UNIVERSITY OF DERBY

THE EFFECT OF COGNITIVE AND EMOTION-BASED PROCESSES ON THE IOWA GAMBLING TASK

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Doctor of Philosophy 2017
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<td>AOI</td>
<td>Area of Interest</td>
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<tr>
<td>AOT</td>
<td>Active Open-minded Thinking</td>
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<td>aPD</td>
<td>Anticipatory Pupil Dilation</td>
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<td>aSCR</td>
<td>Anticipatory Skin Conductance Response</td>
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<td>ASI</td>
<td>Anxiety Sensitivity Index</td>
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<td>BRIEF-A</td>
<td>Behaviour Rating Inventory of Executive Function-Adult Version</td>
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<td>CFC</td>
<td>Consideration of Future Consequences</td>
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<td>CI</td>
<td>Confidence Interval</td>
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<td>CRT</td>
<td>Cognitive Reflection Test</td>
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<td>DLPFC</td>
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<td>ECG</td>
<td>Electrocardiogram</td>
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<td>EU</td>
<td>Expected Utility</td>
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<td>fSCR</td>
<td>Feedback Skin Conductance Response</td>
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<td>FT</td>
<td>Firefighters Task</td>
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<td>GDT</td>
<td>Game of Dice Task</td>
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<td>GSR</td>
<td>Galvanic Skin Response’</td>
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<td>HPA</td>
<td>hypothalamus-pituitary-adrenal</td>
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<td>HR</td>
<td>Heart Rate</td>
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<td>HRV</td>
<td>Heart Rate Variability</td>
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<td>IGT</td>
<td>Iowa Gambling Task</td>
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<td>LC</td>
<td>Locus- Coeruleus</td>
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<td>MBP</td>
<td>Mean Blood Pressure</td>
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<td>Mean Blood Pressure Response</td>
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<td>NFC</td>
<td>Need Foe Cognition</td>
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<td>PAG</td>
<td>Probability-Associated Gambling Task</td>
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<td>PD</td>
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<td>PFC</td>
<td>Prefrontal Cortex</td>
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<td>REI</td>
<td>Rational-Experiential Inventory</td>
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<td>SBP</td>
<td>Systolic Blood Pressure</td>
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<td>SD</td>
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<td>SMH</td>
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<td>Sympathetic Nervous System</td>
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<td>SR</td>
<td>Skin Responses</td>
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<td>TASS</td>
<td>The Autonomous Set of Systems</td>
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<td>TOH</td>
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<td>TSST</td>
<td>Trier Social Stress Test</td>
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<td>VMPFC</td>
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<td>WASI</td>
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<td>Working Memory</td>
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Preface

I hereby declare that this dissertation is my own original work and has not been submitted before to any institution for assessment purposes. Further, I have acknowledged all sources used and have cited these in the reference section. All the experiments in this dissertation have been approved by the Ethics committee at the University of Derby.
‘We think, each of us, that we’re much more rational than we are. And we think that we make our decisions because we have good reasons to make them. Even when it’s the other way around. We believe in the reasons, because we’ve already made the decision’.

Daniel Kahneman
Abstract

Real life decision-making depends on a complex interplay between cognitive and emotion-based processes. Damasio (1994) developed the Somatic Marker Hypothesis (SMH) arguing that emotion-based processes guide decision-making by directing individuals towards alternatives that have been previously ‘marked’ as positive or guide them away from the negative options. The primarily used test-bed of the emotion-based learning is Iowa Gambling Task (IGT, Bechara, Damasio, Damasio, & Anderson, 1994). The SMH makes three assumptions about the IGT behaviour: (a) somatic markers have a negative connotation and bias decision-making covertly in the absence of explicit knowledge, (b) there is a limited role for cognitive procesesing during IGT performance, especially during the initial stages of the task, and (c) anticipatory somatic markers guide decision-choices away from the bad options as participants are able to anticipate the good and the bad options. This thesis tested the SMH using a combination of psychophysiological methods (Eye-tracking, Pupillometry, Heart Rate and Blood Pressure measurements), behavioural measurements and psychometric measures of individual differences in combination with the IGT. The systematic review, meta-analyses and the experiments described in this Thesis explored the validity of these assumptions and found that they are not accurately manifested in behaviour during IGT performance. A novel methodology not previously employed was used to capture somatic markers through pupillary responses. Explicit learning was also assessed by the eye-tracking methodology in testing IGT performance in normal conditions and under stress. The results from the first two experiments indicated that explicit processing and knowledge about the task are more critical factors during the early stages of the game than previously suggested. Although there were some indicators of the existence of somatic markers, it was found that cognitive reflection, conscious awareness and increased cognitive processing occurred early in the game and guided behaviour on IGT. The results from the final experiment revealed that IGT performance in healthy individuals is not always optimal; stress levels impaired performance whereby a lack of, or insufficient cognitive processing early in the game may create a somatic signal that interferes with IGT performance. Furthermore, attentional processing, cognitive reflection and conscious awareness can be disrupted by stress resulting in non-optimal decision-making strategies that consequently interfere with performance on the IGT. Taken together, these results challenge the basic premises of the SMH and could be best explained within the dual-process framework (e.g., Brevers, Bechara, Cleeremans, & Noel, 2013). If somatic markers do not play a significant role in learning IGT than the task needs to be re-evaluated and caution is warranted.
when the IGT is used as a diagnostic tool to measure decision-making deficits in clinical populations.
Acknowledgments

I would like to express my gratitude to members of the Department of Psychology at the University of Derby for encouragement and support in my research career. I’m also eternally grateful to Dr Edward J. Stipple, Dr Maggie Gale and Professor David Sheffield for all their help, enduring support and their kindness during my times of challenge. I would not have finished this dissertation without their encouragement and advice. I’m also thankful to Dr Ian Baker for all his mentoring during my undergraduate years and for inspiring me to pursue a research career.

The thesis would not have been finished without the support and kind words of my family and friends. I could not have done it without them. Special thanks to my family that provided constant support and love through the dark days.
Published papers

Chapter 1

Rationale & Context

Making decisions in uncertain or ambiguous situations is a key function in everyday life. Most of the decisions people make involve some uncertainty and psychophysiological arousal (Starcke & Brand, 2012). Risky choices that may carry extensive financial consequences or different rewards or punishments are physiologically arousing. A long tradition of research in decision-making stemming from the Bayesian maximisation of expected utility theory (e.g., Von Neumann & Morgenstern, 1944) argued that uncertain decision is based on logical, cognitive processes that require rational thought and cost-benefit calculations. It was further assumed that emotions and emotional states have a detrimental impact on judgment and decision-making, whereby they hinder reasoning processes, influence the accuracy of decision-making and increase people’s tendency to take risks (Pham, 2007).

In the 1990s, however, a concept of bounded rationality resurfaced, and decision-making models gradually acknowledged the importance of emotional processes during decision-making. The groundbreaking SMH developed making a compelling case that emotional factors and arousal play a pivotal role in decision-making (Damasio, 1994). SMH postulated that decisions are guided by subjective ‘gut feeling’ (akin to intuition) about the inherent ‘goodness’ or ‘badness’ of future choices. These somatic markers direct individuals towards alternatives that have previously been positive, or guide them away from the negative options, thus creating a platform for emotion-based learning. Early research evidence from the patients with lesions of limbic structures, neurological diseases or psychological disorders emphasised the importance of emotional processes in deciding advantageous during decision-making (e.g., Bechara et al., 1994; Bechara, Damasio, Tranel, Damasio, 1997; Bechara, Damasio, Damasio, & Lee, 1999; Bechara, Tranel, & Damasio, 2000). This was evidenced through psychophysiological measurements (e.g., skin conductance response; SCR), where anticipatory SCR (aSCR) bias advantageous decision-making (e.g., Bechara et al., 1997). Thus, it was suggested that implicitly acquired somatic markers guide future choices and may significantly contribute to advantageous decision-making (e.g., Bechara et al., 1994, 1997). In contrast, reasoning processes were regarded as having much less importance.

Despite the popularity of SMH, many fundamental issues remain unresolved. For instance, psychophysiological evidence (i.e. aSCR) in support of the SMH is equivocal. There has been a limited replication of the SCR findings in healthy populations, and there is a suggestion that
somatic markers may be imperfectly represented by SCR (e.g., Dunn, Dalgleish, & Lawrence, 2006). Bechara et al. (1994) developed the IGT that is often used as an experimental task and a clinical assessment tool for testing the development of the emotion-based learning. They proposed that a healthy control chose optimally on the IGT because they are able to develop somatic markers, compared to the clinical population that shows impairment in IGT performance due to the absence of somatic markers. However, the IGT performance of healthy participants is characterised by substantial variability and individual differences, with healthy participants often failing to develop somatic markers (e.g., Fernie & Tunney, 2013; Steingroever, Wetzels, Horstmann, Neumann, & Wagenmakers, 2013). This contradicted Bechara et al.’s original assumptions that healthy participants learn to prefer the good options over the bad options because of the implicitly acquired somatic markers that signal the bad option and therefore promote the avoidance of the bad choices. A second assumption that conscious awareness develops as a result of the somatic markers late in the game and have little impact on overall IGT performance was also challenged (e.g., Bechara & Damasio, 2005). Several studies have shown that cognitive processes and conscious awareness influence the development of somatic markers, and therefore challenge the basic premises of the SMH (e.g., Maia & McClelland, 2004; Fernie & Tunney, 2006; Fernie & Tunney, 2013). This is line with research suggesting that cognitive processes may be implicated earlier in the IGT than previously suggested (e.g., Hinson, Jameson, & Whitney, 2002; Jameson, Hinson, & Whitney, 2004; Schiebener, Zamarian, Delazer, & Brand 2011; Simonovic, Stipple, Gale & Sheffield, 2016, 2017) thus, challenging a third assumption that the cognitive processes are implicated late in the game (e.g., Brand, Recknor, Grabenhorst & Bechara, 2007).

Recently, a dual-process account of decision-making has been developed to account for the cognitive processes involved during IGT performance, where a potential conflict in decision-making or the ‘disagreement’ between the cognitive processing and the development of somatic markers was identified (e.g., Brevers et al., 2013). Brevers et al.’s account maps on to the dual-process framework of reasoning and decision-making that contrast intuitive, effortless, emotional and unconscious (Type I processing) with effortful conscious and controlled characteristics (Type II, e.g., Kahneman, 2011). This proposal has been linked to SMH whereby the Type I processes include a range of intuitive processes such as emotional responses or gut feelings that can be measured through physiological techniques (Glockner & Witteman 2010). This also corresponds to Brevers et al.’s (2013) recent suggestion that ‘cool’ reflective processing (that maps on Type 2 processes) is needed for evaluation of ‘hot’,
affective choices relatively early during IGT performance. Hence, the emerging evidence suggests that there is a complex interplay between Type I and Type II processes in determining the outcome of the decision-making process and that the basic assumptions of the SMH may need some re-evaluation.

This thesis examined cognitive processes and somatic markers during IGT performance and argued that these processes represent a part of a broader learning complex such as implicit learning, explicit learning and risk-taking behaviour. A robust methodology not previously utilised was used to capture somatic marker signals implicated in implicit and explicit learning. Hence, eye-tracking methodology and hemodynamic measures of physiological arousal were used (Finapres medical system) to test the basic assumptions of the SMH framework. Furthermore, as recent evidence indicated that both types of processing work interchangeably during decision-making, this thesis explored the view that there is an interplay between emotion and cognition during decisional choices, where cognitive functions serve as mediators for emotion-based learning (e.g., Schiebener et al., 2011; Brevers et al., 2013; Simonovic et al., 2016, 2017).

A systematic review including two meta-analyses and three experimental studies were conducted to examine: evidence of the psychophysiological arousal during decision-making in uncertain context; cognitive and emotional types of processing; and the effect of stress on adaptive decision-making. The current evidence suggested that there is conflicting evidence in support of the SMH and that the key assumptions about the performance of the healthy participants warrant closer scrutiny (e.g., Dunn et al., 2006; Steingroever et al., 2013). Furthermore, there is a possibility that Type II processes play a more prominent role during decision-making on IGT than the somatic markers and these hypotheses need examination (Simonovic et al., 2016, 2017).

This thesis used a combination of psychophysiological methods (i.e. Eye-tracking, Pupilometry, Heart Rate and Blood Pressure measurements), behavioural measurements and psychometric measures of individual differences (i.e. Cognitive Reflection Test, CRT1); Active Open-minded Thinking (AOT); Rational-Experiential Inventory (REI); Consideration of Future Consequences (CFC); Anxiety Sensitivity Index (ASI); and Test of Awareness) not previously used to test assumptions made by SMH. A standard experimental paradigm for assessing emotion-based learning was employed (IGT; Bechara et al., 1994). The studies herein contribute to an understanding of emotion-based and cognitive learning systems by: (i) using...
novel measuring techniques to capture emotion-based signals; (ii) using a combination of psychophysiological and behavioural measurements to assess implicit learning and cognitive interaction; (iii) using a stress manipulation to examine beneficial and detrimental emotional effect on decision-making.

The first chapter discusses different theoretical models (i.e. Expected Utility Theory, SMH and Dual-process theory) and their underlying contributions to understanding decision-making. Specifically, decision-making, implicit learning and cognitive and emotional types of processing during decision-making were discussed within the theoretical assumptions and explanation of the SMH and a dual-process account of decision-making. The basic assumptions of the SMH were outlined and evidence examined.

The second chapter examines and discusses psychophysiological evidence in support of SMH. Despite its relevance to scientific research and practice, evidence in support of the SMH remains elusive and poorly understood. A systematic review with two meta-analyses was conducted to examine the evidence presented in support of the SMH and the role of aSCR in predicting IGT. The quality and reliability of current psychophysiological measurements were discussed.

In the third chapter, a novel and faster physiological measurement (e.g., eye-tracking methodology) was used to capture emotion-based signals (i.e. somatic markers). The currently employed SCR methodology is not without limitation and pupil dilation could serve as an alternative physiological marker. This is only the second study that measures pupil dilation during a performance on the original IGT. The study also explored the interplay between cognitive and emotional processes during decision-making on the IGT by using pupil dilation and a measure of cognitive reflection (Extended version of CRT; Toplak, West, & Stanovich, 2014). The CRT1 is constructed to measure peoples’ aptitude to engage in reflective thinking, whereby the more reflective people are, the more likely they are to inhibit the initial response to a problem and engage in finding an alternative solution to a problem. The previous research utilised the original CRT version (Frederick, 2005) during the decision-making on IGT and showed that reflective thinking plays a prominent role during IGT learning (Simonovic et al., 2016), thus contradicting previous research on IGT (e.g., Bechara et al., 1994, 1977).

The fourth chapter considered the possibility that the performance on the IGT is best understood within a dual-process framework (e.g., Brevers et al., 2013). Many studies related to dual-process theories are primarily concerned with the systematic biases related to Type I
processes. However, there is evidence that Type I processes include a range of intuitive processes such as emotional responses or ‘gut feelings’ that may be important for decision-making in uncertain condition. Eye-tracking movements were recorded to examine the nature and organisation of reasoning processes. Specifically, the active role of attention during inspection time was examined as it represents a possible explanation for the cognitive processes involved in the decision-making preferences (e.g., Krajbich, Lu, Camerer, & Rangel, 2012). Continuous, non-invasive cardiovascular measurement by Finometer (Finapres Medical System, Amsterdam, Netherlands) was also used to measure blood pressure and heart rate variability. Previous research indicated that there is substantial variability in IGT performance in healthy participants because of the physiological arousal during decision-making on IGT and this warrants further examination (e.g., Steingroever et al., 2013). In addition, to examine individual differences, critical thinking aptitude and dispositions were also assessed during the IGT performance (CRT1; Toplak et al., 2014; REI, Epstein, Pacini, Denes-Raj & Heier 1996; AOT, Haran, Ritov, & Mellers, 2013; CFC, Strathman, Gleicher, Boninger, & Edwards, 1994; and ASI, Reiss, Peterson, Gursky, & McNally, 1986). Finally, to assess participants’ level of knowledge throughout the IGT a sensitive test of awareness was used (e.g., Maia & McClelland, 2004). To the best of my knowledge this is the first study that examines attentional processing and critical thinking aptitude and dispositions during IGT performance with the eye-tracking methodology.

The fifth chapter introduced stress as an additional element. The complexity of everyday life elicits many stressful situations where it is of great importance for an individual to remain calm under pressure with relatively sound judgment to decide advantageously. Hence, the influence that stress has on the quality of a decision needs better understanding. Simonovic et al. (2016) showed that stress hinders IGT performance and impedes reflective thinking, as measured by the original CRT; and cognitive reflections can be implicated in learning during stress (Simonovic et al., 2016). Hence, the aim of the final experiment was to further explore Simonovic et al.’s previous findings. An extended version of the CRT was used (CRT1, Toplak et al., 2014). Blood pressure and heart rate variability were again measured by Finometer. In addition, inspection time (eye-tracking) and participants’ conscious awareness (Maia & McClelland, 2004) was examined during IGT performance. This is the first study that examines the effect of stress on inspection time, reflective thinking and conscious awareness during the IGT performance.
In the final chapter, potential implications of the findings on theory and practice of real-life decision-making were discussed, and suggestions were made that the eye-tracking measures offer strong promise in investigating emotion-based and cognitive processes. The implications of each experimental results were discussed in relation to SMH and dual-process theory. Possible caveats of the results were also discussed.

1.1. Introduction

People make countless decisions every day; this process ranges from simple decisions (‘What should I have for dinner today’) to highly complex ones (‘The economy is going downhill should I invest or save my money?’), and these choices often involve judging probabilities. Furthermore, any decision that people make usually include degrees of beliefs and/or desires that need fulfilling. In most of our everyday lives, probabilities are uncertain, and the outcomes of our choices are unknown. For instance, taking an umbrella out depends on judging the probability that it will rain (based on the limited and ambiguous forecasting information) and whether you want to avoid getting wet. The final decision to take the umbrella out should pass through several stages: Extracting meaning from ambiguous information in order to construct a mental representation (interpretation process); evaluating the evidence, estimating the value and likelihood of the occurrence of differing outcomes (judgment); and finally, drawing inferences and selecting from the available options (choice) (Blanchette & Richards 2010). Obviously, these processes are complex and rely on a number of cognitive processes such as attention, memory activation, object recognition etc. Thus, cognitive processes play an important part during decision-making choices.

Ever since Descartes’s quest for what is true, cognition has been identified as the ability to be logical, rational and good in mathematics (Gintis, 2007). Logic and mental arithmetics were a hallmark of a ‘rational thought’ and good decision-making. Conversely, emotions are thought to be irrational and have little to do with cognition. Indeed, emotions were usually identified as a ‘nuisance’ that can contaminate rational thought (Damasio, 1994). Although the Cartesian dualistic view is no longer prominent, it has had a profound impact on Western culture’s theoretical understanding of human rationality and decision-making. For example, a long tradition in decision-making theory emerging in the 1960s emphasised means-end reasoning based on a cold, rational logic with little regards for emotional input (Fishburn, 1970). The classical treatment of decision-making postulated that people have simple preferences that are governed by a simple axiom of expected utility and optimisation (Hey & Orme, 1994).
faced with the decision choice, people are assumed to calculate the choice’s expected utility, by estimating and weighing all possible outcome of occurrence, and to decide based on the highest expected utility. Furthermore, it is assumed that people have stable preferences and make rational choices based on the calculation of probabilities (e.g., Barseghyan, Prince, & Teitelbaum, 2013). The idea was based on Von Neumann and Morgenstern’s (1944) expected utility (EU) theory which proposed that people act rationally by endeavouring to maximise their EU.

According to the EU optimisation paradigm, people's preferences during decision-making should be stable, linear and not affected by circumstantial inconsistencies because the overall aim is to maximise subjective utility. However, people’s decisions can be affected by nuances in the decision context, whereby people’s preferences happen to be constructed in a non-linear manner (e.g., Slovic, 1995). Furthermore, EU theory's suggestion that emotions, triggered by the decision-making situations, are epiphenomenal and detrimental for the decision-making (e.g., Lopes, 1995) is refuted by evidence where emotions can be beneficial for learning and decision-making (e.g., Bechara et al., 1997). For instance, the affective input may improve decision-making strategies while suppression of the emotions can hinder it (Pham, 2007). Additionally, emotional experience may assist reasoning by redirecting cognitive processing towards prioritised concerns during decision-making (e.g., Bechara et al., 1997). This important suggestion indicates that emotional arousal can be beneficial for decision-making when integral to the task. Moreover, emotional responses may represent a good assessment tool of decisional choices because they are faster than cognitive evaluation of the decision-making choices and they provide information that may enhance the perception of wrong or correct decisional choice (Bargh, 1984; Todd & Gigerenzer, 2000).

Recently, the relationship between emotion and cognition has received extensive attention in the field of decision-making and it has been argued that emotion can guide higher cognitive processes and successful decision-making (e.g., Damasio, 1994; Dolan, 2002; Thagard, 2006). An influential account of the relationship between emotion and cognition is advanced by the SMH (e.g., Damasio, 1994). This theory still provokes debate among cognitive scientists. For instance, a specific point in question is related to the emotional influence on decision-making and whether somatic markers may guide successful decision-making on the primary. This point further raises a question of whether the somatic markers are acquired and guide decision-making implicitly or explicitly. These issues are explored in next subsections and the basic premises and some of the main assumptions of SMH are discussed.
1.2. Development of the SMH

Damasio (1994) developed the SMH arguing that emotional processes play a central role in risky decision-making. SMH postulates that decisions are guided by subjective ‘gut feelings’ (e.g., bodily representations) of the inherent ‘goodness’ or ‘badness’ of future choices. These somatic markers, direct individuals towards alternatives that have been previously positive or guide them away from those that were previously negative options. This occurs particularly in uncertain conditions; response options are marked with an emotional signal, ‘which may be consciously perceived as good or bad options, or processed unconsciously’ (Bechara & Damasio 2005, p. 343). According to this view, the emotion-based intuitive system (EBI), helps bias the options and plans for action. The EBI system incorporates emotion as an index of embodied changes in brain state whereby a somatic marker reflects activities of the body proper (the ‘body’ loop) or activities in the body based on the brain state signals (the ‘as-if body loop’) (Bechara & Damasio 2005; Dunn et al., 2006). The brain state signals operate covertly (an individual is not aware of bodily changes associated with a particular choice) or overtly (an individual is consciously aware of the bodily change associated with a particular choice). According to SMH, the brain constructs a model of behaviour based on individuals’ experiences that can automatically respond to a decision-making challenge without the cognitive appraisal of the decision choice. Thus, in uncertain cognition, where cost-benefit analysis is not possible, somatic markers can ‘predict’ a good decisional choice based on prior subjective ‘gut feelings’ about the ‘goodness’ or the ‘badness’ of a choice.

