapter Three (p. 56). Unless otherwise stated, all post-hoc analyses were corrected for multiple comparisons using the Bonferroni-Holm method (Holm, 1979). Moreover, results from the following analyses should be interpreted with caution given the relatively small sample size.

Table 6.1: *Descriptive statistics for each trait measure under investigation for both neutral and negative mood induction groups*

	Neutral induction group		Negative induction group	
	Mean	**S.D.**	**Mean**	**S.D.**
BDI	4.13	4.12	10.11	8.64
RRS	37.75	8.19	38.78	10.23
RRS-R	9.88	4.29	8.00	2.18
RRS-B	8.00	1.85	8.56	2.46
ARQ	64.00	18.11	69.44	14.90

Note: BDI = Beck Depression Inventory, RRS = Ruminative Response Scale, RRS-R = Reflection subscale of the Ruminative Response Scale, RRS-B = Brooding subscale of the Ruminative Response Scale, ARQ = Analytical Rumination Questionnaire

6.3 Results

6.3.1 Demographic data

Both neutral and negative mood-induction groups differed significantly in baseline levels of depression, $U(15) = 15.5$, $p = .047$, such that the negative induction group had significantly higher BDI scores ($M = 10.11$) than the neutral induction group ($M = 4.13$) at baseline. No significant differences were observed in either baseline levels of overall trait rumination (as measured by the RRS), reflective, brooding, or analytical rumination, all *ps* > .29.

6.3.2 Mood induction validation

Given the significant difference in baseline levels of depressed mood, BDI scores were used as a covariate when assessing the effectiveness of the mood induction and all subsequent analyses.

Unadjusted descriptive statistics for all state measures pre- and post-induction are given in Table 6.2. Mixed-model ANCOVA on the scores from the PA scale of the PANAS revealed no significant main effects of induction group (negative or neutral), time point (pre- and post-induction scores), nor was there a significant interaction between the two, all *ps* > .264.

Table 6.2: *Descriptive statistics for each state measure under investigation for both neutral and negative mood induction groups pre- and post-induction procedure*

	Neutral induction group		**Negative induction group**	
	Mean	**S.D.**	**Mean**	**S.D.**
PA T1	31.63	8.23	25.33	6.40
PA T2	30.13	11.81	19.00	7.65
NA T1	13.75	3.33	17.44	8.28
NA T2	10.88	.99	20.56	7.42
RRS T1	32.5	10.27	36.11	16.83
RRS T2	29.13	6.33	42.89	17.27
RRS-R T1	9.13	4.22	7.22	3.90
RRS-R T2	8.5	4.18	8.56	4.67
RRS-B T1	7.13	2.70	7.67	3.39
RRS-B T2	6.00	1.31	8.56	3.84
ARQ T1	54.75	20.71	52.33	26.19
ARQ T2	56.00	23.25	62.67	18.24

Note: T1 = Pre-induction, T2 = Post-induction, PA = Positive Affect scale of the Positive Affect and Negative Affect Schedule, NA = Negative Affect scale of the Positive Affect and Negative Affect Schedule.

For NA scale scores, there was a significant interaction between induction group (negative or neutral) and time point (pre- and post-induction scores) after controlling for baseline BDI scores, $F(1,14) = 25.31$, $p < .001$, $\eta^2 = .644$. Paired samples t-tests revealed that in the neutral mood-induction group, state negative affect decreased significantly from pre-induction ($M = 16.08$) to post-induction ($M = 12.72$), $t(7) = 3.37$, $p = .012$. In the negative mood-induction group, negative affect scores increased significantly from pre-induction ($M = 15.37$) to post-induction ($M = 18.92$), $t(8) = -3.18$, $p = .013$. Moreover, the negative mood-induction group also demonstrated a significant decrease in positive affect from pre- ($M = 25.33$) to post-induction ($M = 19$), $t(8) = 4.15$, $p = .003$.

6.3.2.1 Induction effects on rumination

In order to investigate whether the mood induction procedure affected state rumination levels, pre- and post-induction levels of rumination were compared within and between each group.

For RRS scores, a significant interaction between group and time point was observed, $F(1,14) = 25.65$, $p < .001$, $\eta^2 = .596$, such that state RRS scores significantly increased in the negative mood-induction group between pre- ($M = 36.11$) and post-induction ($M = 42.89$), $t(8) = -6.448$, $p < .001$. State RRS scores did not differ significantly in the neutral mood-induction group, $p = .103$. Comparing neutral and negative mood-induction groups on pre- and post-induction RRS scores revealed significant differences in post-induction RRS scores, $t(10.34) = -2.23$, $p = .049$, such that the negative mood-induction group had significantly higher levels of rumination ($M = 42.89$) than the neutral mood-induction group ($M = 29.13$); however this comparison did not survive correction.

For reflection sub-scale scores, a significant interaction between group and time point was observed, $F(1,14) = 10.84$, $p = .005$, $\eta^2 = .436$, such that levels of reflective

rumination increased significantly between pre- (M = 7.22) and post-induction (M = 8.56) in the negative mood-induction group only, $t(8) = -3.58$, $p = .007$. Comparing neutral and negative mood-induction groups on pre- and post-induction reflection scores revealed no significant differences between the groups, all *ps* > .349.