Evidence for the SMH hinges on three main assumptions which will be briefly specified then examined in the subsequent sections. The first assumption comes from a suggestion that somatic markers bias decision-making covertly, in the absence of the awareness of deck contingencies. This cognitive impenetrability is central to the claim that IGT can only be completed through learning via somatic marker signals because participants learn how to discriminate choices by developing a feeling that certain choices are better than others (Bechara et al., 2000). The empirical claims for this proposition are based on evidence that learning deck contingences involves covertly acquired somatic-biasing signals that precede explicit insight on the IGT (Bechara et al., 1994, 1997, 2000). Bechara et al. (1997) claimed that participants could develop aSCRs before they can express conscious knowledge regarding deck contingences. This claim assumes that a type of implicit learning precedes conscious knowledge and the somatic marker activity reflects implicit learning processes. Some early
evidence indicated that participants are not fully aware of the deck contingences and that somatic markers contribute to the development of cognitive processes (e.g., Bechara, Damasio, Tranel & Anderson, 1998; Bechara, Damasio & Damasio, 2000a; Bechara & Martin, 2004). This is however disputed with recent evidence showing the involvement of conscious awareness early in IGT indicating that cognitive processes rather than somatic markers could guide optimal IGT performance (e.g., Fernie & Tunney 2006; Fernie & Tunney, 2013; Maia & McClelland, 2004).

The second assumption comes from a suggestion that there is a limited role for cognitive processes and working memory (WM) during IGT performance (e.g., Bechara et al., 2000a). Bechara et al. argued that IGT performance is relatively independent of WM. This notion is based on evidence from patients with lesions to ventromedial prefrontal cortex (VMpfc), whereby despite the intact WM and general intellectual abilities they performed poorly on IGT because they were not able to express emotion and experience feelings (Bechara et al., 1994, 1997, 1999, 2000). This led to a speculation that these changes in VMpfc patients’ inability to experience emotion were the cause of decision-making problems (e.g., Damasio, 1994; Bechara et al., 2000). However, several studies with healthy participants have shown that there is a role for WM during IGT performance and WM processes could contribute to the development of emotion-based signals (e.g., Hinson et al., 2002; Jameson et al., 2004).

The final assumption is based on evidence that once it is acquired, implicit knowledge informs somatic markers (as evidenced by aSCR) that guide future decision-making choices by anticipating options (e.g., Bechara et al., 1994; Bechara et al., 1997; Bechara et al., 2000). Hence, somatic markers guide decision-choices away from the bad options as participants are able to anticipate the good and the bad options. This assumption was based on the interpretation of the evidence related to the behaviour of healthy controls and VMpfc patients during IGT performance (Bechara et al., 1997; Bechara et al., 1999). Bechara et al. showed that healthy participants’ aSCRs differentiate between the good and bad decks during IGT performance; this was absent in VMpfc patients. This was taken as evidence that aSCRs changes relate to expectancies about reward/punishments before a deck has been selected and guide successful learning and IGT performance.

Before further discussing the SMH assumptions it is necessary to give a short account of the key paradigm to investigate the SMH, the IGT (Bechara et al., 1994). In the IGT, participants are required to choose cards from four decks (A, B, C, and D), which differ in frequencies of
notional rewards and punishments. The overall aim of the task is to make as much notional money as possible over the course of the task. Participants are free to select different options as often as they wish and in any order. Advantageous, ‘good’, decks (C and D) offer moderate rewards and small punishments whereas disadvantageous, ‘bad’, decks (A and B) offer larger rewards but substantial penalties, which result in an overall loss. Each card selection from deck A or B gives a large reward ($100), whereas selections from deck C or D give small rewards ($50). However, the penalties in A and B are also larger, meaning the cumulative losses surpass cumulative gain, such that after ten cards selection the cumulative loss is on average $250. Conversely, selection of C and D will lead to a cumulative gain of $250 over ten cards (Table 1.2.1.). In addition to these varying rewards across the good/bad decks, the probability of loss varies across the good and bad decks. In a ten-card selection sequence from deck A, the negative expected value is distributed over 5 cards (0.5 loss probability; punishment range $150-$350), whereas in deck B there is only one loss of $1250 in ten cards selection (0.1 loss probability). Similarly, the losses on decks C and D mirror the losses on A and B with the reduced magnitude (deck C; 0.5 loss probability; punishment range $25-$75 deck D; 0.1 loss probability; punishment $200). There is some evidence that because of the different gain-loss probability distribution, participants’ choices can be governed by gain-loss frequencies and not the long-term outcome of the game (e.g., Chiu & Lin, 2007; Lin, Song, Chen, Lee, & Chiu, 2013). This is however, disputed with evidence showing that the long-term outcome remains the primary governing factor for participants’ decisions (e.g., Bechara et al., 1994, 2000, 2000a). Thus, based on Bechara et al.’s (1994, 1997, 2000) findings that participant’s decision-making is less influenced by the gain-loss frequency than the long-term outcome, the positive final outcomes (C+D) – (A+B)) are thought to be the primary guiding factor during IGT for the healthy participants.

Table 1.2.1

<table>
<thead>
<tr>
<th>Payoff scheme of the Iowa Gambling Task</th>
<th>Deck A</th>
<th>Deck B</th>
<th>Deck C</th>
<th>Deck D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gain per Card</td>
<td>$100</td>
<td>$100</td>
<td>$50</td>
<td>$50</td>
</tr>
<tr>
<td>Loss per 10 Cards</td>
<td>$1250</td>
<td>$1250</td>
<td>$250</td>
<td>$250</td>
</tr>
<tr>
<td>Gain per 10 Cards</td>
<td>$1000</td>
<td>$1000</td>
<td>$500</td>
<td>$500</td>
</tr>
<tr>
<td>Outcome per 10 Cards</td>
<td>-$250</td>
<td>-$250</td>
<td>+$250</td>
<td>+$250</td>
</tr>
<tr>
<td>Gain-loss Frequency per 10 Cards</td>
<td>0.5</td>
<td>0.1</td>
<td>0.5</td>
<td>0.1</td>
</tr>
</tbody>
</table>
The following sections specifically discuss the first two assumptions while the third assumption is discussed in chapter 2. In particular, evidence in support of these assumptions is considered and discussed. The first subsection discusses the first assumption related to the covert bias influence of somatic markers that guides successful IGT performance in the absences of conscious awareness. The second subsection discusses the second assumptions and evidence related to the WM involvement in IGT performance. At the end of this chapter an alternative theoretical framework is proposed as a possible approach to deconstructing decision-making processes involved in IGT (dual-process framework; Brevers et al., 2013; Stanovich, 2009) and the final objectives and aims of this thesis are established.

1.2.1. The Covert Bias of Somatic Markers

Bechara et al. (1994) made specific claims implicating covert somatic markers generation in successful IGT performance. The ‘cognitive impenetrability’ of the IGT claim, is associated with a suggestion that emotion-based learning, via somatic marker signal, guides successful decisional choice early in the game (Bechara et al., 1994). Thus, in healthy people covert, unconscious biases guide conscious reasoning and decision-making; and emotion-based learning is sufficient to guide decision-making behaviour in the absence of conscious knowledge and cognitive processing (Dunn et al., 2006). A major concern for these claims is which trial of the task participants adopt an advantageous strategy and whether this knowledge is guided by unconscious signals or cognitive processing. For example, Simonovic et al. (2016, 2017) suggest that the learning phase includes the first 20-30 trials; Schiebener et al. (2011) suggest it includes the first 40 trials; Bechara et al., (1997) suggest 50 trials, whereas Preston, Buchanan, Stansfield, & Bechara (2007) argue for 60 trials.

In an empirical test of these claims, Bechara et al. (1997, 2000) suggested that healthy participants learn to adopt an advantageous strategy (to pick from the good and to avoid the bad decks) before they can consciously express the knowledge about the goodness or badness of their choices early in the game. They describe participants undergoing three specific periods during IGT performance such as a ‘pre-hunch’ period (punishment not encountered, and the knowledge is incomplete); a ‘hunch’ period (some punishments encountered, and the knowledge is emerging); and a ‘full conceptual knowledge’ (punishments encountered several times and the conscious awareness is complete). The healthy participants entered the “hunch” period after trial 50, (although the range was between trials 30 and 80) and the “conceptual” period after trial 80 (with a range of 60 to 90). The core idea that emerged from Bechara et al.’s
studies is that a difference in aSCRs precedes participants’ capacity to explicitly express knowledge about the IGT. This is later supported by Tranel, Bechara and Damasio (1999) and Peters and Slovic (2000) who proposed that unconscious biases play a central role in decision-making and that conscious knowledge is sometimes not enough to guide decision-making in uncertain conditions. Peters and Slovic (2000) developed an alternative task based on IGT. In this task, two decks have higher gains (B, D) and two higher losses (A, C) but decks A and B have a negative expected value, whereas, decks C and D have a positive expected value. They found that loss probability affects learning and that knowledge about the task is not complete. However, conscious knowledge was not assessed in this study, thus their results only provide limited support for the SMH. Nevertheless, their result suggests that affective processing can provide some contribution to IGT performance.

The proposal that unconscious biases guide decision-making in the absence of conscious knowledge has been criticised on the basis of shortcomings in the questions that Bechara et al. (1997) used to assess conscious awareness. Bechara et al. (1997) interrupted participants after the first twenty trials and then after every subsequent ten trials and asked them: ‘Tell me all you know about what is going in the game’ and ‘Tell me how you feel about the game’ (p.1293). Their analysis revealed that the participants went through three periods before they could consciously express the knowledge of the game and reach ‘conceptual’ period. The key finding was that in ‘pre-hunch’ period participants developed somatic markers (as manifested by aSCRs) for advantageous decks that were maintained until the end of the game, indicating that implicit knowledge precedes conscious understanding. Maia and McClelland (2004) have challenged this assumption demonstrating that Bechara et al.’s (1997) aSCRs results were not statistically significant and claimed that conscious knowledge occurs earlier than Bechara et al. (1997) suggested.

Analysis by Maia and McClelland (2004) indicated that somatic markers could be generated by conscious knowledge of the deck’s payoffs and showed that awareness of the advantageous and disadvantageous deck picks develops early (after only 20 trials). This meant that conscious knowledge guided participants’ selection choice and they were aware of the selection consequences. Other studies have supported Maia and McClelland (2004) (e.g., Bowman, Evans, & Turnbull, 2005; Cella, Dymond, Cooper, & Turnbull 2007; Evans, Bowman, & Turnbull, 2005; Fernie & Tunney, 2006, 2013); however, their results were disputed by Bechara, Damasio, Tranel and Damasio (2005a). Bechara et al. (2005a) noted that in Maia and McClelland’s (2004) study participants continued to pick from the disadvantageous deck cards.
despite claiming explicit knowledge. They further noted that Maia and McClelland had not recorded SCRs and the possibility that both unconscious and conscious knowledge is acquired in the IGT could not be ruled out. Therefore, somatic markers provide a plausible explanation as to why learning continues until the advantageous strategy is developed. Nevertheless, the evidence suggests that conscious knowledge emerges early in the task and aSCRs sometimes do not precede the development of the conscious knowledge which challenges the basic assumption of the SMH (e.g., Bowman et al., 2005; Evans et al., 2005; Fernie & Tunney, 2006, 2013).

Maia and McClelland’s (2004) explanation provides a parsimonious account that in an environment of uncertainty participants need to balance exploration and exploitation trade-offs. Thus, selecting from the disadvantageous decks facilitates learning through the exploration of the alternative choices. However, the tipping point in exploration needs to be reached for a shift in choices that will lead to optimal exploitation of the advantageous decks. This raises the possibility that somatic marker reflects emotional responses that are elicited by conscious knowledge in the exploration phase; assuming the possibility that knowledge emerges during the period of exploration and that the period of exploitation is related to performance. This suggestion offers a plausible explanation of decision-making, whereby in any decision-making environment, in which there is uncertainty, a good balance between the exploration and exploitation is needed for an optimal decision-making performance (Maia & McClelland, 2005). Therefore, given that learning develops through exploration it is not surprising that participants continue to select from disadvantageous decks until they reach a point at which they have gathered enough information.

Persaud, McLeod and Cowey (2007) indicated that Maia and McClelland’s (2004) assessment method might be intrusive because the nature of the questionnaire may alter participants’ awareness of the nature of the task. They also pointed out that there is difficulty when interpreting verbal reports suggesting that Maia and McClelland’s test should only include a nonverbal method for assessing awareness. To address this issue Persaud et al. (2007) asked the participants to make a wager of £10 or £20 after each deck selection. The reward and punishment schedule of each deck was modified to accommodate wagering option. They had three groups of participants wagering where the second and the third group had to provide verbal assessments (Bechara et al., 1997; Maia & McClelland, 2004) respectively. They reported that all three groups performed similarly, however only the third group showed an effect of wagering. They interpreted this result as demonstrating that the conscious assessment
methods can affect explicit knowledge during IGT performance which raises a possibility that awareness tests may provide clues that make participants aware of the task. Nevertheless, even if a question remains about the suitability of different awareness tests, there is little convincing evidence in support of the claim that IGT performance is dissociable from conscious awareness.

Taken together the evidence presented in this section indicates that, although it is plausible that implicit learning informs somatic markers that guide optimal decision choices, the somatic marker may represent an effect rather than a cause of explicit knowledge. For instance, Gutbraud et al. (2006) reported aSCRs discrimination between the advantageous and the disadvantageous deck picks at about trial 80, even though the participants favoured the advantageous deck picks after trial 40. Indeed, this is similar to Bechara et al.’s (1997) study where it was found that aSCRs were not significant during the hunch period. Nevertheless, Bechara et al. (2005) challenged this suggestion and argued that unconscious biasing signals can be triggered simultaneously, where the stronger signal emerges to consequently bias decision-making. This suggestion is not in line with presented evidence showing that participants acquire conscious knowledge early in the IGT and the interpretation that somatic markers covertly influence decision-making needs to be reconsidered. However, it is in line with the proposition that conscious knowledge guides successful decision-making in the absence of somatic markers (e.g., Fernie & Tunney, 2013). This is also in line with a number of studies that have implicated higher cognitive processes with optimal IGT performance (e.g., Hinson et al., 2002; Jameson et al., 2004; Simonovic et al., 2016, 2017). Some of this evidence is described in the next section and cognitive processing is specifically tested in the second and the third study of this thesis (Chapters 4 and 5).

1.2.2. The Assumption of WM

The assumption that performance on the IGT involves conscious awareness early in the game raises the possibility that explicit learning may play a more prominent role in knowledge acquisition on IGT. Optimal performance on IGT requires participants’ awareness and calculation of the long-term outcomes of the available alternatives. Some studies have investigated the possibility of WM involvement during decision-making on IGT and showed that WM processes contribute to the development of somatic markers and optimal IGT performance (e.g., Hinson et al., 2002; Jameson et al., 2004). This is contrary to the original claim based on Bechara et al.’s (1998) study that suggested an asymmetrical relationship
between decision-making and WM. However, it is debatable if these findings are problematic for SMH since one of the functions of somatic markers is to signal the badness and goodness of the deck choices, whereby attentional processing and WM resources are then needed for further evaluation (e.g., Damasio, 1994).

To test WM involvement on IGT Bechara et al. (1998) used 2s delayed responses and delayed nonmatching to sample task (DNMS) in three groups of participants (healthy control; VMpfc patients; and patients with lesions to dorsolateral/high mesial prefrontal cortices, DLpfc). The delayed responses condition involved seeing four cards that appeared on the computer screen for two seconds. Two of the cards were face up and two of the cards were face down. The participants were asked to select two matching cards after paying attention to the cards for two seconds. The DNMS task was similar to the delayed responses task, except that only one card appeared initially for two seconds. The VMpfc patients group was separated according to more anterior or posterior lesions respectively, where only the posterior lesion group displayed impairment on the DNMS WM task. The posterior lesion group also showed sub-optimal performance on IGT. The DLpfc patients were not impaired on the IGT, and only the patients with right hemisphere lesions were impaired on the WM test. Bechara et al. (1998) concluded that the VMpfc has special importance in emotion-based learning and decision-making and is dissociative from the WM specific roles. Similar results were obtained in individuals with substance addiction (Bechara & Martin, 2004). Bechara and Martin tested healthy participants and participants with substance addiction on IGT and DNMS WM task. Their results showed a similar asymmetric dependence between the decision-making and WM, where the poor performance of the participants with substance addiction was related to the deficit in the WM executive processes. However, even though DNMS task was not a significant factor some of the executive processes were implicated (e.g., response inhibition) suggesting that some aspects of WM are involved in the IGT.

Hinson et al. (2002) investigated the relationship between the WM load and somatic markers in IGT. They used secondary tasks, in the form of digit load and random number generation to load WM during the IGT. Their results indicated that retaining the order of a string of digits loaded WM and impaired IGT performance on a modified version, relative to the no WM condition. This version had three choices where one choice was the best, one was intermediate, and one was bad. The probability nature of gains and losses were retained based on the original task. The WM load in these studies not only inhibited IGT performance but also interfered with the development and use of affective biasing signals, as measured by aSCRs. In a different
study, Jameson et al. (2004) replicated their findings and suggested that WM load disrupts central executive processes. These studies have been criticised because they did not use the original IGT and the possibility that learning occurred through the cognitive mechanism because of the nature of the task cannot be generally agreed upon. However, WM involvement on IGT is somewhat problematic for the SMH because it appears to be an important explanatory mechanism for hypersensitivity to reward and punishment (Bechara et al., 1999; Bechara, Dolan, & Hindes, 2002; Bechara & Damasio, 2002). In some respects, the involvement of WM mechanisms for non-optimal performance on the IGT reflects the complexity of the system that must deal with real-life decisions. Furthermore, if knowledge is required for beneficial performance on IGT then WM must also be involved (e.g., Patterson, Ungerleider, & Bandettini, 2002) because of the activation of the same brain network.

The involvement of central WM and executive processes is also suggested by Turnbull, Berry and Bowman’s (2003) study. Turnbull et al. (2003) developed the Firefighters Task (FT) as a descriptive analogue of the IGT. The participants are asked to evaluate the performance of four firefighters, whose behaviour lead to good, bad or neutral outcomes, by evaluating their daily logbook entries. The logbook entries are analogues to rewards and punishments in IGT because they contain examples of good and bad behaviour. An example of a good logbook entry would be ‘This morning, I removed an unconscious man from his smoke-filled kitchen and carried him to a waiting ambulance, where he regained consciousness’. In contrast, a bad logbook entry would be ‘I’ve been incredibly careless. I carried a boy down the long ladder, but he slipped and fell to his death. I must have failed to clip him to my harness’. The participants were told that they must assess the quality of the performance of four trainee firefighters. The rating values were based on a good/bad valence value on a scale from +3 to -6 that equates to the net win or loss on every deck in IGT. The main difference from the original IGT is that participants experience punishments and rewards indirectly. Hence the participants would not be able to rely on, or develop somatic markers and must perform the task presumably through the explicit awareness by using episodic memory. Participants on the FT showed no learning effect as opposed to the participants performing IGT. Turnbull et al. (2003) argued that this may be because the FT is more impersonal and no emotion-based learning occurred to aid decision-making. However, since no actual physiological measurements were taken the interpretation of the study results is difficult. Furthermore, it could be argued that a memory load in the FT condition interfered with optimal performance.
Conversely, Turnbull, Evans, Bunce, Carzolio and O’Connor (2005) suggest IGT performance is relatively independent of WM. Turnbull et al. (2005) tested three group of participants on standard IGT. In the first group, random number generation was used to load executive processes; in the second group, they used a non-executive articulatory suppression task; and the last group had no secondary task. A key finding from the study showed that learning rate between the groups was not significantly different. This result indicated that IGT performance is not dependent on WM, but rather emotion-based learning processes. Furthermore, these authors also indicated that emotion-based signals have much in common with the processes associated with intuition and implicit learning. However, this suggestion is debatable because it was not tested directly in this study and there was a tendency for best performance in the no secondary task condition which might undermine this interpretation. Nevertheless, they raised an interesting point that cognitive load created by the traditional executive task (e.g., number generator) do not overlap with the emotion-based learning which raises the possibility that different parts of the executive function (EF) may have a different impact on IGT performance.

Indeed, there is evidence that different parts of the executive processes may account for optimal performance on IGT, depending on the trial Blocks (e.g., Brand et al., 2005; Brand et al., 2007; Brand, Heinze, Labudda, & Markowitsch, 2008; Brand, Laier, Pawlikowski & Markowitsch, 2009; Schiebener, Zamarian, Delazer, & Brand 2011). For example, the Game of Dice task (GDT; Brand et al., 2005) was used to tap both executive functioning and feedback learning on IGT (Brand et al., 2005, 2008). Similarly, the Probability-Associated Gambling task (PAG; Sinz, Zamarian, Benke, Wenning, & Delazer, 2008) was used to assess probability-based decision-making and IGT performance (e.g., Schiebener et al., 2011). Both tasks are assumed to measure decision-making under risk conditions. Schiebener et al. (2011) used both, GDT and PAG task and examined IGT performance. The GDT is a decision-making task where participants gamble in 18 trials to decide amongst the 14 alternatives with different winning probabilities. The GDT has been found to highly correlate with executive processes such as categorization, cognitive flexibility and rule recognition (e.g., Brand et al., 2008, 2009). In the PAG task, participants need to decide between gambling on a lottery or taking a safe gain. The decision to gamble or not lies on the winning probability shown in each trial. Performance on the task depends on the categorization and probability-based decision-making (e.g., Sinz et al., 2008; Zamarian, Sinz, Bonatti, Gamboz, & Delazer, 2008). Both tasks are assumed to measure decision-making under explicit risk conditions where the probabilities are known (Brand et al., 2005; Sinz et al., 2008). Schiebener et al. (2011) tested participants on the GDT, the PAG and
the IGT and suggested that implicit learning from feedback and propensity to make good, probability-based choices have a rather small effect on decision-making under explicit risk. They further indicated that the IGT involved learning the probabilities of gains and losses rather than requiring trade-offs of short-term versus long-term outcomes. They concluded that learning from feedback may involve implicit and intuitive processes.

This claim cannot be fully dismissed until it is determined when implicit/explicit knowledge emerges. For example, some theorists argue that higher cognitive processes are implicated later in the game when participants learn the rules of the IGT (e.g., Bechara et al., 2005; Brand, Labudda, & Markowitsch, 2006; Brand et al., 2007). They further argued IGT is a complex task that involves decision-making under ambiguity where the outcomes are unknown (the first 60 trials) and decision-making under risk (the last 40 trials) (e.g., Brand et al., 2007). The proposed distinction is usually examined with the tasks that provide explicit information about the probabilities (e.g., GDT; PAG) that correlate with IGT performance only in the later trials and not the early trials (e.g., Brand et al., 2006, 2007). Thus, it is assumed that the learning process shifts from decision-making under ambiguity to decision-making under risk. It is also likely that this switch is gradual and subject to individual differences (Bechara et al., 2005). However, it is also possible that this switch is observed as a function of the type of measures used to probe the learning effect. For example, Simonovic et al., (2016) used a measure of cognitive reflection (the original CRT; Frederick, 2005) and found significant correlations between the analytic thinking and IGT performance in early Blocks (Block 2) which are considered to be involved in decision-making under ambiguity. Thus, this is in contrast with a proposition that somatic markers inform explicit knowledge and instead suggest that higher cognitive processes are needed to disambiguate the deck's contingences. This assumption is tested in all the studies of this thesis (Chapters 3, 4 and 5).

The IGT depends on multiple processes such as learning and evaluation of long-term and short-term contingencies and deciding between alternative courses of action. The first two assumptions of the SMH postulates that people interact with the environment during decision-making and make alternative choices based on previously learned experience, relatively independent of WM and conscious awareness influence. However, emerging evidence indicates that such decision-making processes are consciously governed processes implicating higher cognitive processes in learning IGT (e.g., Fernie & Tunney, 2013; Simonovic et al., 2016, 2017). This is line with research that emphasises the importance of integration of cognitive processes and emotion-based processes to capture key aspects of decision-making.
deficit in a clinical population (e.g., Cella, Dymond, Cooper & Turnbull, 2012; Fridberg et al., 2010). Some authors also argued that the explicit knowledge (emotion-mediated) may represent a poorly formed ‘hunch’ or a ‘gut feeling’ that is laden with somatic markers and subserves the phenomenon that has been long described as intuition (Turnbull, Bowman, Shanker, & Davies, 2014, p.3). This intuitive process is described in dual-process theories of decision-making as fast and spontaneous ‘gut feeling’ that arises without conscious awareness (e.g., Kahneman, 2003). The next section discusses dual-process account of decision-making as an alternative framework that could be used to investigate decision-making on IGT.

1.3. Dual-Process Theories

Dual-process models assume that when reasoning and decision-making, people rely on either intuitive (autonomous, unconscious, implicit Type I processes,) or deliberate (explicit, conscious, Type II processes), or a combination of both processes (e.g., Evans, 2008; Evans & Stanovich, 2013). This conceptualisation can potentially provide a better explanation of IGT performance than the SMH because of the suggested complex cognition/emotion interplay during the task (e.g., Brevers et al., 2013; Turnbull et al., 2014). Type II processes include controlled, reflective evaluation of decision-making choices, whereas Type I processes operate automatically, outside the conscious awareness. Most of the Type I processes are instigated promptly and their appropriateness is related to peoples’ relevant experience (e.g., Evans, 2008). If, however, the prompted answers are inappropriate and fail to meet the choices set when the decision matters, an intervention with reflective, Type II processes is warranted (Stanovich, 2004). Stanovich (2009) suggested the tripartite model of processing (Figure 1.3.1) making a clear distinction between the types and the modes of processing. Modes of processing represent different cognitive styles (thinking disposition) encompassed by Type II processing, while type I processing depend on the environment, previous experience and available information. This classification is pertinent for SMH, because of the suggestion that automatically evoked somatic markers captures decision-making processes akin to Type I processes (e.g., intuition, e.g. Dunn et al., 2006; Turnbull et al., 2014).
Stanovich (2009) argued that Type I processes encompass a set of systems in the brain that operates autonomously in response to prompting cues. The Autonomous Set of Systems (TASS) automatically triggers, unconscious responses that do not require the analytic system (algorithmic mind). However, the final output of TASS may involve the Type II, reflective processing. Hence, instead of looking at the two types of processing as separate systems this module postulates that between the two processes there are certain hierarchies of control. TASS processes are triggered automatically and include processes of affective arousal, associative learning, implicit and instrumental learning and information integration (Toplak, Liu, Macpherson, Toneatto, & Stanovich, 2007). In contrast, Type II processes incorporate the algorithmic and reflective processing and have a defining feature of cognitive decoupling (Stanovich, 2009). Override of the TASS involves interruption of TASS response tendencies and may depend on higher cognitive processes (e.g., Hasher, Lustig & Zacks, 2007; Aron, 2008). However, the generation of alternative responses is also needed through hypothetical reasoning and cognitive stimulation that may play an important role in the creation of an alternative, better responses (e.g., Evans, 2010). The key function of the algorithmic level of

processing is to maintain decoupling among different alternative choices and exhibit supervision of TASS responses when/if needed. On the other hand, a reflective level of processing is involved in the generation of the alternative responses and is captured through thinking disposition and individual differences.

Recently, a dual process account of self-regulation has been proposed as an explanation for IGT performance albeit related to addictive disorders such as gambling and alcohol dependence (e.g., Giancola, Godlaski, & Roth, 2012; Brevers et al., 2012; Brevers et al., 2013). Brevers et al. (2013) argued that optimal decision-making activates two neural systems: an impulsive system that is consistent with automatic behaviour activation, and a reflective system that is consistent with inhibitory functions. The reflective system incorporates EFs and is under conscious control. The action of the reflective system depends on a ‘cool’ and ‘hot’ elements of the EFs (Brevers et al., 2013). The ‘cool’ system is further described as a process involved in abstract thinking, reasoning and monitoring of behavioural choices and may exert inhibitory control over the ‘hot’ system. The ‘hot’ system is laden with affective tags or ‘gut feelings’ and it depends on previous experience (e.g., Giancola et al., 2012). This distinction is, however, based on the limited research that relates a drug or a food reinforcer to habitual responding as evidenced by studies on animals or self-reported measures in humans (e.g., Dickinson, Wood, & Smith, 2002; Giancola et al., 2012; Miles, Everitt, & Dickinson, 2003). For example, Giancola et al. (2012) used self-reported measure of Behaviour Rating Inventory of Executive Function-Adult version (BRIEF-A; Roth, Isquith, & Gioia, 2005) and tested a group of healthy social drinkers on nine scales related to EFs such as Inhibition, Shifting, Emotional Control, Self-Monitoring, Initiation, WM, Planning/Organizing, Task Monitoring, and Organization of Materials. They argued that ‘specific EFs to be a key moderator of the alcohol-aggression relation’ (p. 7), even though the BRIEF-A is not designed to capture the ‘hot-cold’ systems distinction. Furthermore, the ‘hot’ system resembles Type I processes and it is not clear what criteria were used to define the ‘hot’ systems in this way. Thus, it is very likely that the ‘hot’ and ‘cold’ processes map on the Type I and Type II processes suggested in above mentioned dual-process model and that Brevers et al.’s conceptualization needs further clarification.

Brevers et al. (2013) review reported no association between ‘cool’ executive function and IGT performance but suggested a monitoring function of the ‘cool’ system over the ‘hot’ system. For example, in a study related to problem gambling, Brevers et al. (2012) reported that disadvantageous strategies adopted by problem gamblers may be explained by impaired ‘hot’ processing in the early trials of the task and lack of evaluation of the ‘cool’ processes in later
trails. Conversely, Roca et al. (2008) examined IGT performance and motor response inhibition of twelve problem gamblers. They used a GO/NO-GO task as a measure of inhibitory impulses and reported the importance of ‘cool’ reflective processes in the inhibition of disadvantageous choices in early trials. Thus, the deficit in cognitive reflective processes may be in part responsible for the impairment of IGT performance. This is in line with Kertzman et al.’s (2011) study that reported similar results. In addition to a GO/NO-GO task, Kertzman et al. (2011) used a Stroop test and tested problem gamblers in the early and late trails. They suggested impaired inhibition may be a result of WM and cognitive flexibility deficit. Whilst problem gamblers showed impairment after the first two trials and failed to shift to advantageous decisions, the performance of the healthy control improved after the second Block onwards that was correlated to the inhibitory mechanisms. This indicates that ‘cool’ reflective processing may be at play early in the game which challenges SMH assumption that the IGT performance is not related to cognitive processes. Furthermore, Brevers et al. do not assume any roles for somatic markers in their conceptualisation but nevertheless suggest a conflict between the ‘hot’ and ‘cold’ systems one presumably mediated by affective emotional, processes and the other by cognitive, reflective processes. This is somewhat debatable since they do not provide specific evidence for the existence of the ‘hot’ system. An alternative account would be that the affective components of this system fit within the Type I processes, whereby a potential conflict between the Type I and Type II processes creates emotional arousal.

Indeed, evidence from reasoning literature indicates that the conflict between the two types of processes can be psychophysiologicaly arousing (e.g., Evans, 2003; Kahneman & Frederick, 2005; De Neys & Glumicic, 2008; De Neys, Moyens, & Vansteenwegen, 2010). The important question for the decision-making theory that the dual-process theories dichotomy underline is whether learned experiences from intuitive impressions of the world can be organised and logically assessed and whether encoding of the information through Type I processes lead to a change in people’s behaviour and influence expressible knowledge (Osman, 2004). More importantly, if there is a conflict between the two processes during decision-making, how do people resolve it, and are they aware of such conflict? Examples of reasoning, judgment and conflict detection research find that people often provide contradictory responses, one presumably mediated by emotional, intuitive processes and the other by cognitive, reflective processes (e.g., Evans, 2003; Kahneman & Frederick, 2005; De Neys & Glumicic, 2008). However, as De Neys (2012) points out, most of the experimental tasks are constructed to elicit
heuristics responses and contributed to the prevalent beliefs that logic and cognitive evaluation play a major role in reasoning. De Neys further proposes that people have intuitive ‘gut’ feelings and hold implicit knowledge, related to logic and probabilistic reasoning. Simply put, people possess logical intuition, whereby the intuitive system prompts a logical response. This is supported by recent evidence that sensitivity to violations during logical and reasoning tasks (Stupple & Ball, 2008; De Neys & Glumicic, 2008) are accompanied by a strong autonomic response that signal erroneous intuitive responses is not logically affirmed (e.g., Franssens & De Neys, 2009; De Neys et al., 2010). This relatively new suggestion amplifies intuitive processes and suggests that the conflict between the two types of processes creates arousal, manifested through subjective ‘gut feeling’ that something is not right, and signals that the Type I responses are not fully warranted.

The important aspect of De Neys’s suggestion is the acknowledgement that emotional/intuitive ‘gut’ feeling, implicitly acquired, guides successful conflict resolution between the two processes by creating an affective biasing signal. This idea is similar to SMH and may resolve some of the issues identified within the SMH theory. For example, the dual-process framework may integrate certain aspects of the Type I processes (e.g., emotion) with cognitive reasoning, whereby intuitive processing captures decision-processes that reflect imprecise somatic marker signal that triggers Type II processing (Turnbull et al., 2014). Furthermore, Stanovich’s (2009) dual-process framework accounts for the conceptual components of Type II processes related to the individual difference in cognition, thinking disposition and/or cognitive styles. Individual differences in IGT performance were identified as a very important explanatory factor, whereby thinking dispositions and cognitive styles may be more pertinent to IGT performance than measures of SCR. Furthermore, impaired performance on the IGT may be attributable to different cognitive styles, thinking disposition and cognitive abilities or failure of Stanovich’s (2009) TASS processes because they include processes of instrumental and affective/implicit learning and emotion regulation. If that is the case then the mixed findings regarding higher order processing and IGT performance association may epitomize an artefact of different thinking dispositions, cognitive styles (e.g., Harman, 2011) and the individual differences in higher cognitive processes (e.g., Jameson et al., 2004).

Thus, the aim of this thesis was to examine the effect of cognitive processes and somatic markers on IGT performance. There were several objectives and this thesis aimed:

(i) To systematically examine aSCRs evidence in support of SMH (Chapter 2).
(ii) To test a ‘novel’ methodology (eye-tracking methodology) to record somatic markers (Chapter 3, 4 and 5) and to examine cognition/emotion effect on IGT by using a measure of cognitive ability not previously used (CRT1; Toplak et al., 2014) (Chapters 3, 4 and 5).

(iii) To examine cognitive processes (attention, cognitive ability and conscious awareness; Chapters 4 and 5) and the effect of thinking dispositions and individual differences on IGT performance (Chapter 4).

(iv) To examine the effect of stress on IGT performance and cognitive processing (Chapter 5).
Chapter 2

Overview

This chapter addresses objective (i) of the Thesis and aimed to examine the final assumption of SMH, whereby it is assumed that implicit knowledge informs somatic markers and the decision-maker is able to anticipate options (as evidenced by aSCR) that guide successful decision-making (e.g., Bechara et al., 1994, 1997, 2000a). Thus, participants generate aSCRs during the IGT performance when they receive punishment or reward. As they become experienced with the deck contingencies they generate aSCRs before picking any cards, presumably while they are considering from which deck to pick a card (Bechara & Damasio, 2005). These aSCR signals are more pronounced before making a choice from the disadvantageous decks (A + B) when compared to the advantageous decks (C + D). Hence, aSCR guide decision-choices away from the bad options associated with disadvantageous decks. This assumption is based on the evidence from VMpfc patients who often fail to develop aSCRs in reaction to reward or punishments compared to the healthy control (Bechara et al., 1997). Thus, healthy participants’ aSCRs differentiate between the good and the bad decks during IGT performance while this was absent in VMpfc patients. There has been limited evidence in support of the key aSCR data on IGT in healthy participants (e.g., Carter & Pasqualini, 2004; Guillaume et al., 2009; Wagar, & Dixon, 2006). Thus, the goal of this chapter is to address objective (i) of the thesis and to systematically examine the evidence of an aSCRs effect on IGT. First, the aSCRs evidence is discussed followed by a systematic review with two meta-analyses to examine the reliability and the strengths of the evidence presented in support of the SMH. The first analysis examined the effect of overall aSCRs on IGT performance. The second analysis examined the differences in aSCRs between the disadvantageous and advantageous decks. The quality and reliability of current psychophysiological measurements are also discussed. Systematic reviews and meta-analyses provide a very useful summary of evidence where the results of several studies are combined to provide systematically disciplined approach intended to reduce the potential for bias that arises from conflicting or inconclusive results (e.g., Bartolucci & Hillegass, 2010). Since there are limited examination and replication of aSCRs findings in healthy participants and studies often yield contradictory findings (e.g., Dunn et al., 2006), a systematic review and meta-analyses may provide a statistical synthesis of the results by means of increasing precision of the estimated statistical results of the studies.
2.1. Introduction

A substantial strength of the SMH rests on the specification of its neural architecture. Damasio (1994) argued that somatic states can be generated from primary and secondary inducers. Primary inducers are innate or learned stimuli that induce unpleasant or pleasurable states. They usually elicit an automatic response through amygdala. For instance, seeing a snake would trigger a critical substrate in the neural system connected to the amygdala and induce an obligatory response (fight or flight response). Conversely, secondary inducers of somatic states are generated by thoughts and memories recall of a hypothetical state (i.e. a memory of seeing a snake). The recalled memory also induces automatic, involuntary responses, but contrary to the primary inducers, the responses are generated through a substrate in the neural system related to VMpfc (Bechara & Damasio, 2005). The proposed neural systems are interconnected, and Damasio (1994) links the VMpfc to several bio-regulatory systems of the brain including the basal forebrain, hypothalamus, anterior cingulate and the amygdala. Through these links, VMpfc has direct connections to areas responsible for chemical and motor responses of the brain (Ongur & Price, 2000).

Consistent with the SMH neural architecture, evidence from the studies on patients with lesions to the VMpfc and bilateral damage to amygdala suggest that an absence of physiological activity and the development of somatic markers impairs decision-making (e.g., Bechara et al., 1994; Bechara, Tranel, Damasio, & Damasio, 1996; Bechara, et al., 1999; Bechara et al., 2000; Tranel, Bechara, Damasio, & Damasio, 1996). An absence of emotion-based learning has been observed in patients with lesions to the VMpfc while performing the IGT, and it correlated with the absence of aSCRs during decision-making (Bechara et al., 1994, 1996). The original papers reported that patients with VMpfc damage do not generate aSCRs prior to selecting from disadvantageous decks, while healthy control does (Bechara et al., 1994, 1996, 1997). This provided support for SMH framework that the absence of somatic markers leads to poor learning and consequently performance on IGT. Consistent with these results, amygdala patients exhibit a similar behaviour pattern and inability to develop somatic markers for disadvantageous options on the IGT (Bechara et al., 1999). Thus, there is support for SMH in that the absence of somatic markers (as measured by aSCR) is associated with poor decision-making. This support mainly comes from clinical studies where patients show none or a very little SCR activity, while healthy control develops SCR activity that is associated with optimal decision-making.
For example, Bechara et al. (1999) tested three groups of participants that included healthy control (n=13), patients with the damaged amygdala (n=50) and VMpfc patients (n=5). The VMpfc patients displayed the same aSCRs deficit responses as amygdala-damaged patients. However, aSCRs of the VMpfc patients were delayed compared to amygdala-damaged patients indicating that feedback SCR responses (after selecting a card) may occur in the later trials. Interestingly, one VMpfc patient performed advantageously, and three healthy participants did not choose advantageously indicating that not all of the VMpfc patients show impartment in the development of somatic markers and that not all of the healthy participants develop somatic markers. In a comparison of early and late trials of aSCRs development, only healthy participants showed the constant increase in aSCRs. The problem with this explanation is that early and late trials were not defined and statistically examined. Bechara et al. (1999) acknowledged this limitation and in a subsequent study (Bechara & Damasio, 2002) tested a substance dependent population, VMpfc patients and healthy control during the four stages analysis of aSCRs that included, the “pre-punishment” (trials 1 – 10), “pre-hunch” (trials 11 – 20), “hunch” (trials 21 – 60) and “conceptual” (trials 61 – 100). They replicated previous findings where for the disadvantageous decks, aSCRs occurs in early trials (Blocks 1 and 2) and then stay constant for healthy participants. However, this result interpretation may be questionable because the authors failed to report observations for the advantageous decks. Furthermore, a similar increase in aSCRs was observed for the impaired participants. This suggests a possibility that a risk-taking behaviour overrides weak somatic-markers, or that impaired participants do not respond to the somatic markers in the same way as unimpaired participants. Thus, one interpretation indicates a possibility that somatic markers alone are not sufficient to explain decision-making performance. It is also possible that aSCRs signals in healthy participants reflect the development of learning and understanding of the IGT.

While most published studies with the clinical population have replicated SMH theoretical suggestion that the absence of the somatic markers leads to impaired decision-making; and that there is a difference in aSCRs between the disadvantageous and advantageous options, the replication with healthy population have often found different results. For example, Crone, Somsen, Van Beek and Van Der Molen, (2004) investigated the pattern of aSCRs and heart rate variability (HRV) on an analogue of the IGT. In three groups of participants, split between the bad, good and moderate behavioural performance, they found an effect of slow HRV and high aSCRs on disadvantageous deck selection compared to advantageous decks selection for the good behavioural performance group. This was not found in the bad and moderate groups.
Furthermore, larger HRV and SCRs were observed in post-feedback responses (after the card is chosen) related to frequent punishment from disadvantageous decks for the bad group. This indicates that a behavioural choice rests on a positively or negatively valanced somatic markers where a bad option reflects a negative state that signals avoidance.

Indeed, Tomb et al. (2002) changed the deck's contingences scheme (advantageous decks had a higher magnitude of punishments and rewards than the disadvantageous decks) and demonstrated the importance of elevated aSCRs to advantageous deck selection, and thus, both positive and negative feedback contribute to subsequent performance. Their data showed that somatic markers may serve to record long-term negative and positive consequences of a certain choice option. Although impressive, Crone et al. (2004a) and Tomb et al. (2002) studies’ results cannot discount the possibility that conscious knowledge precedes or works in parallel with the somatic markers. Furthermore, Crone et al. indicated that post-feedback skin conductance (fSCR), response may be more important than aSCRs for the reward and punishments disambiguation on disadvantageous decks. Moreover, they also reported that the best performing group had better conscious knowledge than the poorer performing group.

Crone et al.’s (2004a) suggestion is similar to Suzuki, Hirota, Takasawa, and Shigemasu’s (2003) study that showed SCR to feedback (fSCR) is more important to IGT performance than SCR in anticipation of deck selection during the IGT performance, but less so when contingencies have been learned. However, they found no relationship between aSCRs and overall performance. In contrast to Suzuki et al. (2003) study, Carter and Pasqualini (2004) results related strong anticipatory somatic marker response with optimal decision-making and faster learning. No correlation between the fSCR and optimal performance was found. The results of these studies indicate that SCRs are associated with optimal performance on IGT, however the direction of this association is unclear. This may be problematic for SMH because the fSCR emerges following knowledge about rewards (e.g., Fernie & Tunney, 2013). Hence, it could be argued that aSCR changes also reflect the emergence of knowledge or expectancies or reward and punishment (e.g., Dunn et al., 2006; Fernie & Tunney, 2013).