For brooding sub-scale scores, a significant interaction between group and time point was observed, $F(1,14) = 4.8$, $p = .046$, $\eta^2 = .255$; however no post-hoc test returned significance, all *ps* > .09. Comparing neutral and negative mood-induction groups on pre- and post-induction brooding scores revealed no significant differences between the groups, all *ps* > .09.

For ARQ scores, a significant interaction between group and time point was observed, $F(1,14) = 8.53$, $p = .011$, $\eta^2 = .379$; however a significant interaction between time point and the covariate BDI, $F(1,14) = 6.61$, $p = .022$, $\eta^2 = .321$, suggesting that the regression slopes for pre- and post-induction ARQ scores vary with the level of pre-existing low mood, as measured by the BDI. Comparing neutral and negative mood-induction groups on pre- and post-induction ARQ scores revealed no significant differences between the groups, all *ps* > .518.

6.3.3 mPDP analysis

Descriptive statistics are given in Table 6.3. Comparing negative and neutral mood-induction groups on each mPDP outcome measure revealed no significant differences between either group, all *ps* > .623

Table 6.3: *Descriptive statistics for each mPDP outcome variable for both neutral and negative mood induction groups*

	Neutral induction			Negative induction		
	Mean	**S.D.**	**Range**	**Mean**	**S.D.**	**Range**
Individual score	156.00	19.30	130 - 188	163.78	26.50	120 - 216
Opponent score	-31.00	167.10	-260 - 260	89.33	198.84	-160 - 340
Task score	187.00	174.50	-130 - 400	74.44	199.91	-160 - 314

6.3.4 mIGT analysis

Descriptive statistics for overall task measures and for individual decks are given in Tables 6.4 and 6.5 respectively. First, independent samples t-tests conducted to examine the overall task outcomes (as described in Chapter Three, pp. 52-53), revealed no significant differences between neutral and negative mood-induction groups, all *ps* > .543.

Table 6.4: *Descriptive statistics for task percentage variables calculated for the mIGT for both neutral and negative mood induction groups*

	Neutral induction			Negative induction		
	Mean	**S.D.**	**Range**	**Mean**	**S.D.**	**Range**
Percentage good plays	84.70	13.87	55.56 - 96.55	88.27	9.59	74.6 - 100
Percentage bad plays	60.84	11.38	36.96 - 74.14	64.61	19.16	28.57 - 87.27
Net task score	23.86	16.88	-9.52 – 44.12	23.65	24.86	-6.10 – 71.43

Next, differences in play and pass patterns between each deck were examined as a function of group membership using mixed model ANCOVA. A significant group by deck interaction emerged, $F(3, 42) = 2.93$, $p = .044$, $\eta^2 = .379$. Post-hoc analyses using one-way ANCOVA revealed a significant difference between the neutral and negative mood-induction groups in the frequency of which participants took cards from deck A (considered one of the 'bad', net loss decks), $F(3, 42) = 6.86$, $p = .02$, $\eta^2 = .329$, such that those in the negative mood-induction group took cards significantly more often (M = 66.84%) than those in the neutral mood-induction group (M = 51.19%). However, the covariate term also returned significance, $F(3, 42) = 8.94$, $p = .01$, $\eta^2 = .39$, again suggesting the regression slopes for the frequency at which participants took cards from deck A differs at different levels of BDI score.

Table 6.5: *Descriptive statistics for play and pass percentages of each deck from the mIGT for both neutral and negative mood induction groups*

	Neutral induction		Negative induction	
	Mean	**S.D.**	**Mean**	**S.D.**
Deck A Play	74.61	21.73	62.32	25.38
Deck A Pass	25.39		37.68	
Deck B Play	94.86	6.59	91.30	9.90
Deck B Pass	5.14		8.70	
Deck C Play	51.19	24.08	66.84	28.35
Deck C Pass	48.81		33.16	
Deck D Play	73.28	30.02	85.09	13.72
Deck D Pass	26.72		14.91	

Note: Standard deviations are given for play and pass pairs for each deck

6.3.5 Mediation Analysis

Mediation analysis revealed only one significant mediation model for mPDP scores. State reflection, brooding, and ARQ scores did not significantly predict mPDP task scores (all *ps* > .148). Moreover, no significant indirect effects were observed through any mediating variable; however a significant direct effect of state negative mood was observed, $\beta = 14.81$, $p = .016$, suggesting that increased state negative mood positively predicts ability in the mPDP.

6.4 Discussion

The present study details a preliminary investigation into the effects of mood induction on state rumination, and subsequently the effects on ability in two previously used tasks using different problem solving styles. Moreover, the present study sought to determine whether

using mood induction exerts different effects on state reflection, brooding, and analytical rumination. Initial results suggest that mood induction may indeed be an effective means of inducing changes in state levels of rumination and that these changes may be driven by alterations in state frequency of reflection. Although preliminary, the available data may also give insights into how these changes in levels of rumination impact decision making in the mPDP and the mIGT, though given the small sample these conclusions should be treated as speculative.