The timing and the interpretation of psychophysiological data are something that Dunn et al.’s (2006) review finds challenging. They argued that although SMH is an elegant account of how emotion influences decision-making, it lacks sufficient corroborating evidence. There is evidence that anticipatory markers correlate with successful performance on the task (e.g., Carter & Pasqualini, 2004) and that aSCR is elevated for disadvantageous decks compared to
advantageous decks (e.g., Crone et al., 2004; Bechara & Damasio, 2002). However, replication of key aSCR findings on the IGT in healthy participants is lacking. Furthermore, even if replication is successful, it remains uncertain what these SCRs epitomise. They may be indicators of learning (Carter & Pasqualini, 2004), response to feedback (Suzuki et al., 2003), or a signal of how bad or good a potential choice is (Crone et al., 2004).

Hence, despite the wealth of literature utilising the IGT as a clinical tool, the interpretation of psychophysiological results and IGT data is complex and not without criticism. Thus, a systematic review was conducted to establish whether the effect of aSCRs is genuine and consistent. Systematic reviews are very useful for assessing research-based evidence performance (e.g., Smith, Cipriani & Geddes, 2016) and to the best of my knowledge this is the first systematic review related to aSCR and IGT. The current review aims to systematically examine two hypotheses related to psychophysiological evidence of aSCR and IGT performance in healthy individuals. First, that the strength of aSCR correlates with successful IGT performance; and second, that there are differences in aSCR for disadvantageous and advantageous decks. Finally, the review aims to assess the quality of evidence of aSCR during the IGT.

### 2.2. Systematic Review

#### 2.2.1. Methods

**Search protocol and inclusion/exclusion criteria**

Extensive searches of the following psychology databases were conducted to pinpoint research studies for inclusion: PsycARTICLES, PsycINFO, Business Source Premier, CINAHL Plus, MEDLINE and Web of Science. The content lists of the following key journals were also reviewed: Cognition and Emotion, Cognitive, Affective & Behavioral Science, Psychophysiology, International Journal of Psychophysiology, Journal of Psychophysiology and Frontiers in Psychology. Additionally, reference lists of included studies were examined for additional studies. Key authors were contacted to obtain details of relevant unpublished studies in an attempt to address publication bias. Key terms (‘Somatic Marker Hypothesis’, ‘SMH’, ‘Emotional Based Learning’, ‘EBL’) were combined with terms related to psychophysiological measurements (‘Psychophysiological Response’, ‘Skin Conductance Response’, ‘SCR’, ‘Skin Resistance’, ‘SR’, ‘Autonomic Response’, ‘Heart rate’, ’HR’, ‘Heart Rate Variability’, ‘Galvanic Skin Response’, ‘GSR’, ‘Electrodermal Activity’, ‘EDA’) and the
behavioural task (‘Iowa Gambling Task’, ‘IGT’) with a standardised protocol using Boolean rules to identify the most significant literature. Searches were limited to healthy human participants.

Only English language studies that included psychophysiological measurements with IGT performance where included. Papers were excluded if they used clinical participants, if they did not use psychophysiological measurements or if they modified IGT to such an extent where the important properties of the IGT were not maintained (e.g., frequencies of reward and punishments on 4 decks). Electronic database searches yielded 3,999 results (IGT), 244 (SMH) and 20,046 (psychophysiology measurements). These results were combined generating 84 study titles that were then filtered through the search process summarized in Figure 2.2.1. Forty-three studies were initially included for review. Thirty-three were excluded because: they had not included psychophysiological measurements (N=25); had used a clinical sample (N=1); had not used the IGT (N=2); had not retained key features of the IGT (N=4), or had used a different methodology (N=1). Four studies were identified from the reference lists of included studies. In total, 14 studies were included in the review.

**Quality assessment**

Quality criteria were developed to assess the quality of all included studies to account for potential biases that could result from combining studies using different methodologies, which might lead to a misleading conclusion. Quality criteria were developed based on recommendations made by the Cochrane Collaboration (2011) and included: psychophysiological measurements used, clarity of measurements taken, psychophysiological methodology and procedure used, aSCR measurements taken, IGT methodology followed, original IGT used, description of the study that allows replication, clear aims, appropriate analysis used, effect sizes used, information related to participants’ demographics, inclusion/exclusion criteria included, outcomes provided and details of timing of measures. A score of 0-2 was awarded for each element (0= no details, 1= insufficient details, 2= complete details) and these were summed to give a total (0 to 20).
Figure 2.2.1. CONSORT diagram - Overview of the search process, identification of studies and data extraction

Data extraction

Data were extracted using a standardized extraction sheet. A second (DS) and a third reviewer (ES) independently reviewed extracted data to ensure accuracy and reliability, with reviewers meeting to confirm agreement of extraction and to establish reliability. Where there were discrepancies, these were resolved by discussion. Fourteen published research studies were included and evaluated. The extraction sheet included: a) identifying information (e.g., type of study, source references and research questions); b) inclusion criteria (e.g., healthy, normal participants performing IGT while physiological measurements were taken) and exclusion criteria.
criteria (e.g., patient population, evaluation of behavioural tests of awareness, absence of physiological measurements and different gambling tasks); c) study details (e.g., type of IGT and IGT procedure, number of participants and participants’ details such as age and ethnicity); d) physiological measurements (e.g., types and details of measurements); e) results (e.g., statistical techniques used, p values and effect sizes); f) comments on the paper (e.g., the authors comments, reviewers comments and suitability for inclusion). The aforementioned details are discussed in the review and included in the quality assessment of the studies, but only the number of the participants and the effects sizes were included in both meta-analyses.

**Data analysis and synthesis**

Hak et al. (2016) suggest the use of a fixed effects model when there is little variance in effect sizes between studies whereby, the random effects model automatically converges into a fixed effects model. Thus, the fixed effect model was used for both meta analyses because heterogeneity was low. The reported studies had similar aims and utilized similar psychophysiological measurements; 13 studies measured skin conductance response activity (SCR), and one study measured both SCR along with Heart Rate Variability (HRV).

**2.3. Results**

**Participants**

The eighteen included studies recruited 440 healthy, normal participants in total. The age of participants ranged from 17 years (Carter & Pasqualini, 2004), to 85 years old (Denburg, Recknor, Bechara & Tranel, 2006). Three studies did not report the age of participants (Guillaume et al., 2009; Visagan, Xiang & Lamar 2012; Wagar, & Dixon, 2006). Four studies were conducted in the UK (Carter & Pasqualini, 2004; Fernie & Tunney, 2013; Jenkinson, Baker, Edelstyn & Ellis, 2008; Visagan et al., 2012), three were conducted in the USA (Denburg et al., 2006; Hinson, Whitney, Holben & Wirick, 2006; Hinson et al., 2002), one was conducted in Germany (Werner, Duschek & Schandry, 2009), Japan (Suzuki et al., 2003), Belgium (Mardaga & Hansenne, 2012), Taiwan (Yen, Chou, Chung & Chen, 2012), France (Guillaume et al., 2009), Romania (Miu, Crisan, Chis, Ungureanu, Druga & Vultur, 2012) and Canada (Wagar, & Dixon, 2006). The prevalence of female participants ranged from 30% (Suzuki et al., 2003) to 100 % (Carter & Pasqualini, 2004). Two of the studies did not report gender (Wagar & Dixon, 2006; Yen et al., 2012). Only six studies included inclusion/exclusion criteria for study participation (Carter & Pasqualini, 2004; Guillaume et al., 2009; Jenkinson et al., 2008; Werner et al., 2009; Visagan et al., 2012; Denburg et al., 2006).
Quality assessment of included studies

The quality of the studies was good overall (Table 2.3.1). There were procedural and methodological differences between studies and no study provided information about statistical power to detect effects. Eight studies had insufficient demographic information about their participants (Guillaume et al., 2009; Hinson et al., 2006; Hinson et al., 2002; Miu et al., 2012; Suzuki et al., 2003; Visagan et al., 2012; Wagar & Dixon, 2006; Yen et al., 2012). Four studies did not measure fSCR (Hinson et al., 2006; Hinson et al., 2002; Denburg et al., 2006; Yen et al., 2012). Four studies used a standardised protocol for measuring SCR (Fernie & Tunney, 2013; Werner et al., 2009; Visagan et al., 2012; Denburg et al., 2006). Eight studies stated they ensured IGT protocol and procedures were followed (Jenkinson et al., 2008; Carter & Pasqualini, 2004; Fernie & Tunney, 2013; Guillaume et al., 2009; Werner et al., 2009; Visagan et al., 2012; Denburg et al., 2006; Wagar & Dixon, 2006). Six studies either used a modified version of the IGT or did not provide sufficient details of the IGT protocol (Mardaga & Hansenne, 2012; Miu et al., 2012; Hinson et al., 2006; Hinson et al., 2002; Suzuki et al., 2003; Yen et al., 2012). Only two studies reported effect sizes (Mardaga & Hansenne, 2012; Miu et al., 2012).

Table 2.3.1

Quality assessment of included studies

<table>
<thead>
<tr>
<th>Quality criteria</th>
<th>Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study references</td>
<td>1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18</td>
</tr>
<tr>
<td>Participant’s details</td>
<td>2 2 2 1 2 1 1 1 1 1 1 1 2 1 2 1 1 1</td>
</tr>
<tr>
<td>Inclusion/exclusion criteria</td>
<td>1 2 1 2 1 1 1 1 1 1 1 1 2 2 2 1 1 1</td>
</tr>
<tr>
<td>Original IGT</td>
<td>1 2 1 2 2 2 2 2 1 1 2 1 2 2 2 2 2 1</td>
</tr>
<tr>
<td>IGT procedure</td>
<td>1 2 2 2 1 1 1 1 1 1 1 1 2 2 2 2 2 1</td>
</tr>
<tr>
<td>Psychophysiology procedure</td>
<td>2 2 2 2 2 1 1 1 1 2 2 2 1 2 2 2 2 1</td>
</tr>
<tr>
<td>Exact statistic reported</td>
<td>2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2</td>
</tr>
</tbody>
</table>

1 The studies were numbered as follow: (1) Mardaga & Hansenne (2012); (2) Carter & Smith-Pasqualini (2004); (3) Fernie & Tunney (2013); (4) Guillaume et al. (2009); (5) Jenkinson et al. (2008); (6) Hinson et al. (2006); (7) Hinson et al. (2006a); (8) Hinson et al. (2006b); (9) Hinson et al. (2002); (10) Hinson et al. (2002a); (11) Miu et al. (2012); (12) Suzuki et al. (2003); (13) Visagan et al. (2012); (14) Werner et al. (2009); (15) Denburg et al. (2006); (16) Wagar & Dixon (2006); (17) Wagar & Dixon (2006a); (18) Yen et al. (2012).
Method and Findings

The studies used similar statistical methods to assess the research questions (e.g., ANOVA, ANCOVA and t-test) which were ascertained to be suitable for the study designed. The results are summarised in Table 2.3.2. One study used Wilcoxon signed-ranks test (Denburg et al., 2006). Several studies’ results associated higher aSCRs with picks from disadvantageous decks (Mardaga & Hansenne, 2012; Guillaume et al., 2009; Wagar & Dixon, 2006; Yen et al., 2012). One of the studies reported a borderline association (Jenkinson et al., 2008), one reported no association (Denburg et al., 2006) and six studies did not separately report aSCRs results for disadvantageous/advantageous decks. Significant interactions were found between aSCR amplitude and IGT performance in five studies (Mardaga & Hansenne, 2012; Carter & Pasqualini, 2004; Guillaume et al., 2009; Miu et al., 2012; Wagar & Dixon, 2006) while one study found no interaction (Fernie & Tunney 2013). One study associated aSCRs with picks from advantageous decks (Denburg et al., 2006). High fSCRs responses were evident in one study after encountering feedback from a punishment/reward sequence (Suzuki et al., 2003). Two studies’ results suggested an interdependency between conscious knowledge and the appearance of somatic markers (Guillaume et al., 2009; Hinson et al., 2002). However, in Hinson et al.’s study, conscious knowledge suppressed the development of somatic markers, while in Guillaume et al.’s study performance correlated with both aSCRs and conscious knowledge. One study found that aSCR is not necessary to succeed on IGT: in the absence of a significant aSCR participants still learnt and selected advantageously (Fernie & Tunney, 2013). Hinson et al. (2006) showed that pre-experimental emotion-laden words briefly held in WM influenced deck choices; participants’ choices were facilitated by the preexisting affective state, whereby a positive affective load enhanced the quality of decision-making, and negative load reduced the quality. Finally, one study found no direct relationship between the aSCR and IGT performance (Visagan et al., 2012). Their post hoc analysis, however, revealed that
the aSCR parameters were significantly related to threat-anxiety and emotion regulation, which were in turn associated with IGT performance.

All studies analyzed aSCR amplitude for disadvantageous versus advantageous decks. Ten studies analyzed both aSCR and fSCR amplitude for disadvantageous and advantageous decks (Wagar & Dixon, 2006; Guillaume et al., 2009; Jenkinson et al., 2008; Visagan et al., 2012; Miu et al., 2012; Fernie & Tunney, 2013; Mardaga & Hansenne, 2012; Werner et al., 2009; Carter & Pasqualini, 2004; Suzuki et al., 2003). Three studies analyzed aSCR but not fSCR amplitude (Hinson et al., 2006; Hinson et al., 2002; Yen et al., 2012). There were differences in timing and quantification of aSCR peak amplitudes. Eight studies defined anticipatory and feedback responses within a 5 second window both before and after deck selection (Wagar & Dixon, 2006; Guillaume et al., 2009; Jenkinson et al., 2008; Visagan et al., 2012; Miu et al., 2012; Fernie & Tunney, 2013; Yen et al., 2012; Hinson et al., 2006). Two studies used 5-second aSCR and 10-second fSCR for quantifying responses (Mardaga & Hansenne, 2012; Hinson et al., 2002). Three studies defined aSCR and fSCR responses within 1-7 second (Werner et al., 2009), 1-9 second (Carter & Pasqualini, 2004) and 10 seconds (Suzuki et al., 2003) before and after the participants chose a deck. Ten studies quantified aSCR peak as a mean response within their proposed time frame and then averaged mean amplitudes across 100 trials (Wagar & Dixon, 2006; Guillaume et al., 2009; Jenkinson et al., 2008; Miu et al., 2012; Fernie & Tunney, 2013; Yen et al., 2012; Hinson et al., 2006; Mardaga & Hansenne, 2012; Werner et al., 2009 Hinson et al., 2002 ). In contrast, three studies calculated the largest SCR amplitude or the first SCR peak amplitude and designated the responses as aSCR or fSCR (Visagan et al., 2012; Carter & Pasqualini, 2004; Suzuki et al., 2003).

Table 2.3.2

Characteristics of included studies (N=18)

<table>
<thead>
<tr>
<th>Study Id and references</th>
<th>Participants demographics</th>
<th>Type of IGT</th>
<th>Psychophysiological measurements</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Carter &amp; Smith-Pasqualini (2004) UK</td>
<td>30 healthy women, aged 17-53. (Mean = 29.7, SD = 8.39).</td>
<td>Bechara et al. (1994). Two conditions: fake vs. real money.</td>
<td>Performance and beneficial SCR interaction (IGT scores as DV); SCR and learning rate per block.</td>
<td>Correlation between aSCR and money won on IGT. **</td>
</tr>
<tr>
<td>(2) Denburg et al. (2006) USA</td>
<td>80 healthy, older adults, aged 56-85. 40 participants sampled from the previous study</td>
<td>Bechara et al. (2000)*2.</td>
<td>SCR anticipative advantageousness in two different groups.</td>
<td>Effect of aSCR for disadvantageous decks in one group. ***</td>
</tr>
</tbody>
</table>

Note all * are computerised version
<table>
<thead>
<tr>
<th>Study ID</th>
<th>Authors and Year</th>
<th>Participants</th>
<th>Design</th>
<th>Methods/Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>(3)</td>
<td>Fernie &amp; Tunney (2013) UK</td>
<td>32 post-graduate students, 16 males (Mean age 25.68, SD = 1.22)</td>
<td>Bechara et al. (1994)*: Knowledge probed (Maia &amp; McClelland 2004).</td>
<td>SCR anticipative response amplitude (effect of decks); SCR-awareness interaction. No effect of aSCR on IGT. Effect of knowledge of the task contingencies. **; ***</td>
</tr>
<tr>
<td>(5)</td>
<td>Hinson et al. (2002) USA</td>
<td>Study 2: 45 students, aged 18-24. 58% female</td>
<td>Bechara et al. (1994)*: Overall payoffs are less extreme.</td>
<td>Anticipatory SCR; SCR amplitude as DV.</td>
</tr>
<tr>
<td>(6)</td>
<td>Hinson et al. (2002a) USA</td>
<td>Study 3: 47 students, aged 18-24. 58% female</td>
<td>Bechara et al. (1994)*: Overall payoffs are less extreme.</td>
<td>Anticipatory SCR; SCR amplitude as DV.</td>
</tr>
<tr>
<td>(7)</td>
<td>Hinson et al. (2006) USA</td>
<td>Study 1: 70 students, aged 18-25. 60% female.</td>
<td>Bechara et al. (1994)*: Affective reaction manipulated.</td>
<td>SCR and learning rate per block. Positive and negative (emotionally charged) word load was used and related to learning rate per block.</td>
</tr>
<tr>
<td>(8)</td>
<td>Hinson et al. (2006a) USA</td>
<td>Study 2: 40 students, aged 18-25. 55% female.</td>
<td>Bechara et al. (1994)*: Affective reaction manipulated.</td>
<td>SCR and learning rate per block. Positive and negative (emotionally charged) word load was used and related to learning rate per block.</td>
</tr>
<tr>
<td>(9)</td>
<td>Hinson et al. (2006b) USA</td>
<td>Study 3: 70 students, aged 18-25. 60% female.</td>
<td>Bechara et al. (1994)*: Affective reaction manipulated.</td>
<td>SCR and learning rate per block. Positive and negative (emotionally charged) word load was used and related to learning rate per block.</td>
</tr>
<tr>
<td>(10)</td>
<td>Jenkinson et al. (2008) UK</td>
<td>41 healthy individuals aged 18-28 (M = 20.5, SD = 2.8; 11 male, 30 female).</td>
<td>Bechara et al. (1994)*: Real and fake money versions.</td>
<td>Anticipatory and appraisal SCR; Performance and beneficial SCR interaction (IGT scores as DV).</td>
</tr>
<tr>
<td>(11)</td>
<td>Mardaga &amp; Hansenne (2012) Belgium</td>
<td>32 healthy participants (10 males) aged 19-34 (mean = 22.9, SD = 4.03) students.</td>
<td>Bechara et al. (1994)*: Gains and losses presented sequentially, as opposed to the original parallel presentation.</td>
<td>Anticipatory and Appraisal SCR; SCR amplitude; Performance and beneficial SCR interaction (IGT scores as DV).</td>
</tr>
</tbody>
</table>

Note all ** Testing hypothesis 1 (relationship between overall aSCR and IGT performance)  
Note all *** Testing hypothesis 2 (differences between good and bad decks)
2.3.1. Meta-analyses

All analyses were performed using Meta-Essentials (Van Rhee, Suurmond, & Hak, 2015). The meta-analysis calculator was used to compute R statistics (Lyons, 2004). Three studies were excluded: one because of the consistency of IGT and SCR methods used (Yen et al., 2012) and two because of insufficient data (Denburg et al., 2006; Visagan et al., 2012\textsuperscript{5}). Accordingly, eleven studies were included in the meta-analysis. Two separate meta-analyses were performed testing hypothesis 1 (the relationship between overall aSCR and IGT performance) and hypothesis 2 (differences between good and bad decks).

\textsuperscript{5} Note that Denburg et al. (2006) and Visagan et al. (2012) studies are not included in meta-analyses because of insufficient data. The Authors had been contacted, however, they were not able to provide meaningful effect sizes.
Anticipatory SCR and IGT performance

First, analyses were conducted and effect sizes calculated for each study (Table 2.3.3). Specifically, we calculated r and Confidence Interval (upper and lower) for studies that found an effect of aSCRs in relation to IGT performance. Then a combined effect size was calculated and examined by using Forest plot (Figure 2.3.2). The Forest plot revealed a combined effect size of $r = 0.22$ (CI 0.16 to 0.29, $p<0.00001$) representing a small to medium effect (Table 2.3.4). The overall effect size was also homogenous $Q (13) = 10.97, p<.0001; I^2 = 0.00$ thus indicating that there are no heterogeneity issues. Publication bias analyses were undertaken first by calculating fail-safe N (Rosenthal, 1979). The fail-safe N was 137, suggesting that even if a great number of additional relevant studies with null results were included, the overall effect size would remain significant. However, because fail-safe N is biased towards overestimating the number of null studies required to render the overall effect size nonsignificant (Carson, Schriesheim, & Kinicki, 1990), a funnel plot of the standard error by the standard mean differences was generated (Figure 2.3.3). The distribution is symmetrical, suggesting no issues regarding publication bias.