As reported in Chapter Three, levels of reflective rumination were positively associated with the participant's individual score when playing the game (that is, the number of points the participants actively awarded themselves) which may be a result of reflective ruminations function of focussing an individual's thought processes on the self. Thus, this focus on the self may be reflected in making decisions that benefit the individual, thereby resulting in higher individual scores. In the present study, participants who underwent negative mood induction did have greater individual scores, although they did not differ significantly from the neutral mood-induction group. Though power is a primary concern when dealing with small sample sizes, one potential explanation for the absence of a significant difference may be due to an absence of differences in reflective rumination. Indeed, the negative mood-induction group did show a significant increase in reflective rumination indicating that the mood induction was successful in facilitating reflective rumination; however the neutral mood-induction group did not differ in levels of state reflective rumination from the negative mood-induction group following the induction procedure, suggesting that although reflective rumination was induced, it was not enough to significantly differ from the neutral mood-induction group. Thus, if reflective rumination has exerted similar effects in both groups, then it follows that the two groups would not differ in their independent scores.

Regarding the results for the mPDP task, the lack of a significant difference in opponent scores (that is, the score which the participant has determined for the computer) between the neutral and negative mood-induction groups may be indicative of an absence of anxious ruminations in the negative mood-induction group *or* elevated levels of anxious ruminations in the neutral mood-induction group, given that frequency of anxious ruminations has been associated with lower opponent scores previously (see Chapter Three). In the present sample, the latter explanation appears unlikely as the neutral mood-induction group experienced a significant decrease in negative affect, in addition to experiencing no significant changes in any rumination measure. Thus it is possible that the negative mood-induction group's ruminations did not contain an anxious component. Anxious-type ruminations are still poorly understood and at present, it is difficult to conceptualise how they may be incorporated in to the adaptive framework without further study. That anxious ruminations were not measured, and that participants were not directed to the type of memory they recalled, only that they encompassed sadness, makes it difficult to draw firm conclusions regarding this result.

Regarding the mIGT, a significant group interaction emerged which conflicts with previous findings. Examining the individual decks for play and pass patterns, participants who underwent negative mood induction took cards from deck A more frequently than the neutral mood-induction group. As detailed in Chapter Three (pp. 52-53), deck A is conceptualised as a bad deck due to the net loss accrued by continually taking cards over the course of ten trials. Based on our previous findings we would expect individuals with elevated levels of rumination to take fewer risks, and therefore take cards less frequently from a bad deck. Indeed, even though deck A pays out 50% of the time, which is frequent enough to make the deck appear to be a good option, it also penalises 50% of the time and so for individuals who may have heightened punishment sensitivity, it is reasonable to

predict that they would on average take cards less frequently; however this is not the case. One explanation lies in the potential interaction between state rumination and trait measures of mood and rumination. The significant covariate interaction indicated that the effects were not uniform across baseline levels of mood, and as such, the effect of state rumination may have varied also depending on baseline mood. Indeed, it is possible that the beneficial effects of induced rumination may only occur in those who already have low levels of mood to begin with, and that those who have normal levels of mood remain unaffected. Thus, if a large enough portion of the sample began below this low mood threshold, then it stands to reason that rumination may not be able to exert its potential benefits in spite of being induced. To our knowledge no study to date as examined how the effects of state rumination may depend on trait mood, and unfortunately the present sample is too small to be able to draw any conclusions based on the available data. In order to fully address this, a replication of the present study utilising a priori groups based on baseline mood, organised into 'normal', 'low' and 'extreme' groups, could be conducted. Consequently, one may observe the effect of induced rumination as a function of baseline mood.

The results from the mediation analysis indicated that no mediation effects occurred, with only a significant main effect of state negative mood on mPDP scores being observed, such that as state negative mood scores increased (i.e. state mood worsened) so too did scores on the mPDP task. The absence of mediation effects would appear to run contrary the predictions made by the analytical rumination hypothesis; however, as noted, with the mPDP anxious ruminations may play a more prominent role than other types of rumination in problem solving tasks which involve a form of social component (i.e. interacting with an opponent). In the absence of these measurements, this is difficult to determine. A second explanation pertains to the differential involvement of state and trait

rumination depending on the task used. Indeed, the absence of mediation effects in the present study contrasts with those reported in Chapter Three; however it is important to note that the present study used state measures whereas the study reported in Chapter Three used only trait measures. As such, it is possible that trait rumination may act as a mediator, as opposed to state rumination. This could be due to trait rumination being measured as the propensity to ruminate following a stressor, as opposed to the frequency of rumination at that point. This may more be more appropriate as the mPDP mimics social-type interactions and from a problem solving perspective, may be viewed as a more chronic type of problem. Thus, the propensity to ruminate over time may be more related to such problems than any state measurement.

To the author's knowledge these preliminary findings are the first to give an indication that mood induction techniques may be a suitable method for manipulating state frequency of rumination, and as such, may offer a viable alternative for investigating the effects of state rumination in the absence of reliable rumination induction procedures. It is important, however, to note the limitations of this method and steps should be taken to improve or modify the procedure. First, while changes in rumination were observed, these changes were not specific to any one type of rumination and were more general in nature. Indeed, where one may be interested in the general effects of an increase in rumination then this is of no concern; however, in the face of growing evidence that rumination's sub-components may exert differential effcts (e.g. Arditte & Joormann, 2011; Hasegawa et al., 2016; Joormann, Dkane, & Gotlib, 2006; Whiteman & Mangels, 2016; see also Chapter Three), it is critical that induction techniques become more targeted in order to evaluate each component's individual effect. With respect to the present method, the instructions given to participants asked for no specific type of memory other than one in which the recalled a feeling of intense sadness, and as such, participants could recall memories of

variable thematic content. Blagov and Singer (2004), for example, found that levels of distress experienced by participants recalling a self-defined memory varied as a function of thematic content. Moreover, within negatively valenced memories, distress varied depending on the content of the memory. As such, if levels of distress vary as a function of thematic content, it is possible that rumination may also vary, not only in frequency but also in type. For example, memories which may involve an element of threat may induce more anxious-type ruminations, whereas memories involving loss may induce more brooding-type ruminations. Thus, future studies employing a similar methodology should experiment with the specificity of the instructions regarding the *type* of memory which is recalled and how this may affect the frequency of different types of rumination.

One potential problem with the present study pertains to the measures used to assess state rumination. To the author's knowledge, there are currently no validated state measures of rumination, nor have there been efforts to develop one, and so previous investigations into state rumination have relied predominantly on the effectiveness of their induction techniques without measurement. The measures used here were modifications of established quesitonnaires, where instructions, both written and verbal, emphasised the importance of answering the questions with respect to the *here and now*, as opposed to in general. One criticism may be, therefore, that in spite of the altered instructions participants may still have answered the state measures in a similar manner to the trait measures. This is particularly critical if trait measures did not differ from state measures taken post-induction for those in the negative mood-induction group, as it is then difficult to be sure that the induction has worked, and indeed whether we are acrtually measuring state as opposed to trait rumination. This would then not only shed doubt upon the validity of the state measures but also that of the trait measures. Specifically, trait measures are thought of as relatively stable, and so, if the state measures are not different from the trait

versions and differences are observed in these measure pre- and post-induction, the validity of the trait measure is also called into question. Post-hoc analyses comparing trait scores with with state scores revealed mixed results, with some differences observed between state and trait measures for neutral mood-induction group participants only. As one of the groups demonstrated a difference between state and trait measures where the other did not, there remains the possibility that the instructions were interpreted differently by one group, resulting in the absence of a difference. Specifically in this scenario, if the group completed both sets of measures as if they were both trait or both state then it follows that no differences would be observed in the scores. Equally, there may exist a high correlation between state and trait rumination and so observing a difference between state and trait rumination may be unlikely if a particular group has a propensity to frequently engage in rumination to begin with. However, in such a group, it follows that one may be unlikely to observe differences in state rumination pre- and post-induction if they are already likely to be engaging in rumination based on their trait scores. This latter explanation seems unlikely, as significant increases in rumination were observed in the negative mood-induction group. Moreover, the two mood-induction groups did not differ in baseline levels of rumination, allowing for the attribution of the increase to the induction technique. Such an observation necessarily requires caution in interpreting the other results reported here, but more importantly highlights the need for better measures of state rumination so we may dlineate the effects of state and trait rumination should they exist.

6.5 Conclusion

The present study provides preliminary evidence that the recall of autobiographical memories can be used as an effective means of inducing changes in state rumination. The data from the current study suggests that state rumination may have an impact on problem solving ability which contrasts but also complements previous observations using trait

measures. Indeed, it would appear that entering a low mood state assists with problem solving; however, this seems to be a generalised process, as the induced low mood had no relation to the tasks with regards to content. Moreover, mediation analyses suggest that the causal pathway proposed by the analytical rumination hypothesis may be dependent on whether state or trait rumination is examined. While the conclusions made here should be treated with an element of caution given the small sample size, it is becoming more evident that rumination should be treated as a dynamic and malleable construct and future studies should strive not only to include this view of rumination but also to develop better means for inducing and measuring state rumination.

Chapter Seven: General Discussion

The initial aim of this thesis was to investigate whether rumination may be associated with improvements in problem solving ability, and investigate the relative contributions of reflection and brooding to the process, thereby providing evidence that rumination should be viewed as a continuum which exhibits differential effects as one moves from healthy to clinical presentations. Critically, it may be the relative balance of reflection and brooding which characterises whether rumination is an adaptive function or not. In trying to achieve this aim, it was hoped that such evidence may encourage the development of new research questions which do not approach rumination as a universally maladaptive construct, but rather as a potentially functional mechanism.

Results from the initial study (Chapter Three) suggest that rumination and low mood may have functional benefits at non-clinical levels in social-style and risk-reward problem solving tasks, a conclusion that conflicts with previously held accounts of rumination being detrimental. Initial results also indicated that there were no associations between rumination and abstract problem solving, as measured with the Raven's Advanced Progressive Matrices (RAPM), suggesting that the potential functional mechanism of rumination may be domain-specific, requiring problem solving scenarios similar to those encountered in the evolutionary past. Nevertheless, a recent study examining rumination and performance on the RAPM did in fact observe an inverted U-shaped relationship between trait rumination and performance on the RAPM (Hubbard et al., 2015), such that when trait rumination was low or high, performance on the RAPM was much better as compared to medium levels of trait rumination. This suggests that trait rumination may be somewhat conducive to general problem solving. While these findings may initially seem contrary, they are not necessarily incompatible. Indeed, while evolutionarily relevant stimuli have been shown to elicit clearer effects (e.g. Jackson & Calvillo, 2013; New, Cosmides, & Tooby, 2007), this does not