Table 2.3.3

Effect sizes of included studies in meta-analysis related to aSCR correlates with successful IGT performance

<table>
<thead>
<tr>
<th>Study ID</th>
<th>N</th>
<th>R</th>
<th>95% CI</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carter &amp; Pasqualini (2004)</td>
<td>30</td>
<td>.49</td>
<td>.14, .73</td>
<td>4.59%</td>
</tr>
<tr>
<td>Guillaume et al. (2009)</td>
<td>30</td>
<td>.38</td>
<td>.01, .66</td>
<td>4.59%</td>
</tr>
<tr>
<td>Hinson et al. (2006)a †</td>
<td>70</td>
<td>.15</td>
<td>-.09, .38</td>
<td>11.39%</td>
</tr>
<tr>
<td>Hinson et al. (2006)b †</td>
<td>40</td>
<td>.19</td>
<td>-.14, .48</td>
<td>6.29%</td>
</tr>
<tr>
<td>Hinson et al. (2006)c †</td>
<td>70</td>
<td>.16</td>
<td>-.08, .38</td>
<td>11.39%</td>
</tr>
<tr>
<td>Hinson et al. (2002) †</td>
<td>45</td>
<td>.10</td>
<td>-.21, .39</td>
<td>7.14%</td>
</tr>
<tr>
<td>Hinson et al. (2002)a †</td>
<td>47</td>
<td>.07</td>
<td>-.23, .36</td>
<td>7.48%</td>
</tr>
<tr>
<td>Mardaga &amp; Hansenne (2012)</td>
<td>32</td>
<td>.30</td>
<td>-.07, .60</td>
<td>4.93%</td>
</tr>
<tr>
<td>Miu et al. (2012)</td>
<td>135</td>
<td>.29</td>
<td>.13, .44</td>
<td>32.20%</td>
</tr>
<tr>
<td>Suzuki et al. (2003)</td>
<td>40</td>
<td>.00</td>
<td>-.32, .32</td>
<td>6.29%</td>
</tr>
<tr>
<td>Wagar &amp; Dixon (2006)</td>
<td>12</td>
<td>.40</td>
<td>-.30, .82</td>
<td>1.53%</td>
</tr>
<tr>
<td>Wagar &amp; Dixon (2006)a</td>
<td>12</td>
<td>.60</td>
<td>-.04, .89</td>
<td>1.53%</td>
</tr>
<tr>
<td>Werner et al. (2009)</td>
<td>64</td>
<td>.25</td>
<td>.00, .47</td>
<td>10.37%</td>
</tr>
</tbody>
</table>

Note: * all p significant at .05

Note † all effect sizes provided by the Author
Figure 2.3.2. Forest plot. Combined effect size (CI with SE bars) of Studies correlating aSCR and successful IGT performance (meta-analysis 1)

Table 2.3.4
Summary of meta-analysis related to aSCR correlates with successful IGT performance

<table>
<thead>
<tr>
<th>All studies</th>
<th>Combined effect size (r)</th>
<th>95% CI</th>
<th>Combined z</th>
<th>Combined p</th>
<th>I²</th>
</tr>
</thead>
<tbody>
<tr>
<td>K</td>
<td>N</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>627</td>
<td>.22</td>
<td>.16 to .29</td>
<td>5.55</td>
<td>p&lt; .0001</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.00</td>
</tr>
</tbody>
</table>

Figure 2.3.3. Funnel Plot of Standard Error by Effect Size for Studies correlating aSCR and successful IGT performance
Anticipatory SCR for disadvantageous decks

First, analyses were conducted and effect sizes calculated for each study (Table 2.3.5). Specifically, r and Confidence Interval (upper and lower) were calculated for studies that found an effect of aSCRs in relation to disadvantageous deck picks. Then a combined effect size was calculated and examined by using a Forest plot (Figure 2.3.4). The Forest plot revealed a combined effect size of $r = 0.21$ (CI 0.07 to 0.34, $p=0.009$) representing a small to medium effect (Table 2.3.6). The overall effect size indicated low heterogeneity ($Q (6)=13.65, p=.009; I^2=0.08$). Publication bias analyses were undertaken first by calculating fail-safe N (Rosenthal, 1979). The fail-safe (N = 17) indicated that if a relatively small number of additional studies with null results were included, the overall effect size would not remain significant. However, because fail-safe N is biased towards overestimating the number of null studies required to render the overall effect size nonsignificant (Carson et al., 1990), a funnel plot of the standard error by the standard mean differences was generated (Figure 2.3.5). The distribution is not symmetrical, confirming issues regarding publication bias.

Table 2.3.5

<table>
<thead>
<tr>
<th>Study ID</th>
<th>N</th>
<th>R</th>
<th>95% CI</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fernie &amp; Tunney (2013)</td>
<td>32</td>
<td>-.06</td>
<td>-0.41, .31</td>
<td>20.71%</td>
</tr>
<tr>
<td>Guillaume et al. (2009)*</td>
<td>30</td>
<td>.05</td>
<td>-.36, .36</td>
<td>20.71%</td>
</tr>
<tr>
<td>Jenkinson et al. (2009)*</td>
<td>32</td>
<td>.22</td>
<td>-.15, .54</td>
<td>20.71%</td>
</tr>
<tr>
<td>Suzuki et al. (2003)*</td>
<td>40</td>
<td>.12</td>
<td>-.15, .54</td>
<td>26.43%</td>
</tr>
<tr>
<td>Wagar &amp; Dixon (2006)*</td>
<td>12</td>
<td>.73</td>
<td>.19, .93</td>
<td>6.43%</td>
</tr>
<tr>
<td>Wagar &amp; Dixon (2006)a*</td>
<td>12</td>
<td>.77</td>
<td>.28, .94</td>
<td>6.43%</td>
</tr>
</tbody>
</table>

Note: * all p significant at .05
**Figure 2.3.4.** Forest plot. Combined effect size (CI with SE bars) related to aSCR differences between the disadvantageous and advantageous decks (meta-analysis 2).

**Table 2.3.6**

Summary of meta-analysis related to aSCR differences between the disadvantageous and advantageous decks

<table>
<thead>
<tr>
<th>All studies</th>
<th>Combined effect size (r)</th>
<th>95% CI</th>
<th>Combined z</th>
<th>Combined p</th>
<th>I²</th>
</tr>
</thead>
<tbody>
<tr>
<td>K</td>
<td>N</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>158</td>
<td>.20</td>
<td>.06 to .33</td>
<td>2.37</td>
<td>p=.009</td>
</tr>
</tbody>
</table>

**Figure 2.3.5.** Funnel Plot of Standard Error by Effect Size for Studies correlating aSCR differences between the disadvantageous and advantageous decks
2.4. Discussion

In summary, this systematic review identified eighteen studies in healthy populations for inclusion. All of the studies included in the systematic review used SCR measurements and predominantly Bechara et al.’s (1994) original IGT. Eleven studies were included in two meta-analyses testing the overall aSCR effect on IGT performance differences and aSCR responses between the good and the bad decks. The first meta-analysis revealed a small to medium significant relationship between aSCR and IGT performance. The results provide support for SMH, however, the effect size indicates that other factors are important during decision-making. The second meta-analysis revealed a small to medium significant effect of aSCR between the good and the bad decks. However, the overall effect size was not homogenous, and the distribution was not symmetrical indicating that there is no clear aSCR distinction between the good and the bad decks.

The studies provide consistent evidence that overall aSCR correlate with successful performance on the IGT (Mardaga & Hansenne, 2012; Guillaume et al., 2009; Carter & Pasqualini, 2004, Wagar & Dixon, 2006; Werner et al., 2009; Miu et al., 2012). The results are reliable although interpretation may be complicated due to a number of factors. For instance, aSCRs found on IGT may be the result of the expectancies about reward and punishments after a deck has been chosen rather than an anticipatory signal of how good or bad a particular deck is (e.g., Hinson et al., 2006; Wagar & Dixon, 2006). It is also plausible that the somatic marker develops after good IGT performance and is driven with the risk associated with a specific deck (e.g., Hinson et al., 2006; Suzuki et al., 2003; Wagar & Dixon, 2006). For example, Suzuki et al. (2003) reported that psychophysiological response to feedback (post deck selection) rather than anticipation is more important for successful performance on the IGT. They suggest that fSCR rather than aSCR of deck selection, may be more important for mediating IGT performance. This feedback response was related to punishment encountered when choosing from the disadvantageous decks (Suzuki et al., 2003). This is an important suggestion since their results relate optimal performance on the IGT to participants’ expectation of punishments and rewards, only after a deck has been selected and is driven by the higher variance of the deck (Wagar & Dixon, 2006). Thus, it appears that there may be an issue when quantifying SCR measurements. Levinson, Edelberg and Bridger (1984) suggest that any SCR that begins between 1-3s following stimulus onsets can be considered to be elicited by the stimulus. This latency effect is followed by SCR rise and recovery time. One possible issue that may arise...
when quantifying aSCRs is when a response is elicited before a preceding response has had time to recover. The amplitude of the second response may be distorted by being superimposed on the recovery of the first response. This may explain fSCR and emphasizes the necessity for logarithmical data transformation to remedy this issue or that there is sufficient latency to avoid response distortion.

Indeed, Lykken and Venables (1971) proposed standardised techniques of SCR measurement where the correction procedure (e.g., computing the logarithm of SCR) can significantly reduce errors in measurements. Although most of the studies reviewed here have used some form of the computational logarithm, it is noticeable that they are not standardised. Furthermore, it has been noticed that room temperature and handwashing with soap and water may create errors in SCR measurements (Venables & Christie, 1973). Venables and Christie (1973) recommended handwashing with nonabrasive soap before having the electrodes attached and a constant room temperature of 23°C. However, only two studies reported that they had controlled room temperature (Guillaume et al., 2009; Mardaga & Hansenne, 2012) and none of the studies reported asking participants to use nonabrasive soap hand washing.

The results from a second meta-analysis indicate that there is a difference in aSCRs signals between the disadvantageous and advantageous decks selection. It should be noted that $I^2$ indicated low heterogeneity suggesting small variability between studies and that the variance of true effects is small. The $I^2$ describes the percentage of total variation across studies that is due to heterogeneity rather than chance and it is a useful approach that quantifies the effect of heterogeneity (Higgins, Thompson, Deeks, & Altman, 2003). However, the $I^2$ needs to be interpreted with caution because the estimates of $I^2$ are unlikely to be completely accurate unless the number of studies in the meta-analysis is substantial (Ioannidis, 2007).

Some studies reported aSCR differences in response to disadvantageous decks selection and not advantageous deck selection (e.g., Mardaga & Hansenne, 2012; Guillaume et al., 2009; Wagar & Dixon 2006). This is consistent with Damasio’s (1994) original proposition that aSCRs for disadvantageous decks lead to a shift in choices preferences from bad to good decks. However, there was evidence of a correlation between the aSCR related to the advantageous decks’ selection and successful performance on the task (e.g., Denburg et al., 2006). This raises a possibility that it is not the intensity of aSCRs signals before the bad decks that is important, but the contrast between this signal and the signal that develops before the good deck choices (e.g., Guillaume et al., 2009). It may also be that SCRs measurements fail to differentiate...
between the positive and negative aSCRs, and so these studies fail to provide definitive data about the aSCRs signals. This accords with the argument that SCR is influenced by the activation of the neuropsychological, behavioral inhibitory system implicated in responding to punishment, frustrated non-rewards and passive avoidance, and is difficult to interpret SCR as being based on negative outcomes alone (e.g., Fowles, 1988).

Thus, the meta-analyses results show support for the involvement of somatic markers in decision-making. While there is agreement that there is a correlation between the strength of overall aSCRs signals and IGT performance, it is difficult to differentiate what SCRs for bad and good decks actually represent. Dunn et al. (2006) review pointed out that the SCR signal may be ‘a response to feedback, an indicator of risk, a marker of post-decision emotion state, or a signal of how good or bad a particular response option is’ (p. 251). Furthermore, the absence of the SCR signals can lead to a good IGT performance and SCR activity is not necessary to succeed on the IGT (Fernie & Tunney, 2013). Fernie and Tunney (2013) showed that the participants learn to select advantageously on the IGT and develop knowledge of the task contingencies sufficient to guide behavior after approximately 40 trials without developing SCR. Furthermore, the post-knowledge difference in fSCRs indicate that the choices could have been made based on conscious knowledge. This is in line with suggestion that performance on IGT may be guided by two pathways; aSCR may represent somatic markers that guide successful decision-making during the IGT (Bechara et al., 1996); or SCRs represent a proxy of good performance and are caused by conscious knowledge (e.g., Guillaume et al., 2009; Maia & McClelland, 2004; Wagar & Dixon, 2006). Thus, it appears that there is a complex interplay between the emotion-based signals and conscious knowledge during the task and the relatively slow time course of SCR signals makes it difficult to separate different SCR signals in a clear manner.

Studies included in the review are not without limitation. Most of the studies had more female than male participants, and this may skew the results. A recent review suggested that there is a difference in performance between male and female participants when performing the IGT (van den Bos, Homberg & de Visser, 2013). Van den Bos et al., (2013) emphasized that due to sex differences, female participants tend to be more loss-averse and typically outperform male participants. There was also a mixture of studies using original IGT following the exact procedure or using the alternative IGT. It could be argued that different IGT methodologies may generate conflicting results which are difficult to compare. Furthermore, future studies
could explore the effect of potential mediators, such as age and gender, on the aSCR and IGT performance.

Notably, the IGT is a complex task and possibly involves an intrinsic affective shift, whereby an affective evaluation of choices guides future decision-making. For the optimal performance, this evaluation needs to evoke both positive and negative evaluation, potentially causing a net-weighted (expectancy-valence; heuristic-based) approach (Busemeyer & Stout, 2002). Since the SCR has a relatively slow time course, it is possible that a distinct somatic marker cannot be distinguished by conventional SCR measurements (Newell & Shanks, 2014). Furthermore, some authors argue that the actual SCR level is not, on its own, very informative or easy to derive (Bouscein et al., 2012). Moreover, there is a possibility that the SCR is not particularly sensitive in discriminating between negative and positive valence (e.g., Bradley, Codispoti, Cuthbert & Lang, 2001). This has the potential to make the measurement procedure and interpretation of the results considerably more complicated because it is difficult to capture valences of an unconscious emotion-based signal. Thus, this would undermine the utility of the SMH as a test of emotion-based learning.

**Conclusion**

This chapter addressed objective (i) of the thesis, and the results suggest that SCR may represent a good indicator of somatic markers. Nonetheless, the possibility that somatic marker can be imperfectly represented by SCR cannot be excluded. The somatic markers may represent an anticipatory, affective reaction before the choice had been made, however, they may also represent an affective reaction after the choice had been made and when a person has enough knowledge of the task to predict a choice. Thus, the somatic marker may represent a reflection of good performance rather than a cause of it. Using faster sources of emotion feedback that can be measured including heart rate and blood pressure with an electrocardiogram (ECG) or pupil dilation using eye trackers may disentangle this issue. For example, using pupil size as a somatic marker would help in differentiation of the somatic markers on potential options and provide a relatively clearer picture about the role of the emotion-based learning during the IGT. The use of an eye-tracker may help to distinguish between somatic reactions on each possible option before and after a decision has been made. This is particularly important because the aSCR captured during the IGT performance may represent a part of a broader response complex such as attentional bias, implicit learning and risk-taking behavior that can be easily encapsulated by eye-tracking measurements.
Furthermore, an eye-tracker can encapsulate a preconceptional period of decision-making that precedes the development of the somatic markers. This could reveal if implicit learning occurs and is then strengthened by the somatic markers or both processes run in parallel. For instance, Bierman, Cleeremans, Ditzhuyzen and van Gaal (2004) used the eye-tracking methodology and an artificial grammar learning task to test SMH. They discovered that the intuitive decisions involve several processes: Participants first learn implicitly about the features of a task, then, the implicit learning and positive/negative feedback create an association that result in somatic marking. Furthermore, Lavin, San Martin and Jubal (2014) showed that pupil dilation changes represent a marker of learned uncertainty and may be used as a marker of noradrenaline activity, which has been associated with reward prediction errors. This is examined in the next chapter.
Chapter 3

Overview

As discussed in Chapter 2, an important finding for SMH is that anticipatory somatic markers of emotions occur before a decision is made, and guide successful decision-making (e.g., Bechara et al., 1994, 1997, 2000). The systematic review showed that there is some evidence linking anticipatory somatic markers (as evidenced by aSCR measurements) with IGT performance. This finding can be interpreted as demonstrating the importance of emotions for optimal decision-making. However, there is a possibility that anticipatory somatic markers are imperfectly represented by the SCR measurement and they are not sufficiently sensitive in discriminating between negative and positive valence (Dunn et al., 2006). Although it is possible that positive or negative somatic markers guide successful decision-making, interpretation of the SCR measurements clouds this distinction. Furthermore, a major assumption regarding somatic markers is that they operate unconsciously, particularly in situations of high uncertainty (beginning of the task) whereby repeated feedback from punishment frequencies creates a loss aversion for disadvantageous decks (e.g., Bechara et al., 1997). If that is the case, then a greater effect of negative somatic markers (disadvantageous decks) than the positive (advantageous decks) should be expected. However, the review results showed that there is no clear aSCR distinction between the disadvantageous and the advantageous decks. Thus, one of the recommendations from the systematic review is that faster physiological measurement should be employed in an effort to capture this distinction and provide further insight into the cognitive processes during IGT decision-making. Furthermore, some authors have argued that somatic markers reinforce learning early in the IGT (ambiguous stage) while the later stages of the task are informed by conscious knowledge and higher cognitive processes (e.g., Brand et al., 2007; Wagar & Dixon, 2006). However, contrasting evidence indicate that conscious knowledge and higher cognitive processes guide decision-making early in the IGT (e.g., Fernie & Tunney, 2013; Maia & McClelland, 2004; Simonovic et al., 2016). This violates a principle regarding the engagement of higher cognitive processes during the game and is tested in this chapter’s experiment by using a measure of cognitive reflection (CRT1; Toplak et al., 2014). Thus, this chapter addressed objective (ii) of the Thesis and details the first experiment that examines alternative physiological measurements for detecting somatic markers (eye-tracking methodology) and a direct measure of cognitive reflection that may be involved in learning IGT (e.g., Simonovic et al., 2016).
3.1. Introduction

Eye-tracking methodology

Eye-tracking methodology records pupil dilation, eye positions and eye movements and is often used in decision-making research (Glockner, & Witteman, 2010). Eye-tracking systems usually monitor eye-movements, gaze direction and pupil movement in a non-intrusive manner and has been recognized as a reliable method that can capture automatic, deliberate, conscious and nonconscious processes related to the decisional choices (e.g., Glockner & Herbold, 2011). Evaluation of the pupillary responses to light stimulation and dilation is often used as a measure of affective and cognitive processes (e.g., Granholm & Steinhauer, 2004; Nassar et al., 2013; Piquado, Isaacowitz, & Wingfield, 2010). The effect of affective and cognitive stimuli on pupil dilation (PD) has been attributed to the direct stimulation of the parasympathetically mediated sphincter muscle by different brain regions linked to the affective and cognitive processing of the stimuli (e.g., Steinhauer & Hakerem, 1992). PD has been linked to amygdala activation, dorsolateral prefrontal activity (connected to executive control), anterior cingulate cortex (related to error detection and outcome monitoring) and the activation of the Locus- Coeruleus (LC) and noradrenergic system (related to learning and surprise) (e.g., Hewig et al., 2011; Preuschoff, Marius ‘t Hart & Einhauser, 2011; Siegle, Steinhauer, Carter, Ramel, & Thase, 2003). Thus, there is a wide spectrum of brain activity that can be encapsulated by PD measurement that is related to the specific decision-making problems.

The increase in PD has been linked to LC and uncertainty signals. The LC – norepinephrine theory suggests that when an outcome of a choice comparison indicates the presence of a significant arousing element, a burst of norepinephrine is delivered to attentional brain regions via LC to enhance subsequent learning and processing of that outcome (Nieuwenhuis, Aston-Jones, & Cohen, 2005; Aston-Jones & Cohen, 2005). Thus, LC may be important in developing a person’s ability to learn in uncertain conditions because it mobilizes a para-sympathetic vigilant response to negatively valenced stimuli (e.g., Yu & Dayan, 2005; Jepma & Nieuwenhuis, 2011; Costa & Rudebeck, 2016). The LC – norepinephrine is also important for learning to distinguish the important negative emotional signals which are further implicated in associative learning and memory consolidation (e.g., van Stegeren, 2008). For instance, Einhauser, Koch and Carter (2010) used PD to predict the timing of choices for reward and no reward options distinguished by a button press. They found that, in ambiguous situations, norepinephrine could consolidate interpretation of the emotional signals by directing individual
attention and increasing cognitive demand. This suggestion may be linked to the SMH’s underlying assumption that the affective biases, experienced at the moment of losses from disadvantageous decks, are used to evaluate and direct decision-making. Furthermore, according to the SMH, the response to negative stimuli should evoke emotional arousal (a preparatory affective bias signal for avoiding the bad outcomes) that consequently creates loss aversion to the bad outcomes (e.g., Shiv, Loewenstein, Bechara, Damasio, & Damasio, 2005).

Thus, measures of PD could provide a parsimonious clarification of the physiological path between the negative emotion arousal, delivery of norepinephrine and consequent avoidance of the bad decks during IGT performance. This could reveal if the emotionally aroused loss aversion (as evidenced by PD) requires heightened cognitive attention for the bad choices in the face of conflicting cognitive information during the IGT performance (e.g., Dunn et al., 2006).

Bechara et al.’s (2005) suggestion that negative affective bias underpins adaptive strategy on IGT coincides with evidence suggesting that negatively valenced events are more likely to impact decision-making than the positively valenced (Baumeister, Bratslavsky, Finkenauer & Vohs, 2001); Baumeister et al. referred to this concept as the negativity bias. This is similar to Kahneman and Tversky’s (1979) argument that increased physiological responses following losses generate a behavioural basis of loss aversion, where a decisional choice leads to instant outcomes evaluation and consequently avoidant behaviour of the bad outcomes. This view is supported by the evidence from brain imaging studies that reveal greater functional cortical changes in the prefrontal cortex (PFC) following losses compared to gains (e.g., Gehring & Willoughby, 2002; Christakou, Brammer, Giampietro, & Rubia, 2009). For example, a neuroimaging study showed that the processing of losses in IGT occurs in the VMpfc and the DLpfc, whereby the processing of accumulated losses shifts decisions away from bad choices (Christakou et al., 2009). This coincides with evidence that relates loss aversion sensitivity to punishment cues and the decision shift towards the good options in healthy population (e.g., Weller, Levin, & Bechara, 2010). Hence, loss aversion may be pertinent to Bechara et al.’s (1994, 1997, 2000) explanation as to why greater physiological responses are expected from the disadvantageous decks.

Loss aversion provides a reasonable explanation for IGT performance. However, evidence from different experience-based studies suggests that during decision-making people exhibit both loss neutral and non-loss averse behaviour (Hochman, Glockner, & Yechiam, 2010; Hochman, & Yechiam, 2011). For instance, Hochman and Yechiam found a greater increase
in PD and heart rate in response to losses than gains, but this was not associated with loss aversion. The authors observed the gap between the autonomic arousal and choice behaviour, where autonomic arousal lead to attentional orientating responses. They suggested that attention may be drawn to losses just to increase demand for cognitive processing during decision-making task. This suggestion indicates that attention to the bad choices instigates cognitive processing that is important, not only to the loss component but the whole outcome patterns. Therefore, unexpected losses signal a potential threat that needs to be cognitively processed after an initial signal and physiological arousal. Thus, unexpected losses may be interpreted as a surprise signal that initiates cognitive processes (e.g., de Gee, Knapen, & Donner, 2014; Preuschoff et al., 2011; Satterthwaite et al., 2007). For instance, Preuschoff et al., (2011) measured PD while participants performed an auditory gambling task. The cards were drawn from a deck of ten, where before hearing the cards values, the bets were placed on whether the first or the second drawn card is higher. They found that an increase in PD signals errors and surprise in assessing uncertainty. This was interpreted as evidence that noradrenaline plays an important role in judging uncertainty. This suggestion can be linked to IGT. Although it is possible that loss aversion underpins avoidance of the bad options, it is more likely that the somatic markers initiate cognitive processing of the future choices, where the interaction between the two creates anticipatory signals that guide future decisional choices. This is in line with SMH assumption that somatic marker influences the decisional choice that is displayed in the WM by conveying body information to the WM processing (Bechara & Damasio, 2005).