preclude the ability to observe effects in non-evolutionarily relevant tasks or stimuli; suggesting that evolutionarily relevant tasks may increase the likelihood of observing an effect. For example, Simpson et al. (2015) found that infant macaques were highly adept at discriminating adult macaque faces despite having little to no experience with adult macaques. As adult conspecifics pose a potential threat to infant macaques, it is more important for them to be able to discriminate between adults in order to recognise potential threats. Moreover, infants were better able to discriminate adult faces as compared to other infant macaque faces and human infant faces, and this effect was larger than the discrimination between macaque and human infant faces. This is critical as other infant macaques and human infants pose no threat; however infant macaques were better able to discriminate other infant macaques from human infants. As such, this suggests that macaques are still able to discriminate non-evolutionarily relevant stimuli, yet the effects are larger for evolutionarily relevant stimuli. With respect to the RAPM data, the absence of any observable effects suggests that the effect of rumination on general problem solving is smaller than that observed for other tasks, and therefore may require larger samples to detect, as evidenced by Hubbard et al. (2015).

A further aim of this thesis was to better understand the ruminative sub-components of reflection and brooding (Joormann et al., 2006; Treynor et al., 2003; Whitmer & Gotlib, 2011) and how they may be integrated into the adaptive framework proposed by the analytical rumination hypothesis. Originally conceived as adaptive and maladaptive respectively, it was initially hypothesised that reflection would exhibit positive associations with problem solving ability, whereas brooding would exhibit negative associations with problem solving ability. While reflection conformed to our predictions, brooding was found to be positively associated with risk-reward problem solving in a unique manner, such that individuals who more frequently engaged in brooding-type

rumination were less likely to take cards from a disadvantageous deck in the modified Iowa gambling task in which it was not clear that this was a disadvantageous deck. As such, this suggests that brooding may not be entirely maladaptive and may, in fact, elevate punishment sensitivity such that brooders were better able to recognise the disadvantageous deck. Critically, this is to our knowledge the first demonstration of brooding as a potentially adaptive force, conflicting with previous reports describing brooding as destructive (e.g. Chan, Miranda, & Surrence, 2009; Koval, Kuppens, Allen, & Sheeber, 2012; Polanco-Roman, Jurska, Quiñones, & Miranda, 2015).

As discussed in Chapter Four, brooding may functionally alter an individual's punishment and reward sensitivity, thereby altering their decision-making and subsequent problem solving. More recent evidence has begun to emerge which supports this explanation and suggests that this phenomenon is not limited to risk-reward scenarios. For example, Hasegawa et al. (2016) investigated the relationship between trait reflection, brooding, and social problem solving ability as measured by the Means-Ends Problem Solving test (MEPS), reporting that brooding was associated with cognitive and behavioural responses that attempt to avoid negative consequences. Much like the aversion to the bad decks in the mIGT, attempts to avoid negative consequences in the MEPS may be interpreted as the result of elevated punishment sensitivity. Similarly, rejection concerns and submissive interpersonal style have been associated with elevated brooding levels (Pearson, Watkins, Mullan, & Moberly, 2010), where submissive behaviours indicate an effort to avoid social reprisal from peers. Moreover, examples from the clinical literature have linked elevated levels of brooding with avoidant personality disorder (van Rijsbergen, Kok, Elgersma, Hollon, & Bockting, 2015), a disorder characterised by fears of rejection, criticism, and disapproval (American Psychiatric Association, 2013), which may be considered forms of social punishment, and thus brooding in this pathological context may

underpin these fears as a result of abnormal punishment sensitivity. Taken together, these observations support the idea of brooding as a risk aversion mechanism that becomes dysfunctional at extreme levels. The precise functional mechanism, however, remains unknown, such that individuals who engage more frequently in brooding-type rumination may either be more sensitive to actual risks, and thus, more accurate at identifying them; or may be more likely to overinterpret risk, such that they identify situations as risky irrespective of their objective risk levels.

The apparent role of brooding as a risk aversion mechanism has important implications for current adaptive theory. As Andrews and Thomson (2009) argue, rumination may be an adaptive mechanism to assist in solving complex problems encountered in our environment. Ancestrally, environments were subject to frequent changes, and thus, once safe behaviours may no longer be safe and may incur significant fitness costs. Therefore, in such scenarios, one must re-evaluate their behaviours with respect to the new environment. In the analytical rumination account, low mood serves both as an involuntary brake in order to discourage action in the new environment, and as a mechanism for the reallocation of cognitive resources for the purposes of rumination and subsequent problem solving. Expanding on this model, it is argued that the two ruminative sub-components subserve these two proposed mechanisms. The reflective sub-component is already largely considered to be adaptive in some respect (e.g. Hasegawa et al., 2016; Joormann et al., 2006; Treynor et al., 2003; Whitmer & Gotlib, 2011) and may well be related to problem solving, either by enhancing an individual's ability to problem solve or by encouraging an individual to actively engage with a given problem. Thus, in the analytical rumination account, reflection may comprise the mechanism by which cognitive resources are reallocated. Similarly, brooding has been largely characterised as maladaptive (e.g Joormann et al., 2006; Koval et al., 2012; Moberly & Watkins, 2008;

Treynor et al., 2003; Whitmer & Gotlib, 2011; Willem, Bijttebier, Claes, & Raes, 2011); however, in the face of evidence that brooding may serve a risk aversion function, within the analytical rumination framework brooding may be a likely candidate for the supposed brake mechanism. Indeed, when considering the evolutionary environment as proposed by the analytical rumination hypothesis, taking action in a frequently changing environment represents a risky behaviour as one does not know if a previously safe behaviour is viable in the new environment. As such, elevated brooding may promote risk aversion, resulting initially in inaction; however, as cognitive resources are reallocated via reflective rumination, analysis of the new environment with a view to determining which behaviours are safe and which are not takes place. Once this has been determined, low mood alleviates as rumination is no longer required, and the individual begins to engage once more with the environment.

In conceptualising reflection and brooding as mechanisms through which risky behaviours are discouraged and safer behaviours encouraged, dysfunctional brooding may offer a potential explanation for the persistence of depressive symptoms, particularly if one considers the implementation of a developed solution as a risk, given that the effectiveness of said solution is unknown. Thus, problem solving may be impaired in depressed individuals due to an unwillingness to implement any solution they may develop as a result of altered reward and punishment sensitivity. A multitude of studies have documented diminished problem solving ability in depression patients (e.g. Gotlib & Asarnow, 1979; Heppner, Baumgardner, & Jackson, 1985; Marx, Williams, & Claridge, 1992; Nezu, 1985, 1986), while other studies report associations between elevated levels of brooding and severity of depressive symptoms (Armey et al., 2009; Burwell & Shirk, 2007; Koval et al., 2012; Moberly & Watkins, 2008; Olatunji, Naragon-Gainey, & Wolitzky-Taylor, 2013)

and elevated levels of brooding in patients compared to healthy controls (Hamilton et al., 2011; Joormann et al., 2006; Lo, Ho, & Hollon, 2008).

As noted, there are two potential mechanisms through which brooding may be functional: either by elevating risk sensitivity or by making individuals more risk averse generally. However, these two mechanisms may represent two points on a continuum, such that at lower levels of brooding individuals may be more sensitive to risks while their responses to non-risky scenarios remain unaffected. However, as the frequency of brooding increases, so too does risk sensitivity, eventually resulting in a more general risk aversion as individuals become hypersensitive to risk. Consequently, such a mechanism may maintain depressive symptoms s a result of extreme hypersensitivity leading to an interpretation bias, such that individuals begin to interpret non-risky scenarios as risky and therefore cease to engage with the triggering problem as they begin to view relatively safe behaviours as risky.

At present, there is little in the way of direct investigations into the association between brooding and risk aversion, with the majority of studies instead examining risk aversion in relation to depression. The available evidence, however, suggests that depressed individuals have altered risk and reward processing. Murphy et al. (2001), for example, used a decision-making task in which participants were required to wager points on whether a yellow token was hidden amongst either a group of red boxes or blue boxes, the number of which varied on each trial. Thus, participants could theoretically make safer bets by selecting the group that was greater in number on a given trial. While healthy controls made more optimal decisions, depressed patients exhibited a general risk aversion, demonstrated by a reluctance to wager more points even when the odds of success were in their favour. Similarly, Forbes, Shaw, and Dahl (2007) found that adolescents who had recently experienced a depressive episode or went on to experience a depressive episode

demonstrated similar difficulties in recognising low-risk high-reward scenarios, as do young adults with a family history of depression (Mannie, Williams, Browning, & Cowen, 2015). Finally, there is some evidence that experimentally induced tryptophan (the biochemical precursor to serotonin) depletion is also associated with similar alterations to the processing of relative risks and rewards (Rogers et al., 2003), which may give some indication of a potential neurochemical mechanism; however, to date there has been no investigation into links between levels of brooding and either tryptophan or serotonin levels.

Much like the available risk aversion research, few studies have expressly investigated the links between brooding (and rumination more generally) and interpretation biases, and as such only indirect conclusions can be made based on the depression literature. It is also important to note that in depression, the balance of reflection and brooding may be altered as compared to non-clinical populations; however, the findings in this thesis may still help with interpreting the depression literature. In line with the risk aversion literature, depression symptoms and severity have been inversely associated with positive association biases (Orchard, Pass, & Reynolds, 2016) and positively associated with negative interpretation bias (Lee, Mathews, Shergill, & Yiend, 2016), which suggests that as symptom severity increases, the interpretation of neutral or ambiguous scenarios as positive decreases, and as such, these scenarios are increasingly interpreted as negative. Thus, as noted with respect to risk taking, individuals who are faced with situations in which the outcome are uncertain may interpret these negatively and thus refrain from engaging with the situation. To the author's knowledge, there have been only two studies that have investigated the relationship between rumination and interpretation bias. Schick, Wessa, Vollmayr, Kuehner, and Kanske (2013) found that reflection, not brooding, was negatively associated with positive interpretation biases such that those who engaged more

frequently in reflective rumination interpreted ambiguous stimuli more negatively, in a clinically healthy sample. This would appear to conflict with the idea that brooding is primarily responsible for negative interpretation bias, although the authors comment that within their sample there was minimal variance in brooding scores, thereby limiting the ability to detect any correlations between brooding and interpretation biases. Conversely, Hertel, Mor, Ferrari, Hunt and Agrawal (2014) found more frequent brooding ruminators were faster to interpret ambiguous scenarios negatively compared to individuals who do not frequently engage in brooding rumination, suggesting that brooding does indeed play a role in negative interpretation bias. The authors, however, offer no explanation as to why brooders may be faster in this regard.