The standard interpretation of somatic markers is that a future optimal choice is determined by previously encountered negative feelings (e.g., negative feedback during monetary loss) that act as ‘covert biases on the circuits that support processes of cognitive evaluation and reasoning’ (Bechara et al., 1997, p.1294). Anticipatory emotions from this perspective do not depend on the explicit evaluation of the choices and arise unconsciously as a result of the early sensory procession of a choice. An alternative explanation, however, could be that emotions arise as an outcome of negative surprise and attentional biases that could be measured with PD (e.g., Bierman et al., 2004; Lavin et al., 2014; Satterthwaite et al., 2007; Turnbull et al., 2014). For instance, Bierman et al. tested participants on a grammar task analogue to the IGT version in two conditions that consisted of a series of symbols and words constructed according to grammar rules, A and B. The symbols [, #, * and + were used, whereby words having three consecutives ‘#’ and ‘]’ (grammar A) or ‘**’ and ‘+’ (grammar B) characters could not occur according to the rules. Bierman et al. reported a greater increase in PD before incorrect choices.
The PD was also significantly larger when participants looked at the incorrect option. The PD was, however, observed only at the beginning of the task indicating that somatic markers only partly account for an optimal choice. Although PD per Blocks was not assessed, their results indicated that the strengthening of the somatic marker entails cognitive processing.

To date, only one published study has utilised eye-tracking methodology during the IGT performance in a healthy population. Lavin et al. (2014) tested IGT performance and measured PD in a sample of 10 participants and demonstrated changes in PD due to learned uncertainty. Their results suggest that the changes in PD reflect learned uncertainty about future feedback conditions, thus indicating differential processing of unexpected feedback. However, a non-standard version of the IGT was used, cognitive processes were not assessed, and they did not differentiate between disadvantageous and advantageous deck selection. Furthermore, they pooled the data into four bins of 50 trials and did not account for learning and performance trials as traditionally suggested by Bechara et al. (1997). Hence, the first aim of the experiment in this chapter is to extend Lavin et al.’s (2014) finding with an alternative approach to measuring anticipatory PD (aPD). The second aim is to replicate Simonovic et al.’s (2016) previous findings demonstrating that the cognitive reflection is highly predictive of IGT performance. This is discussed in the next section of this chapter.

**Cognitive reflection**

As discussed in Chapter 1, Brevers et al. (2013) proposed a dual-process model that explains problem gamblers’ decision-making. They argued that anticipation of long-term consequences in uncertain conditions rely on two neural systems: a ‘cool’ and a ‘hot’ system. Learning and optimal decisions depend on the integration of both systems whereby, a ‘cool’ reflective process can be critical in monitoring or inhibiting ‘hot’ processes. Brevers et al. further suggests that the deficit in ‘cool’ executive processes leads to impaired IGT performance. Furthermore, the impact of ‘cool’ processes is higher during the later trials of the IGT and these should be evidenced after Block 4 (the first 80 trials) and the ‘cool’ processing should reach ceiling after Block 5. However, there is a suggestion that 100 trials are not enough to learn about the deck contingences (e.g., Wetzels, Vandekerckhove, Tuerlinckx, & Wagenmakers 2010). Wetzels et al. showed that participants learn the goodness and the badness of the decks, but that requires more than 100 trials. One way of testing this suggestion is to extend the number of IGT trails. For example, Bagneux, Font and Bollon, (2013) extended the IGT to 140 trials and tested the effect of certain (anger, happiness) and uncertain (fear, sadness) emotions.
on IGT performance. They showed that extended version of IGT may have an effect on learning. Thus, an extended version (140 trials) is used in this experiment to examine Brevers et al.’s suggestion that this could improve learning and performance of IGT.

It was further argued in Chapter 1 that Brevers et al.’s (2013) conceptualisation needs further clarification but nevertheless maps on the traditional dual-process models of decision-making (e.g., Stanovich, 2009; Evans & Stanovich, 2013). More specifically, this resembles the default-interventionist model postulating that Type I processing generates initial responses that are subsequently evaluated with reflective Type II processes (Evans, 2008). This model implies that the two processes are not completely distinct because the Type I processes represent a cognitive continuum that can be observed within the Type II processes (e.g., Evans & Stanovich, 2013). Thus, most behaviour is under Type I processes, prompted by default responses, that sometimes may recruit reflective, Type II processes when required. The key function of the Type II processing is to maintain decoupling among different alternative choices and exhibit supervision of the Type I processes. This suggestion maps on to the SMH and the argument that the affective bias is likely to inform decision choices, that requires cognitive processing of the information provided by affective biases (Stocco, Fum, & Napoli, 2009). However, it is not clear if the cognitive evaluation occurs relatively early or in later stages of the decision-making processes (e.g., Bowman et al., 2005; Brand et al., 2007; Brevers et al., 2013; Simonovic et al., 2016). Brand et al., tested executive function and IGT performance on healthy participants. They used the Wisconsin Card Sorting Test (WCST, Heaton, Chelune, Talley, Kay, & Curtiss, 1993) of cognitive flexibility in which participants need to sort a deck of cards according to a predetermined rule; the Wechsler Abbreviated Scale of Intelligence (WASI) to test overall intelligence (Wechsler, 1997); and the Tower of Hanoi (ToH) to assess planning abilities and rule-guided and goal-oriented behaviour (Spreen & Strauss, 1998). They found that only last Blocks of IGT trials correlated with WCST while the first trials did not. The authors interpreted the results as an indication that IGT measures decisions under ambiguous uncertainty (learning phase) and decisions under explicit risks (performance phase). Conversely, Simonovic et al. (2016) showed that cognitive reflection is significant in early trials, which are considered to be learning phase where participants develop somatic markers. Simonovic et al. used the original CRT (Frederick, 2005), as a measure of reflective thinking, and tested IGT performance on healthy participants and participants under stress. The results showed that reflective evaluation of affective choices occurs relatively early in decision-making processes. The CRT scores highly correlated with IGT performance in Blocks two and
three indicating that disadvantageous decks disambiguation depended on the participant's analytic ability. Thus, Type II processes occurred early in the game; these results challenged the assumption number 2 of the SMH; that somatic markers precede cognitive processes that ensue later in the game (e.g., Block 4 and 5).

The CRT that Simonovic et al. (2016) used is one of the extensively used experimental paradigms in the evaluation of dual-process theories that captures heuristic/analytic conflict (Frederick, 2005). The CRT was developed to measure the ability to withstand heuristic, intuitive responses, thus substituting Type I processing for Type II (Frederick, 2005). The original CRT consists of three problems where an intuitive answer must be resisted in order to reach the correct solution. For example, a typical item is ‘A bat and a ball costs $1.10. The bat costs $1.00 more than the ball. How much does the ball costs?’ The incorrect answer is 10 cents which is commonly believed to be generated by Type I processing. Conversely, to reach the correct response of 5 cents is commonly assumed to engage Type II processing that inhibits the intuitive response (Toplak et al., 2014). The original CRT is increasingly being criticised and there continues to be a debate about the aspect of Type II processes that the CRT measures (Toplak, West, & Stanovich, 2011; Toplak et al., 2014; Stupple, Gale & Richmond, 2013; Stupple, Ball, & Ellis, 2013; Campitelli & Gerrans, 2014; Stupple, Pitchford, Ball, Hunt, & Steel, 2017). While Toplak et al. (2011, 2014) argued that CRT is related to ‘cognitive miserliness’ (a tendency to expend as little cognitive effort as is necessary to complete a task), others have associated CRT with WM capacity and the relevant mindware, including numeracy skills (Stupple et al., 2013, 2017).

Toplak et al. (2011, 2014) suggested that poor performance on the CRT is due to cognitive miserliness, where people do not engage in deep thinking enough and are unwilling to invest cognitive effort to reach a correct answer. This assumption is made on the observation that CRT is an independent measure of intelligence, executive function and thinking disposition (Toplak et al., 2011). In contrast, Stupple et al. (2013) conducted two experiments examining if reasoning response-times, normative responses from two syllogistic reasoning tasks and WM capacity predict individual differences in performance on the CRT. The variation in WM capacity was the strongest predictor of CRT performance. Conversely, variation in response time to reasoning tasks was not a strong predictor, thus providing limited support to a cognitive miserliness paradigm. Stupple et al. (2013) acknowledged a possibility that cognitive miserliness may be involved in CRT performance, but nevertheless suggested that errors in the syllogistic reasoning task may be the result of corrupted or missing mindware (e.g., Stanovich,
2009). The mindware terminology refers to the rules and strategies that can be restored by the Type II processes and used to remodel decoupled choices (Stanovich, 2004). The mindware metaphor describes the mental processes needed for an individual to retrieve knowledge, rules and strategies stored in memory. Thus, it could be argued that the learning phase on IGT could be thought of as the development of mindware related to deck contingencies, whereby inability to reflect and/or cognitively processes deck outcomes may be the result of missing mindware as Stupple et al. (2013) suggest elsewhere.

Indeed, in line with Stupple et al. (2013) results is a suggestion that people may lack the required mindware (e.g., numeracy skills) to calculate the correct solution on the original CRT (Campitelli & Gerrans, 2014). Campitelli and Gerrans used a mathematical modelling approach, based on a sample of 2,019 participants to test CRT performance. Their results indicate that although mathematics ability may play a role in CRT performance cognitive reflection as a disposition to initiate cognitive processes is also important. Although the CRT noticeably requires some degree of numeracy skills, it is thought to also capture the propensity to think reflectively and analytically (Cokeley & Kelley, 2009; Pennycook, Cheyne, Koehler, & Fugelsang, 2015). That is, participants who do well on CRT are more likely to engage in analytic thinking and are less prone to rely on heuristically driven responses. However, some aspects of poor CRT performance may derive from dispositional individual differences and misdirected analytic thinking due to a mindware gaps failure (e.g., mathematics ability) to generate a correct response (Stupple et al., 2017). For that reason, some researchers suggest that self-reported measures of cognitive disposition such as AOT (Stanovich & West, 2007) and REI (Epstein, 1994) may provide an additional insight into the task and individual thinking predispositions during reasoning and decision-making tasks performances (Campitelli & Gerrans, 2014; Pennycook et al., 2015; Stupple et al., 2013).

The three item CRT has proven to be an effective predictor of performance on expected-values gambling tasks, probabilistic prediction tasks, profit maximising strategies, general numeracy and gambling tasks (Cokely & Kelley, 2009; Fernbach, Sloman, Louis, & Shube, 2013; Mata, Ferreira, & Sherman, 2013; Simonovic et al., 2016). However, the three items have become well known and this casts doubts about whether the original test can continue to be used as a valid measure of analytic cognitive style (e.g., Bialek & Pennycook, 2017). Toplak et al. (2014) created four additional questions, thus creating a seven-items extended version with the median correlation among the seven items of .27 and Cronbach’s alpha of a .72. Toplak et al. assessed cognitive ability (intelligence and executive functioning) and four different thinking
dispositions (Need for Cognition (NFC), AOT, Superstitious Thinking (ST), and CFC)). The additional items showed moderate to strong correlations between the CRT and WASI (r=.50), NFC (r=.31) AOT (r=.42), CFC (r=.30), Belief Bias and Syllogistic reasoning (r=.57), Denominator neglect (r=.42), Temporal Discounting (r=.16), Rational Thinking Composite (r=.56), and Thinking Dispositions Composite (r=.41). Thus, the extended CRT scale showed better predictive values of rational thinking, cognitive ability and thinking disposition than the original CRT and the 4 additional questions tested separately. Thus, the extended CRT items may be very important for IGT learning and performance because they tap into cognitive abilities and analytic thinking that may account for variability in individual IGT performance. For example, studies employing WASI as a measure of intellectual ability and WM performance in relation to IGT performance showed small effect of EFs on the task performance (e.g., Brand et al., 2007; Ernst et al., 2003; Toplak, Jain, & Tannock, 2005; Johnson, Yechiam, Murphy, Queller, & Stout, 2006). Furthermore, individual differences in thinking disposition and IGT performance may provide further explanation about the heterogeneous performance of the healthy population (e.g., Steingroever et al., 2013). Thus, a seven-item CRT provides a more comprehensive test than the three items CRT and has been used for the purposes of this chapter’s experiment.

3.2. The Experiment

The present experiment extends Lavin et al.’s (2014) findings, with a larger sample and an alternative approach to measuring anticipatory pupil dilation (aPD). The focus was on the period during the IGT where participants had hypothetically developed somatic markers, but they were not yet sufficient to extinguish particular card selection. On this basis, PD in the 500ms time frame prior to the final selection from each deck was measured and it was hypothesized that there should be negative anticipation for disadvantageous decks and positive anticipation for advantageous decks. Final aPD were measured for the advantageous (C + D) and the disadvantageous (A + B) final options. If anticipatory somatic markers play a role in IGT performance, then these should be evident prior to the final selection of each type of card. It was also expected that if the somatic markers operate on a continuum (e.g., they develop slowly) there would be an increase in aPD for both the disadvantageous and the advantageous decks. Moreover, a direct measure of deliberative thinking was included to replicate previous findings demonstrating that the CRT was highly predictive of IGT performance (Simonovic et
al., 2016). The extended seven-item CRT1 was used to provide a more comprehensive measure than the original three item CRT used in the Simonovic et al. (2016) study.

The standard analysis of IGT performance across Blocks was extended to test whether performance reached ceiling levels in the fifth Block (the final Block in the standard IGT) or whether performance continued to improve. This was based on evidence that extended trials of IGT may improve learning and consequently IGT performance. Thus, it was hypothesised that IGT performance will continue to improve after Block 5. It was also hypothesised that the correlations observed by the Simonovic et al., (2016) between CRT score and disadvantageous card selections across Blocks would be replicated such that strong correlations would be found in early Blocks (e.g., Blocks 2 – 4) because of the importance of analytic processing early in the game. According to SMH, somatic markers develop slowly during the IGT and the differences in somatic markers reactivity should be observed from the baseline (e.g., Bechara et al., 1994, 1997, 2000). Hence, it was hypothesised that there will be an increase in PD responses between the baseline PD and last aPD responses for both disadvantageous and advantageous decks. Finally, it was hypothesised that the CRT1 and last aPD for advantageous and disadvantageous deck picks would predict IGT performance.

3.3. Method

Participants

Thirty male and 39 female,6 healthy students with an age range of 19–29 years, were recruited from a UK university. All participants gave informed consent, in accordance with stipulations of the local ethics committee. People with severe vision impairment were excluded from participation. The participants had normal or corrected to normal vision. After providing information about the study, participants were informed that they would receive participation points.

Materials

IGT

Bechara et al.’s (1994) computerised version of IGT and standard instructions were used. Inquisit 4 programme was used to run the IGT script; participants were required to choose

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6 Six participants were excluded from the analysis of the study due to incomplete data (N=4) and extreme outliers (N=2)
individual cards from four decks that provide financial rewards and punishments. The gain loss frequencies were as follows: Deck A= 5 gains, 5 losses; Deck B= 9 gains, 1 loss; Deck C= 6.25 gains, 2.5 standoffs, 1.25 losses; Deck D= 9 gains, 1 loss. The overall final outcomes were as follows: A= -1000; B= -1000; C= +1000; D= +1000. Bechara et al.’s IGT instructions for computerised version were followed. One hundred and forty trials (seven Blocks of 20) were completed to examine whether additional learning trials can improve decision-making (e.g., Bagneux et al., 2013).

**CRT1**

The seven-item CRT1 (Toplak et al., 2014) was used to measure the ability to resist and override intuitive responses by engaging analytic ability. The score was the total number of correct answers. Higher CRT1 scores indicated higher reflective ability. The CRT1 consists of problems where an intuitive answer must be resisted to reach the correct solution. An example of a new question is ‘If John can drink one barrel of water in 6 days, and Mary can drink one barrel of water in 12 days, how long would it take them to drink one barrel of water together?’ The correct answer is 4 days and the intuitive answer is 9 days.

**Pupillometry**

Eye movements were recorded with the Eye-gaze binocular system Tobii-X2-30 (Inquisit 4 milliseconds plugins), with a remote binocular sampling rate of 30 Hz and an accuracy of about 0.45°. The X2 Eye Tracker is a stand-alone eye tracker, and it was attached to a laptop (Dell, Precision M6700, 2.70Ghz). Participants were seated approximately 70 cm from the laptop monitor. The Tobii measured 184mm (7.2”) in length and enabled tracking at close distances (up to 36° gaze angle). The eye-tracker used both bright and dark pupil illumination setups to calculate the optimal gaze position. During a recording, the Tobii collected raw eye movement data points every 16.6ms. The firmware calculated the pupil size by measuring the diameter of the pupil on the image and multiplying it by a scaling factor. Each data point was identified, analyzed and averaged across both eyes by a timestamp and “x, y” coordinates. Blinking periods were filtered and replaced via linear interpolation (e.g., Siegle et al., 2003). Pupillary responses were measured continuously throughout the task.

**Procedure**

One consideration in designing this experiment was to replicate Simonovic et al. (2016) with the inclusion of additional measures. Thus, following consent, the CRT1 was administered first
to be consistent with the previous study. The CRT1 is easy to administer to participants and is not time-consuming for participants to complete. Before the eye-tracking recording was started, the participants were taken through a calibration procedure. During this procedure, the eye tracker measured characteristics of the participant’s eyes and used them together with an internal, physiological 3D eye model to calculate the gaze data. This model included information about shapes, light refraction and reflection properties of the different parts of the eyes (e.g., cornea, placement of the fovea). During the calibration, the participants were asked to look at specific points on the screen, also known as calibration dots. During this period, several images of the eyes were collected and analyzed. The resulting information was then integrated into the eye model, and the gaze point for each image sample was calculated. When the procedure has finished the quality of the calibration was illustrated by green lines of varying length. The length of each line represented the offset between each sampled gaze point and the center of the calibration dot. During the calibration, both the light and dark pupil methods were tested to identify the most suitable for the current light conditions and the participant’s eye characteristics. After the completion of the IGT participants were debriefed.

**Analytic strategy and Scoring**

Before the initiation of the analyses, data were inspected for normality by checking for outliers, Skewness and Kurtosis, normality tests and Z-scores to ensure that the assumptions of parametric statistics were met before analyses were performed. If parametric assumptions were not met the data were log transformed, corrections used, and non-parametric tests used when appropriate.

**IGT scoring and CRT1**

Standard scoring was derived by deducting total disadvantageous card picks (A + B) from total advantageous picks (C + D. A positive score suggests a more advantageous decision-making strategy, whereas a negative score suggests a disadvantageous decision-making strategy. Initial analyses focused on checking the IGT performance per Block. Next, bivariate correlations between the disadvantageous decks and CRT1 scores were examined.

**Pupillometry**

To determine baseline PD, data were averaged for each participant over the 30 sample of raw PD data in the period from 2500 to 500ms before the commencement of the task (e.g., Jepma & Nieuwenhuis, 2015; Satterthwaite et al., 2007). The PD during the 500ms preceding the first
card selection was not included in the baseline period to avoid bias of a potential anticipatory increase that is assumed to start 500ms before stimulus onset (e.g., Satterthwaite et al., 2007). Next, to create the aPD variable, the anticipatory pupil diameter at the time points of the initial and the last pick for each deck was calculated. The pupil diameter 500ms prior to the mouse click indicating card selection (y) was subtracted from the pupil diameter at the time point when the card was seen (x) and divided by the pupil diameter when the card was seen (x) resulting in an anticipatory pupil change relative to the 500ms period offset (see Preuschoff et al., 2011 for further details). Resulting in the following formula \((x-y)/x\). Repeated measure paired t-tests were used to examine the differences between baseline PD and last aPD for disadvantageous and advantageous decks. The last aPD category was defined as pupil dilation generated 500ms before the last picks for both advantageous and disadvantageous decks. Finally, a multiple regression was conducted to test whether the CRT1 scores and the last aPD for disadvantageous/advantageous decks would predict IGT performance. The analysis was conducted using IBM SPSS 22 for Windows with an alpha = .05. Six participants were excluded from the analysis because of incomplete data and extreme outliers.

### 3.4. Results

Performance across Blocks was tested using a Greenhouse-Geisser adjusted repeated measures ANOVA. There was a main effect of Block condition, \(F(3.86, 239.12)=25.21, p<.001, \eta^2 = .16\). Bonferroni-adjusted post hoc tests demonstrated that performance improved significantly through the Blocks of trials (excluding Block 6). Notably, the nonstandard additional Blocks 6 and 7 continued to show changes in performance relative to earlier Blocks such that performance dipped in Block 6, but Block 7 was significantly better than all but Block 5 (Figure 3.4.1).
Correlations between CRT1 score and selection of disadvantageous cards across Blocks were conducted (see Table 3.4.1). These demonstrated a significant negative relationship between CRT1 score and disadvantageous card selections in all but the first Block of trials.

Table 3.4.1

<table>
<thead>
<tr>
<th>Trial Block</th>
<th>Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block 1</td>
<td>r = -.093, p = .467</td>
</tr>
<tr>
<td>Block 2</td>
<td>r = -.363, p = .001</td>
</tr>
<tr>
<td>Block 3</td>
<td>r = -.438, p &lt; .001</td>
</tr>
<tr>
<td>Block 4</td>
<td>r = -.497, p &lt; .001</td>
</tr>
<tr>
<td>Block 5</td>
<td>r = -.488, p &lt; .001</td>
</tr>
<tr>
<td>Block 6</td>
<td>r = -.449, p &lt; .001</td>
</tr>
<tr>
<td>Block 7</td>
<td>r = -.449, p &lt; .001</td>
</tr>
<tr>
<td>Total</td>
<td>r = -.583, p &lt; .001</td>
</tr>
</tbody>
</table>

On average, last aPD for disadvantageous decks (M=3.02, SE=.05) did not significantly increase from baseline (M=3.03, SE=.05), t(61)=.50, p=.61, r=.06. Similarly, last aPD for
advantageous decks (M=3.00, SE=.05) did not significantly increase from baseline (M=3.03, SE=.05), \( t(62)=.62, p=.54, r=.07 \).