The evidence presented in this thesis, in conjunction with that reported in the wider literature, would suggest that brooding does indeed have some form of adaptive function; however, it is also apparent that brooding is destructive when dysfunctional. As suggested in Chapter Three, it is possible that in healthy populations brooding is regulated by reflective processes, such that as long as reflective rumination remains dominant, the negative effects of brooding are mitigated. Thus, once reflection breaks down and becomes subordinate, brooding becomes dominant and subsequently dysfunctional, resulting in more destructive ruminations associated with more severe depressive episodes due to brooding ruminations being more abstract and less goal oriented. Indeed, reports from the clinical literature indicate that levels of reflective rumination are generally diminished relative to brooding in depression patients (Joormann et al., 2006; Pearson et al., 2010; Roelofs, Huibers, Peeters, Arntz, & van Os, 2008) and in previously depressed individuals with a history of suicidal ideation (Crane, Barnhofer, & Williams, 2007). Additionally, elevated levels of reflection have been found to predict recovery from depressive episodes (Arditte & Joormann, 2011). As evidenced, reflection has been associated with problem

solving, and so problem solving deficits as a result of diminished reflection might present another mechanism through which depressive episodes are maintained, in tandem with the effects of dysfunctional brooding. Specifically, where brooding inhibits action, individuals with diminished reflection may struggle to develop effective solutions to problems they may face. As a result of being unable to develop potentially viable solutions, individuals are unable to overcome their risk aversion and thus remain in a depressed state. Therefore, depressed individuals may only have problems with developing solutions rather than executing them. To date, only one study has examined the relationship between depression and solution execution and generation independently. Fossati, Ergis, and Allilaire (2001) found that depression patients had no deficits in concept execution (that is, the ability to enact a solution which is independent of developing a solution for themselves), but rather deficits emerged when asked to generate solutions independently, supporting the notion of a specific deficit in solution generation. Critically, however, reflection was not measured and thus it is difficult to be certain in any conclusions regarding reflection, depression, and solution generation based on these findings.

At the cognitive level, it would appear that rumination is associated differentially with various aspects of executive function, and these observations may offer some insight as to how rumination may benefit problem solving from a cognitive perspective. First, the frequency of reflective ruminations is positively associated with working memory capacity, such that more frequent reflective ruminations were associated with greater working memory capacity (Chapter Four). Originally, working memory has been theorised to be involved in problem solving (Baddeley & Logie, 1999), a proposal that has since been evidenced in adults (Just, Carpenter, & Hemphill, 1996; Lv, 2015) and children (Swanson & Beebe-Frankenberger, 2004), such that working memory capacity predicts problem solving ability. Thus, if both reflection and working memory capacity have been

shown to be associated with problem solving ability, it reasonable to assume that working memory capacity may provide a cognitive mechanism through which reflection can affect problem solving ability; a prediction the data from Chapter Four conforms to.

More recently, greater working memory capacity has been associated with improvements in global executive functioning (McCabe et al., 2010). McCabe et al. suggest that working memory may itself be subserved by an executive attention mechanism responsible for goal maintenance, allowing for the dedication of other executive functions (for example, working memory) to the active goal. As discussed in Chapter Four, brooding and analytical rumination were found to be negatively associated with reaction times on certain trials in, respectively, the Posner attention task and in the stop signal reaction time task, although accuracy was not affected, and that these results may be explained by the action inhibition account. Integrating these findings with both executive attention and problem solving accounts suggest that in a problem solving context, frequent ruminators may be better able to remain goal oriented (i.e. solving a particular problem). With individuals who are more goal oriented, there may be a trade off in speed versus accuracy of response, such that these individuals will sacrifice rapid responses for the sake of ensuring accurate responses, particularly in difficult or ambiguous situations. From an adaptive perspective, this indicates where outcomes are uncertain or the consequences of failure severe, ruminators delay engaging a solution until they are confident that their solution is likely to succeed.

One final consideration pertains to the effects of state and trait rumination and their potential overlap from an adaptionist perspective. As evidenced in Chapter Six, there were potentially differential effects of state rumination compared to the effects of trait rumination evidenced in previous chapters, which may be indicative of rumination's involvement in problem solving based on the short- versus long-term nature of the problem

at hand. Specifically, state rumination may be involved in short-term problems whereas trait rumination may be more involved in long-term problem solving. As observed in Chapter Three, trait rumination was associated with ability in the Prisoner's dilemma task, an analogue for social problem solving, whereas in Chapter Six state rumination was not associated with ability in this task. This observation indicates that state rumination may not be associated with the ability to solve problems that are more long-term in nature. Indeed, human social interactions often occur over multiple encounters with multiple individuals over a period of time, particularly when forming social bonds (Humphrey, 1976; Trivers, 1971). Thus, when social problems occur, one must not only solve the problem at hand, but also must be aware of how others in the social group may respond in future. Moreover, solving a given social problem may be more prolonged due to these distal effects within social groups, and so one's propensity to ruminate over time may be more related to solving such problems. Conversely, state rumination may exhibit stronger associations with short-term problems as one must engage in rumination on the given problem more immediately. Unlike social problems, short-term problems, such as evaluating and mitigating risks associated with resource gathering, have a more immediate impact upon an individual and may rely on an individual's ability to effectively engage in rumination quickly and purposefully.