A multiple regression (Enter method) tested the relative predictive strength of last anticipatory pupillary responses for disadvantageous (A + B) and advantageous (C + D) deck picks and CRT1 scores for performance on the IGT. Data indicated that the three predictors combined reliably accounted for 35% of the variability in IGT scores. The Beta for disadvantageous cards showed a negative correlation with PD while the advantageous cards showed a positive correlation. This indicated that increased aPD on the last pick of a disadvantageous card predicted poorer overall performance in contrast with increased aPD for advantageous cards which was associated with better overall performance. The CRT1 score was the strongest predictor with higher scores on the CRT1 predicting better card selections.

Table 3.4.2

*Multiple Regression Analysis of Cognitive Reflection Test, Final Anticipatory Pupil Dilation for Disadvantageous (AB) Decks, Last Pupil Dilation for Advantageous (CD) decks as predictors of IGT performance*

<table>
<thead>
<tr>
<th>Predictors</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 'Enter.'</td>
<td>( R^2=.384, \quad R^2_{\text{adj}}=.352 ) \ F(3, 58)= 12.03, p&lt;.001</td>
</tr>
<tr>
<td>CRT1 scores</td>
<td>( B^2=14.29; \beta=.556, p&lt;.001 )</td>
</tr>
<tr>
<td>Last aPD (AB)</td>
<td>( B=-57.50; \beta=-.463, p=.048 )</td>
</tr>
<tr>
<td>Last aPD (CD)</td>
<td>( B=61.79; \beta=.520, p=.028 )</td>
</tr>
</tbody>
</table>

Durbin Watson= 1.93, VIF= 1.042; 4.965; 4.992

**3.5. Discussion**

Consistent with the first hypothesis, the Block performance analysis demonstrated that IGT performance did not reach ceiling at Block 5 and significantly improved in Block 7 after a non-significant dip in Block 6. The second hypothesis was also supported; correlations between CRT1 scores and disadvantageous deck selection broadly replicated findings from the control group in Simonovic et al. (2016) but with stronger correlations and evidence that cognitive reflection is implicated not only in early Blocks but also later in the task. The third hypothesis

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7 \( B \) is unstandardized beta value and \( \beta \) is standardized coefficient
that there would be an increase in PD from the baseline evident in the last aPD responses was not supported. This indicated the possibility that learning occurred without the slow development of somatic markers. Finally, the analysis showed that aPDs and cognitive reflection were reliable predictors of IGT performance, thus supporting the final hypothesis. The results indicated that anticipatory pupillary responses may operate as learning markers and these effects differ according to the nature of the decks. More specifically, increased aPD on the last pick of disadvantageous cards predicted poorer overall performance, whereas, increased aPD for the last pick of advantageous cards was associated with better overall performance. This provides some support for SMH and may indicate that differing somatic markers develop for advantageous and disadvantageous decks, and that these influence IGT performance. However, since there was no increase in PD between the baseline PD measurements and last aPD measurements the analysis in support of the SMH cannot be definitive. These findings are discussed in turns.

Results implications

According to Bechara et al. (1997, 2000), healthy participants should have enough information concerning the IGT after the fourth Block (80 trials) that will allow optimal strategy during the last Block (last 20 trials) or a ‘performance phase’. Hence, during the performance phase selecting from advantageous decks should reach ceiling after the fourth trial which will indicate optimal performance phase. The results from this experiment indicate that optimal learning and performance require more than 100 trials. This is in line with Steingroever et al.’s (2013) argument that 100 trials are not enough to learn the nature of the decks and they proposed that the trial numbers should be extended to improve learning. Administration of 140 trials in this experiment showed that learning could be improved by extended trials as participants’ performance did not reach ceiling by the fifth trial. This is in line with evidence demonstrating that increased numbers of trials improve learning (e.g., Bagneaux et al., 2013; Humphries, Bruno, Karpievitch, & Wotherspoon, 2015; Overman & Pierce, 2013; Reavis & Overman, 2001; Wetzels, Vandekerckhove, Tuerlinckx, & Wagenmakers 2010). Thus, administration of more than 100 trials might reveal important insight into cognitive processes related to the performance phase and raises a possibility that some participants may be slow to learn the task (e.g., Overman & Pierce, 2013).

Lavin et al. (2014) suggested that successful performance on IGT depends on positive feedback (based on the money gain) and highlighted pupillary responses to unexpected punishments on
advantageous decks. The differing methodologies between this experiment and Lavin et al.’s study make direct comparison difficult. For example, they did not dissociate disadvantageous/advantageous decks selection to explain the physiological mechanisms responsible for successful IGT performance. Hence, it is not clear if physiological arousal differs according to the nature of the decks, which is a central claim to SMH (e.g., Bechara & Damasio, 2005). Nevertheless, they did find the effect that pupillary responses indicate different processing of the positive feedback. This effect, although not conclusive, suggest that PD signal surprise if given feedback does not meet expectations. The results from this experiment add to this claim, that while positive feedback may be responsible for an increase in PD, anticipatory responses of both negative and positive feedback may be important for IGT performance.

While the data indicate that participants’ last aPD responses predict successful IGT performance the possibility that these somatic markers are instead markers of cognitive load cannot be excluded. This is because pupil dilation can be interpreted in several ways with anticipated reward or threat and general cognitive effort all potentially resulting in pupil dilation (e.g., Granholm & Steinhauser, 2004; Piquado, Isaacowitz, & Wingfield, 2010). The data showing increased pupil dilation for the advantageous deck is consistent with participants anticipating a positive outcome rather than a threat. However, it is possible that an increased level of cognitive effort may be in play and this would be consistent with the observed correlations with cognitive reflection.

According to Bechara et al.’s (1997) original proposition, participants slowly develop anticipatory markers that are evident after the third Block (around trials 60). Hence a steady increase in anticipatory markers should be evident during the IGT performance and Bechara et al. claimed that implicit nature of the anticipatory signals is core to the SMH explanation. However, this argument is disputed in a later paper claiming that:’ The central feature of the SMH is not that non-conscious biases accomplish decisions in the absence of conscious knowledge, but rather that emotion-related signals assist cognitive processes even when they are non-conscious’ (Bechara et al., 2005, p. 159). This looks like a departure from their previous argument that somatic markers are implicitly acquired and would mean that the somatic markers arise as a consequence of the explicit knowledge and cognitive processing. Irrespective of these interpretations the data from this experiment demonstrate a role for somatic markers in performance on the IGT but allow for the possibility that these somatic markers are of cognitive effort as well as an indicator of emotional learning.
This interpretation would also explain the correlation in early trials with cognitive reflection. The CRT1 was shown to be a stronger predictor of IGT performance than the aPD measures, with higher scorers clearly outperforming lower scorers. This is clear evidence that Type II reflective processing plays a salient role in the task and supports the view that the IGT is best understood within a dual-process framework (e.g., Brevers et al., 2013). Brevers et al. suggest the monitoring function of ‘cool’ processes over ‘hot’ processes, whereby the ability to control emotional reaction related to ‘hot’ processes would allow cognitive processing of positive and negative choices associated with choice selections. The CRT1 data presented here are consistent with this view and shows that the learning on IGT is indicative of a role for reflective monitoring of disadvantageous decks contingencies early in the game. This also raises a possibility that the learning phase on IGT could be thought of as the development of mindware related to deck contingencies, whereby the inability to reflect and/or cognitively process disadvantageous deck outcomes may be the result of missing mindware. According to Evans and Stanovich (2013) if the relevant mindware is available for a specific task, the next question is whether a person is able to detect the rules of the task and engage in sustained cognitive decoupling and hypothetical thinking in order to perform well on the task. Since most of the participants in this experiment began the task by exploring disadvantageous decks (A + B) it is possible that they were developing required mindware to disambiguate disadvantageous deck contingencies. This would explain early correlation between the CRT1 and disadvantageous deck selection, whereby a developing mindware of the task and sustained higher cognitive reflection led to prompt learning of the disadvantageous deck contingencies.

The suggestion that cognitive processing (as measured with CRT1) is associated with IGT performance early in the game is inconsistent with previous research that related higher cognitive processing with later trials on IGT (e.g., Brand et al., 2005, 2007, 2008). This inconsistency could be explained by the type of measures used to probe the learning effect. As discussed in Chapter 1, Brand et al. used tasks that measured decision-making under risk (the GDT; the PAG). These measures show a high correlation with executive processes such as categorization, cognitive flexibility and rule recognition (e.g., Brand et al., 2009). Although there is some indication that CRT performance may be related to WM (e.g., Stupple et al., 2013) some authors argued that the CRT measures cognitive reflection that generates representations of choices in a complex environment (e.g., Zonca, Coricelli, & Polonio, 2017). Zonca et al., argued that cognitive reflection intervenes in the processes of representation generation (e.g., choices formation) and has an impact on representation-building processing.
that is highly accurate in predicting patterns of information related to reward or punishment values. In other words, cognitive reflection would not directly improve performance in the complex tasks but can influence the ability to form the understating of the complex environment, which in turn would predict optimal performance. Thus, it is possible that higher cognitive reflection helps learning IGT, by means of understanding the disadvantageous deck's contingencies, which in turn forms a representation about the goodness/badness of the decks that consequently influence optimal performance.

These CRT1 data nonetheless need to be interpreted with some caution. The CRT1 was administrated prior to IGT and in order to rule out any possible issues with order effects the experiment should be replicated with a reversed or counterbalanced presentation order. There is also some debate as to whether the CRT1 is a measure of cognitive miserliness or a more general measure of analytic thinking or numerical ability and it has been correlated with both WM capacity (e.g., Stupple et al., 2013) and risk neutrality (Oechssler, Roider, & Schmitz, 2009) which could impact on performance or task strategy. Further, Toplak et al.’s (2014) extended CRT1 could be criticised on the basis that some of the questions (e.g., number 7 has three forced options) are not open-ended and it is possible to generate a correct option by chance. Moreover, the dimensionality of the scale was originally not analysed, and it is not clear whether different items were considered for the scale. Nevertheless, the scale has been successfully used in several studies indicating that is a potent measure of cognitive reflection (e.g., Alos-Ferrer, Garagnani, & Hügelschäfer, 2016; Corgnet, Espín, & Hernan-Gonzalez, 2015; Hertzog, Smith, & Ariel, 2016; Rinaldi, Radian, Rossignol, Kandana Arachchige, & Lefebvre, 2017; Ring, Neyse, David-Barett, & Schmidt, 2016).

To summarise, evidence from this experiment showed that cognitive reflection and anticipatory somatic markers both contribute to decision-making, but the anticipatory signal may be of a cognitive nature. However, it needs to be noted that the measures used in the present study are relatively narrow and further applications of the pupil dilation methodologies are necessary to more fully explore the utility of this measure in investigating the IGT and the SMH more broadly. Nevertheless, the experiment showed clear implication of Type II processes during IGT performance. This is in line with previous research suggesting that higher order cognitive processes guide successful decision-making early in the game (e.g., Hinson et al., 2002; Maia & McClelland, 2004; Fernie & Tunney, 2013). Thus, there is substantial evidence that explicit learning guide IGT learning and performance which challenges SMH. In the next chapter alternative eye-tracking measures such as fixations on particular decks of cards were used.
because they offer strong potential in investigating the locus of explicit attention as learning progresses on the task. Furthermore, measures of conscious awareness and analytic ability were included to test a possibility that Type II processes guide IGT learning and performance.
Chapter 4

Overview

This chapter addresses objective (iii) of the thesis and details the second experiment that examines the effect of cognitive processes (e.g., attention, cognitive reflection and conscious awareness), thinking dispositions and individual differences on IGT performance. As discussed in Chapter 1, Bechara et al.’s (1994, 1997, 2000) claim that conscious awareness of the game develops as a result of somatic markers unconscious signals has been challenged several times (e.g., Bowman et al., 2005, Evans et al., 2005; Fernie & Tunney, 2006, 2013; Maia & McClelland, 2004, 2005). Conscious awareness may develop early in the game which indicates that somatic markers may represent an effect rather than a cause of explicit knowledge (e.g., Maia & McClelland, 2004). This is contrary to the suggestion that somatic markers reinforce learning early in the IGT (ambiguous stage) while the later stages of the task are informed by conscious knowledge and higher cognitive processes (e.g., Brand et al., 2007). Furthermore, the results from Experiment 1 (Chapter 3) showed that higher cognitive processes are associated with decision-making early in the IGT, thus supporting previous research regarding the engagement of higher cognitive processes during the IGT performance (e.g., Hinson et al., 2002; Simonovic et al., 2016; Turnbull et al., 2003). It was also argued in Chapter 3 that the IGT performance is best understood within the dual-processing framework of decision-making. Firstly, because of the possibility that somatic markers may reflect intuitive, Type I processes; and secondly because a sustained higher cognitive reflection may be important in learning and consequent IGT performance. Thus, there is an important role for Type II processes in deck contingency disambiguation. In the current chapter, the locus of explicit attention, cognitive reflection and conscious awareness were discussed as potentially important explanatory mechanisms of the Type II processes that may be implicated in learning the IGT. Furthermore, individual differences in thinking dispositions were examined in the current chapter because of the suggestion that they could capture reflective level of processing that is involved in the generation of the alternative choices during decision-making (e.g., Evans, 2008). Steingroever et al. (2013) argued that there is substantial variability in IGT performance in healthy participants because of the physiological arousal and thinking dispositions; this proposition warrants investigation because only a careful examination of fine-tuned elements of the cognitive processes and thinking dispositions will allow for an accurate description of the
processes involved in learning and performance of the IGT. Thus, the aim of Experiment 2 in this chapter is to address the aforementioned issues.

4.1. Introduction

As discussed in Chapters 2 and 3, Brevers et al. (2013) proposed that a dual-process framework may provide a better explanation for non-optimal IGT performance in a population diagnosed with addictive disorders such as gambling and alcohol dependence than SMH. The conceptualisation of the ‘cool’ systems maps on Type II processes that are conscious, controlled, and involved in abstract and deliberate thinking and reasoning (e.g., Kahneman, 2003). Hence it is assumed that the ‘cool’ system monitors and corrects affective processes triggered by the ‘hot’ system. This is in line with a proposition that, depending on the context of the situation, Type II processing may exert influence on Type I processing, thus providing alternative answers to the contextual problems (e.g., Evans & Stanovich, 2013). Brevers et al.’s conceptualisation of the ‘hot’ system is somewhat ambiguous. Brevers et al. argued that the ‘hot’ system (laden with affective tags that depend on previous experience) regulates emotional responses and inhibits impulsive reaction, p. 2). Hence, the ‘hot’ system is self-regulatory, and it depends on the ability to control emotional responses. If the ‘hot’ system is intact, and the control of emotional responses is attained, the ‘cool’ system will engage reasoning and problem-solving aspects of EFs. The problem with this conceptualisation is twofold: First, Brevers et al. did not provide any substantial evidence to support multiple aspects of the ‘hot’ system; and second the ‘hot’ system maps on Type I processes that are based on previous experience, implicit knowledge and basic emotions. Thus, it could be argued that the ‘hot’ system emulates the Type I processes, because their execution involves processes of emotional regulations (e.g., Evans & Stanovich, 2013a). This suggestion needs exploring in a ‘normal population.

There is some evidence that ‘cool’ processes, as measured by EF tasks may account for IGT performance in later trials (Brand et al., 2006, 2007, 2008). For example, Brand et al. (2007) conducted two experiments and tested EFs measured by the WCST, the GDT, WASI and the ToH. The WCST the ToH and the GDT tasks moderately correlated with IGT performance after the third trial, and there was, however, no effect of intelligence on IGT performance. Brevers et al. (2013) interpreted these results as evidence ‘that individuals with lowered “cool” executive functioning (i.e., concept formation, shifting between multiple tasks, and dominant response inhibition) but with intact “hot” executive processing (i.e., pre-choice emotional
activation reactivity associated with an advantageous decision-making profile) exhibited less disadvantageous choices in situations of decision-making under ambiguity as compared with situations of decision-making under risk’ (p. 665). This is further supported by the evidence that the EFs are not associated with IGT performance, (at least not during the ambiguous stage) (Toplak, Sorge, Benoit, West, & Stanovich, 2010). Toplak et al. (2010) reviewed 43 studies that examined the association between IGT performance and measures of EFs and intelligence. They reported small to medium effects where only a small proportion of the studies yielded significant results. The focus of the review was on studies that measured inhibition of interference of a response, shifting between tasks or mental sets, intelligence, and updating and monitoring of WM representations. Overall, the results indicated a lack of correlations between the EFs, intelligence and IGT performance, with the majority of studies reporting no relationship. However, this lack of correlation could be associated with a mixed studies’ sample that consisted of healthy participants, and participants with neurological and psychiatric disorders who may have different impairments or intact cognitive abilities (e.g., Sahakian et al., 2015). Nevertheless, both Bovers et al.’s and Toplak et al.’s reviews suggested that the IGT is best explained within a dual-process framework where attentional processing may be pertinent to IGT performance as a prerequisite for activation of inhibitory response preferences, presumably through the Type II processes.

The presence of attentional processing in IGT is explained by the necessity for executive inhibition that involves suppression of recently inspected, bad choices (e.g., Fuster, 2008; Eslinger & Chakara, 2004). SMH postulates that decision options are determined by somatically marked choices consisted of stochastically sampled information (e.g., Bechara & Damasio, 2005). Attention is determined by physiological arousal and by the information needs that are acquired passively, presumably in the early trials, followed by an active attentional online processing in the later trials (e.g., Brand et al., 2007). Gansler, Jerram, Vannorsdall and Schretlen (2011) used structural equation modelling (SEM) to test whether the IGT relates to attention and processing speed, executive functioning and visual and learning memory. Their results indicated that attention may play a special role during IGT performance. Attention was a very strong predictor on trials 1-100, and attention and executive functioning were weaker predictors on trials 41-100. These are very interesting results because they propose an active role for attention rather than the previously assumed passive role. Gansler et al. (2011), however, used EF tests that are closely related to the cognitive abilities involved in action organization rather than inhibitory responses and this may explain EF’s weak predictive value.
Furthermore, they used neuropsychological tests to examine attention (e.g., BRIEF, Schretlen, 1997) and it is difficult to infer stronger conclusion related to the active role of attentional processing during IGT performance.

Recent evidence on attentional processing has challenged the assumptions of passive attention which questions the basic premises of SMH regarding automatic attentional information acquisition (e.g., Hayhoe, & Rothkopf, 2011; Krajbich, Armel, & Rangel, 2010; Krajbich et al., 2012; Orquin, & Loose, 2013). For example, Krajbich et al. (2010) used value-based binary-choice and examined inspection time and choice data. They showed that inspection time increases with the difficulty of the choices, thus suggesting that inspection time reflects cognitive demand and actively construct decision-choice. This is in line with a suggestion that attentional online processing reflects active, higher order cognition that could be investigated with an eye-tracking methodology and could be related to Type II processes (Orquin & Loose, 2013). One of the underlying features of Type II processes is a requirement for controlled attention, conscious representations of decisional choices and WM resources, compared to Type I processes that do not require controlled attention and make minimal demands on WM resources (Evans & Stanovich, 2013a). Previous research on IGT has shown that conscious awareness develops early in the game, thus indicating a role for higher cognitive processes (e.g., Bowman et al., 2005; Maia & McClelland, 2004; Fernie & Tunney, 2006, 2013). This is further supported by the results from Experiment 1 and previous research that showed the effect of cognitive reflection on deck’s contingences disambiguation early in IGT (Simonovic et al., 2016). Taken together the evidence indicate that there is an active role of Type II processes in IGT which could challenge the SMH assumption. The role for attention during IGT performance is assumed, but to the best of my knowledge, not examined yet. The next section discussed the locus of explicit attention and the evidence from decision-making studies that used the eye-tracking methodology. It is argued that examination of attentional processing during IGT may provide an important insight into cognitive processes involved in learning the IGT.

**Eye tracking and attention**

Eye-tracking movement in reasoning and decision-making research provides an insight into the nature and organisation of reasoning processes. The active role of attention during fixation periods is now acknowledged to represent a good explanation for the cognitive processes involved in the decision-making preferences (e.g., Krajbich et al., 2010; Krajbich et al., 2012).
For example, attention plays an important role during information extraction which is encoded during a given fixation and inspection time during the choice comparison (Krajbich et al., 2010). Krajbich et al. (2010) developed a computational model of value-based choices and pointed out that fixations guide the comparison processes between the choices. Their model implies a causal effect between the fixation processes and choices after comparison processes. The model received good support from research that included tasks that involve information complexity, reasoning difficulties and time pressure (e.g., Horstmann, Ahlgrimm, & Glöckner, 2009; Glaholt & Reingold, 2011; Glockner & Herbold, 2011). For instance, Glaholt and Reingold, (2011) used images of photographic art and tested stimulus exposure during decision-making. They measured the spatial and temporal profile of decision makers’ information sampling with an eye-tracking methodology. They reported that the duration of inspection-time is related to the encoding of the alternative choices during decision-making. Furthermore, they argued that the inspection time not only encapsulates information sampling, but also evaluation and comparison of relevant choices alternatives. Although this suggestion is still under debate (e.g., Bird, Lauwereyns, & Crawford, 2012; Nittono & Wada, 2009) it is generally assumed that inspection time could have an important role in information gathering and choices evaluation and comparison (e.g., Lim, O’Doherty, & Rangel, 2011).