Beyond the need to replicate the findings presented here and continue to investigate the potential beneficial effects of rumination, one final consideration for future work concerns metacognitive beliefs about ruminative processes. Metacognition refers broadly to an individual's knowledge of their own knowledge and cognitive processes (Koriat, 2007), or "thinking about thinking" (Flavell, 1979; Soderstrom, Davalos, & Vazquez, 2011), and is thought to capture a self-reflective component. To date, there exists an extensive literature documenting the effects of metacognition on memory, demonstrating

how dysfunctional metacognitive beliefs on the processes learning and memory can result in poorer recall and engagement in inferior learning strategies (e.g. Karpicke, 2009; Karpicke, Butler, & Roediger, 2009), and how metacognitive interventions can improve learning (e.g. Kramarski & Mevarech, 2003; Schmidt & Ford, 2003). Moreover, the role of metacognition has been implicated in pathological disorders such as substance abuse (Spada, Moneta, & Wells, 2007; Spada & Wells, 2005), paranoia (Morrison et al., 2005; Varese, Barkus, & Bentall, 2011), and obsessive compulsive disorder (Moritz, Peters, Larøi, & Lincoln, 2010; Myers, Fisher, & Wells, 2009). From these examples alone, it is apparent that metacognitive beliefs can impact on behaviour, but also an individual's reaction to certain cognitive phenomenon. For example, an individual's metacognitive belief about voice-hearing determines whether they find their experiences distressing (and subsequently symptomatic), or not, and subsequently non-indicative of disorder (Brett, Johns, Peters, & McGuire, 2009). Thus, the effects of certain cognitive phenomenon may vary dependent on the metacognitive beliefs of the individual.

The metacognitive literature surrounding rumination, much like the majority of the larger rumination literature, has predominantly concerned itself with the examination of metacognitive attitudes in depression patients. Roelofs, Huibers, Peeters, Arntz and Van Os (2010), for example, found currently depressed individuals receiving treatment typically endorsed ruminative thought styles, believing that the process was helpful, but subsequently worry that they cannot control the process. Similarly, Papageorgiou and Wells (2009) found depression patients were more likely to endorse positive metacognitive beliefs as compared to healthy controls. Moreover, Papageorgiou and Wells present a potential causal model for the manifestation and perseveration of rumination, suggesting that initially, patients believe rumination to be a helpful coping strategy in response to a stressor, but soon develop negative appraisals of rumination viewing it as uncontrollable

and detrimental. As a result of believing rumination to be uncontrollable, these patients are unable to attenuate their ruminative response, which may then become maladaptive or distressing, thereby perpetuating the depressive episode.

Although the evidence suggests that metacognition may play a role in the manifestation of pathological rumination, there has been a relative lack of investigation into metacognition and levels of rumination in non-clinical populations. Moreover, of those that have conducted such investigations, few if any have made distinctions between potentially adaptive and maladaptive forms of rumination. Thus it is difficult to determine whether positive and negative metacognitive beliefs promote different types of rumination differentially, or whether they may promote rumination generally. Perhaps more critically, without such studies, potential moderating effects of metacognitive beliefs on rumination and subsequent behaviour remain unknown. To date, only one study has examined individuals' metacognitive beliefs toward reflection and brooding with respect to levels of depressed mood. Gooding, Taylor, and Tarrier (2012) asked participants to self-report the frequency at which they engaged in reflective and brooding type ruminations along with their levels of depressed mood. Moreover, they also asked participants to rate how effective they felt these ruminative strategies were in response to depressed mood, finding that individuals who endorsed reflective type rumination were more likely to engage in reflective rumination during depressed moods. Finally, individuals who engaged more frequently in reflective rumination *and* endorsed reflection as an effective strategy were found to predict lower levels of depression as compared to those who engaged in reflective rumination but did not endorse this as an effective strategy. This would suggest that changing an individual's metacognitive beliefs may have a demonstrable impact on depressed mood. It is threfore possible that metacognitive beliefs may also impact the effectiveness of reflection and brooding in problem solving contexts, such that individuals

who reflect more and endorse this strategy may experience greater benefits than those who do not endorse these beliefs. Indeed, it is possible that the beneficial effects of rumination are dependent on the individual endorsing rumination as a strategy, and future work should seek to address this gap in the literature.

7.1 Conclusion

What is clear is that rumination can no longer be considered a unitary concept. Moreover, the work presented in this thesis indicates that reflection and brooding have distinct effects on behaviour and that these effects do not follow the pattern one would expect based on the available literature. This is of particular importance for brooding, which has largely been considered maladaptive; however, the evidence presented here challenges this preconception and invites a reimagining of what may be considered adaptive and maladaptive. More broadly, this thesis has addressed a systematic gap in the literature by investigating the effects of rumination and its sub-components in a healthy population but has also provided a basis for future studies to identify methods for the manipulation of rumination in vitro. Indeed, by showing that rumination is susceptible to state manipulation, it is possible that in disorders where rumination has been identified as a key factor (e.g. depression), state frequency of rumination may be manipulated in order to assist in treatment.

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