Inspection time is also related to information integration during decision-making that may be explained by the different types of processing (e.g., Glockner, 2007; Glockner & Betsch, 2008; Glockner & Herbold, 2008, 2011; Horstmann et al., 2009). Glockner and Herbold (2008) examined participants’ performance on forty decision tasks and related long inspection time to deliberate calculations. They also reported that information search increases if there is a decrease in expected value during a gamble. A specific strategy related to the task is then needed to circumvent the decrease. This is in line with earlier experiments on the choice patterns of the probabilistic cues (e.g., Glockner, 2007). Glockner used a city size task, where participants needed to decide which of the two suggested cities is larger based on probabilistic cues. Although the result suggests that a decision can be made promptly (Type I processes), Type II processes (e.g., calculation of weighted sums) are needed for a correct response. Furthermore, information integration depended on the reflection of the consistency of the maximizing process where automaticity and cognitive reflection of the decision choices were integrated holistically and operated on a continuum. A similar suggestion is made by Horstmann et al. who conducted a study to examine the effect of intuitive processing and deliberation on learning information. In addition to the city size task, participants completed a
complex legal inference task where they had to decide who committed a crime in a hypothetical murder case. The study results pointed out that there is an interaction between the Type I and Type II processes that depend on similar information search and information integration. However, Type II processes add supplementary analytical features to the Type I processes. Taken together these studies’ results related longer inspection time with deliberation and Type II processes.

This is in line with research on syllogistic reasoning studies that associated longer inspection time with increased reasoning processing (e.g., Ball, Lucas, Miles & Gale, 2003; Ball, Phillips, Wade & Quayle, 2006; Stupple & Ball, 2008). For example, Ball et al. (2006), provided good evidence that eye-tracking measures of online attentional processing may capture reasoning processes. Ball et al. reported an experiment in which participants’ inspection time on syllogistic reasoning was tested by using an eye-tracking methodology. Reasoning processes were also tested by means of manipulation of conclusion validity and believability on reasoning tasks. Ball et al. monitored the duration of people’s eye fixation on premises and conclusion of syllogistic problems and suggested ‘that increased inspection time of the problems components are a reflection of increased processing effort’ (p.84). Furthermore, it was suggested that the application of the eye-tracking measures might provide a deeper understanding of the reasoning processes, where fixation durations, attentional processing and high-level reasoning mechanisms can help facilitate plausible explanation for differences in reasoning processing.

In three experiments that tested Evans’ (1996) heuristic-analytic account of reasoning on the Wason’s selection task (Wason, 1966), Ball et al. (2003), used an eye-tracking methodology to examine inspection time. In the Wason selection task participants are presented with a rule if p then q and four decks of cards to which the rule assigns. For example, the rule might be If a card has a vowel on one side, then it has an even number on the other side with the facing cards showing A (p), D (-p), 4 (q) and 7 (-q). Participants are then asked to turn over cards to determine whether the rule is true or false. The logical correct response should be A and 7 (p and -q) (Wason & Shapiro, 1971). Ball et al. (2003) provided a direct measure of online, attentional processing of the cards by using eye-tracking measures and tested inspection time. Two out of three experiments provided reliable evidence for inspection time; participants spent more time inspecting cards they selected than those they rejected. However, Evans and Ball (2010), re-examined the data from Ball et al.’s (2003) study and argued that attention may be necessary but is not sufficient for card selection on the logically correct responses. Further
analysis of Ball et al.’s (2003) data revealed that the inspection time differed significantly from participants’ subsequent card selection. Evans and Ball acknowledged that the measure of card inspection times may provide very important information of cognitive processing on the reasoning task, however, this cognitive processing does not include the key logical insight for a rule if p then q falsifying statement. Nevertheless, Evans and Ball’s (2010) re-analysis of the data suggests that the eye-tracking methodology can be very useful in capturing different types of processing whereby the competitive nature of decision difficulty may have different effects on inspection time.

The above presented evidence is consistent with the notion that the eye-tracking methodology can be useful in detecting attentional processing during decision-making. The primary advantage of the eye-tracking methodology is that provides a more direct measure of covert and overt attentional processing during decision-making. More specifically, inspection time has been shown to be a very useful measure for detection of Type I and Type II processes, with longer inspection time related to increased processing effort. As discussed in the previous chapter, the results from the first experiment indicated that Type II processes are involved early in IGT. In this chapter’s experiment a direct measure of the locus of explicit attention (inspection time) is used to examine cognitive processes during the IGT performance. This will allow for closer examination of attentional processing that may be implicated early in the game. Furthermore, the basic premises of SMH is that emotions guide decisions covertly and that participants are not able to explicitly verbalize their experience. The evidence discussed in Chapter 2 indicate that participants are able to generate conscious impressions of the goodness and the badness of the decks early in the game. According to dual-process framework, the input and output of the Type II processes are conscious, controlled and occur in deliberate mode (e.g., Evans & Stanovich, 2013). This is discussed next.

**Conscious Awareness**

Bechara et al. (1994) made an argument that the performance on the IGT is ‘cognitively impenetrable’, meaning that somatic marker signals guide successful decision-making covertly in the absence of conscious knowledge of the game. As discussed in Chapter 1, this argument was challenged numerous times with contrasting evidence that conscious knowledge guides participants’ selections and they are aware of the deck contingences sometimes even without acquiring somatic markers (e.g., Bowman et al., 2005; Cella et al., 2007; Evans et al., 2005; Maia & McClelland, 2004; Fernie & Tunney, 2013). For example, Maia and McClelland’s
(2004) analysis indicated that somatic markers could be generated by conscious knowledge of deck payoffs and showed that awareness of the advantageous and disadvantageous deck picks develops early (after only 20 trials). Maia and McClelland’s results were replicated several times (e.g., Fernie & Tunney, 2006, 2013; Wagar & Dixon, 2006), and similar outcomes were obtained in studies that used subjective awareness questions (e.g., Bowman et al., 2005; Cella et al., 2007; Evans et al., 2005). Bowman et al. used subjective experience ratings where participants were asked to provide deck ratings in terms of how good or bad they thought each deck was on a scale of zero to ten. Bowman et al. reported that participants developed awareness of the goodness and the badness of the decks after the first Block of trials. Similarly, by using the same subjective rating question, Evans et al. reported that both healthy people and people with schizophrenia developed awareness of which decks were ‘good’ and ‘bad’ ratings at above chance levels, after the first and second Blocks of trials. This compelling evidence challenged Bechara et al.’s argument and raised considerable doubt over the inference that somatic markers act covertly and cause conscious awareness of the goodness and badness of the decks.

Conversely, Persaud et al. (2007) argued that the beginning of the task is based on unconscious informations. Persaud et al. asked the participants to wager on the payoffs of the trials. The wager that could be placed was high (£20) or low (£10). The reward from disadvantageous decks was twice the amount wagered (with occasional penalties being larger) whereas the reward from the advantageous decks was equal to the amount wagered. The point of the task was that wagering could probe awareness. If/when participants had some awareness then he/she would bet higher in that choice because of a higher payoff. Persaud et al. reported that the wagering bias started after 70 trials, and therefore concluded that unconscious (covert) influence of somatic markers guide decision-making early in the game. This however, is more likely to be theoretical speculation because it examines the correctness of the decisional choices rather than conscious awareness (e.g., Seth, 2007). Furthermore, the problem with wagering method of assessing awareness could be loss aversion (e.g., Dienes & Seth, 2010; Konstantinidis & Shanks, 2013). Participants could be loss aversive and may choose to make low wagers even if they experience some level of conscious awareness.

Persaud et al. (2007) have criticized Maia and McClelland’s test of awareness and argued that participants’ verbal report of their mental processes is sometimes unreliable. However, only one part of Maia and McClelland’s test consists of verbal report. The rest of the test is based on a structured questionnaire that encompasses subjective experience (in the form of deck
ratings) and the estimation and calculation of the deck values, that requires conscious awareness of the deck contingencies (e.g., Newell & Shanks, 2014). Furthermore, the structured questionnaire is presented in a clear numerical form which aids explicit tracking of the deck contingencies (e.g., Turnbull et al., 2014). Therefore, Maia and McClelland’s (2004) test of awareness could provide an examination of explicit awareness and provide multiple sources of information that could explain decision-making on IGT. Thus, despite some criticism, Maia and McClelland’s (2004) test was successfully used in studies that examined conscious awareness during IGT performance. (e.g., Fernie, & Tunney, 2006, 2013; Wagar & Dixon, 2006). 

As discussed in Chapter 1, there is substantial evidence for the effect of conscious awareness on IGT (e.g., Turnbull et al., 2014). Furthermore, conscious awareness is implicated in information integration (Strauss et al., 2015), learning (Dickinson & Balleline, 2009), and memory consolidation (Tononi, 2004) that again challenges Bechara et al.’s (1994, 1997) argument that somatic markers guide information integration during the IGT covertly and in the absence of conscious knowledge. In fact, some researchers argued that there is very little evidence in support of the unconscious (deliberation without attention) processes and that most of the attentional processing is associative with awareness (Newell & Shanks, 2014). While questions remain about the suitability of different awareness assessments (Bechara et al., 1997; Maia & McClelland, 2004; Persaud et al., 2007) there is convincing evidence that awareness emerges in early trials on IGT. Thus, in addition to the attentional online measurements, an assessment of participants’ conscious awareness (Maia & McClelland, 2004) was used in the experiment because of the suggestion that conscious awareness may facilitate Type II processing (e.g., Shea, & Frith, 2016). Furthermore, according to Evans (2007, 2010), Type II processes incorporate the algorithmic and reflective processing whereby the reflective level of processing is involved in the generation of the alternative responses and is captured through thinking disposition and individual differences. This is discussed next in relation to IGT performance.

**Thinking dispositions and IGT**

As discussed in Chapter 1, Evans and Stanovich (2013) argued that the difference between the algorithmic and the reflective processes is depicted in the measurements of individual cognitive abilities and thinking disposition. The cognitive abilities measure the ability of algorithmic mind ‘to sustain decoupled representations for purposes of inhibition of simulation’ (p.230);
whereas thinking dispositions measure reflective processes and tendencies to collect information, calibrate decision choices, think about future consequences and to weigh minuses and pluses of a situation before deciding on a choice. Individual differences and thinking dispositions in IGT are not extensively researched (e.g., Dunn et al., 2006). Individual differences during IGT performance are not well-researched. There is some evidence that associated IGT performance and sensitivity of rewards and punishment and measures of personality, behavioural activation and inhibition, neuroticism and sensation seeking (e.g., Buelow & Suhr, 2013; Carter & Pasqualini, 2004; Franken & Muris, 2005; Hooper, Luciana, Wahlstrom, Conklin & Yarger, 2008; Mardaga & Hansenne, 2012). However, research that examined the effect of thinking dispositions on IGT performance is relatively sparse. To the best of my knowledge, only one study examined thinking disposition differences on IGT (Harman, 2011). Harman used Cacioppo & Petty’s (1982) NFC test to examine people’s tendency to engage in and enjoy effortful thought during IGT performance. Harman (2011) reported that the high NFC group outperform the low NFC group, showing that performance of the healthy participants on the IGT is not optimal. Thus, different thinking dispositions and processing styles alongside often used measures of EFs could be used, to account for a non-optimal performance in a healthy population (e.g., Dunn et al., 2006; Steingroever et al., 2013). This could also provide some further insight into the effect of explicit processes on IGT and if the explicit knowledge on IGT represents an artefact of individual’s different thinking dispositions (cf Toplak et al., 2010).

Several thinking disposition measures were included in Experiment 2 to examine this notion: Epstein et al.’s (1996) REI was included because it measures different thinking dispositions (analytical and intuitive) that could be helpful in understanding IGT performance. For example, people who score high on REI are assumed to adopt the analytical thinking style and have the capability to understand intuitive style (e.g., Epstein & Pacini, 2001; Lu, 2015). Pertinent to the IGT performance, if there is a role for higher cognitive processing early in the game (e.g., Experiment 1; Simonovic et al., 2016), examination of the different thinking styles could show if the cognitive processing is related to cognitive ability or thinking disposition. This allows exploration of whether it is thinking dispositions or cognitive ability facilitate learning and guide successful IGT performance.

Similarly, the use of measures such as AOT (Haran et al., 2013) and CFC (Strathman et al., 1994) could provide closer examination of thinking disposition related to a number of attributes: the tendency to weigh new evidence against favoured beliefs, the tendency to
calibrate the degree of strength of an opinion to the degree of evidence available and the
tendency to think about future consequences before taking action. Macpherson and Stanovich,
(2007) showed that participants who score high on AOT were more likely to overcome belief-
bias reasoning task. They argued that an increase in AOT reflects a desire for more information
before making a prediction where the higher attention to information may improve estimation
performance. Similarly, Haran et al. (2013) showed that information acquisition (as measured
with AOT scale) predicts performance in an estimation task. In three studies, participants made
estimates and predictions of uncertain quantities, with varying levels of control over the amount
of information they could collect before estimating. AOT predicted a tendency to collect
information which consequently predicted performance. This is relevant to IGT performance,
because people need to pass through the exploration stage (sampling from different decks)
where higher attention to collected information may improve performance in the subsequent
exploitation stage. Equally, CFC (Strathman et al., 1994) could be related to IGT performance,
because participants need to forgo high-immediate rewards and learn to favour long-term
positive outcomes for advantageous decks. The CFC measures the extent to which individuals
consider distant outcomes when choosing their present behaviour and it has been shown that
individual differences in CFC predict a range of behaviour related to self-control (e.g.,
Joireman, Strathman, & Balliet, 2006), impulsivity and aggression (Joireman, Anderson, &
Strathman, 2003). Thus, in addition to REI, both AOT and CFC scales are included in this
chapters’ experiment to examine the effect of thinking dispositions on IGT performance.

In addition, hemodynamic measures of physiological arousal are included in this chapters’
experiment (blood pressure and heart rate variability) because of the suggestion that this could
have an effect on IGT performance (e.g., Colombetti, 2008; Steingroever et al., 2013). Research on emotion often employs different measures of autonomic arousal such as blood
pressure, heart rate and SCR during decision-making (e.g., Carter & Pasqualini, 2004; Christie
& Friedman, 2004; Crone et al., 2004; Wagar & Dixon, 2006). Most of the studies related to
IGT performance were focused on the anticipatory aspects of the physiological measurements.
However, it would be helpful to specify different dimensions of arousal and tracking their roles
according to the disadvantageous and advantageous aspects of decision-making (Colombetti,
2008). In particular, it is important to understand if general arousal differs between the IGT
Blocks and how it affects overall performance. Furthermore, one of the reasons for participants’
non-optimal performance on IGT may be sensitivity to punishments and rewards that may lead
anxiety sensitive participants to disadvantageous decision-making (e.g., Dunn et al., 2006).
Thus, in addition to hemodynamic measures of arousal, an Anxiety Sensitivity Index (ASI) was used (Reiss, et al., 1986) to examine a tendency to endorse a negative implication for anxiety on other negative implications. Meaning that people who believe that anxiety has few or no negative effects may be able to cope with a relatively high level of exposure to anxiety-provoking stimuli. In contrast, people who believe that anxiety has serious effects, tend to have anxiety reactions that grow in anticipation of severe consequences (e.g., Steinman & Teachman, 2010).

4.2. The Experiment

To the best of my knowledge, the Experiment 1, and only one published study has utilised eye-tracking that measured pupil dilation methodology during the IGT performance in a healthy population (Lavin et al., 2014). Hence the predictions made here are based on the dual-process account of decision-making and research that focuses on reasoning and decision-making. CRT1 was used as a direct measure of deliberative thinking to replicate previous findings demonstrating that the CRT1 was highly predictive of IGT performance (e.g., experiment 1; Simonovic et al., 2016). In addition, thinking disposition measures (AOT, REI, CFC and ASI) were used because the self-reported measures may provide useful insights into how participants experience their own cognitive processes and attitudes. Eye-tracking measures (inspection time) and conscious awareness measure were also included to examine explicit attentional processes. Finally, participants hemodynamic activities were measured to test whether physiological arousal affects IGT performance. The following predictions were tested:

1. The standard analysis of IGT performance across Blocks was extended as in Experiment 1 to check if IGT performance will continue to improve after Block 5.

2. It was also predicted that the correlations observed in Experiment 1 between CRT1 score and disadvantageous card selections across Blocks would be replicated such that strong correlations would be found in early Blocks because of the importance of analytic processing early in the game.

3. It was also predicted that the measures of thinking disposition should correlate with disadvantageous decks selection.

4. The focus of eye tracking measurements was on inspection time for the advantageous (C + D) and the disadvantageous (A + B) decks before making a choice. If cognitive
processing plays a role in IGT, then this should be evident in increased inspection time (e.g., Ball et al., 2003; Horstmann et al., 2009).

5. Inspection time should differ according to the nature of the decks and it should predict overall IGT performance.

6. If attentional processing plays a role in early trials it is also expected that conscious awareness of the decks emerges early in the game (e.g., after Block 2).

7. According to dual process theories, Type II processes include both, attention and conscious awareness. Hence it is expected that the conscious awareness of the game and inspection time should be related.

8. If there is arousal during the game it was predicted that the physiological measurements (blood pressure and heart rate variability measures) differ between the Blocks.

4.3. Method

Participants

Fifty healthy students from the University of Derby, aged 19-56 years, received participation points for participating in the experiment. Research was conducted in accordance with stipulations of the local ethics committee. Participants had normal or corrected to normal vision.

Materials

Iowa Gambling Task

Participants completed Bechara et al.’s (1994) computerised version of IGT. The procedure and scoring were identical to that described in Experiment 1.

CRT1

The procedure and scoring were identical to that described in Experiment 1. The Cronbach alpha in this experiment was α = .65.

Rational Experiential Inventory (REI; Epstein et al., 1996)

The ten-item REI measured rational and experiential thinking styles and processing modes with two factors: Need for Cognition (rational measure) and Faith in Intuition (experiential measure). The ten items were rated on a 5-point scale, from completely false to completely
true. Higher REI scores indicated higher analytic thinking style. An example of a question is ‘Thinking hard and for a long time about something gives me little satisfaction’. Several studies have confirmed that the REI is a reliable measure of the individual difference in information processing, and that the two independent thinking styles measures account for a substantial amount of variance that is not addressed by other personality theories (i.e. Norris, & Epstein, 2011). The Cronbach alpha in this experiment was α= .54.

**Actively Open-Minded Thinking Scale (AOT; Haran et al., 2013)**

The seven-item AOT is based on Stanovich and West’s (2007) scale and is designed to capture thinkers’ desire to be more informed before making an estimate or prediction. The focus of the scale is the tendency to maximise or satisfice when making a decision. The seven-item scale was rated on a 7-point scale, from completely disagree to completely agree. Higher AOT scores indicated a higher tendency for information acquisition before making a decision. An example of a question is ‘One should disregard evidence that conflicts with one’s established beliefs’. The Cronbach alpha in this experiment was α= .40.

**Consideration of Future Consequences (CFC; Strathman et al., 1994)**

The twelve-item CFC measured the extent to which people consider distant versus immediate consequences of potential behaviour. This may be very important for the participants engaging in the IGT, since to maximize their profit participants need to consider choice consequences (punishment/reward). The twelve-item scale was rated on a 5-point scale, from extremely uncharacteristic to extremely characteristic. Higher CFC scores indicated higher consideration of future consequences when making a decision. An example of a question is ‘I consider how things might be in the future and try to influence those things with my day to day behaviour’. The Cronbach alpha in this experiment was α= .84.

**Anxiety Sensitivity Index (ASI; Reiss et al., 1986)**

The sixteen-item ASI was used to examine participants’ concern about or fear of anxiety related symptoms. ASI measures a tendency to show exaggerated and prolonged reactions to anxiety-provoking stimuli. The sixteen-item scale was rated on a 4-point scale, from very little to very much. Higher ASI scores indicated a higher tendency to endorse a negative implication for anxiety on other negative implications. An example of a question is ‘When I cannot keep my mind on a task, I worry that I might be going crazy’. The Cronbach alpha in this experiment was α= .84.
Conscious Awareness Test

Maia and McClelland’s (2004) Test of Awareness, measures emergence of the conceptual knowledge of the decks’ contingencies. This sensitivity test encompasses 5 questions in total with question 3 having 4 additional sub questions. Three measures of knowledge are obtained for each deck: a deck rating from –10 to 10 how good or how bad decks are (Deck Rating), an estimate of the average net amount won or lost on the deck (Estimated Net) and a calculated net amount based on participants’ estimates of how much they would win, how often they lost, and how much that average loss was (Calculated Net). An example of a question related to estimated net calculation is ‘What would you expect your average net result to be?’ An example of a question related to calculated net calculation is ‘For those trials in which you would get a loss, what would you expect the average loss to be?’ The participants are also asked which deck they would choose if they only had one choice (One Deck). Participants’ levels of knowledge were arranged according to the deck’s ratings and one deck category (Level 1 knowledge) and calculated and estimated net values (Level 2 knowledge).

Eye Tracking Measurements

Eye movements were recorded with the Eye-gaze binocular system Tobii-X2-30 (Inquisit 4 milliseconds plugins), with a remote binocular sampling rate of 30 Hz and an accuracy of about 0.45°. The X2 Eye Tracker is a stand-alone eye tracker, and it was attached to a laptop (Dell, Precision M6700, 2.70Ghz). Participants were seated approximately 70 cm from the laptop monitor. The Tobii measured 184mm (7.2’’) in length and enabled tracking at close distances (up to 36° gaze angle). Fixations were identified using a fixation radius of 20 pixels and minimum fixation duration of 100ms or above. Before starting the experiment, a 9-point calibration routine was executed. Each data point was identified with a timestamp and “X,Y” coordinates, and these coordinates were processed further into fixations and overlaid on a video recording of the IGT. Choices, decision times, and basic eye-tracking parameters such as inspection time and coordinates were recorded. To avoid methodological artefacts, an eye tracking metrics were delineated through fixation filters. Non-overlapping areas of interest (AOIs) around each cell in the matrix were defined, each containing different decks during the performance. Hence, four AOIs were obtained with the size of 690 x 458 pixels for decks. For each participant and each decision, the inspection time within each AOI was calculated.

Blood Pressure Measurements
Beat-to-beat blood pressure was measured continuously via a finger monitor (Finometer; TPD Biomedical Instruments, The Netherlands). Finometer measured Mean Blood Pressure (MBP), Hear Rate (HR) and Systolic Blood Pressure (SBP) responses to check participants arousal during the IGT performance. A baseline MBP, HR and SBP measurements were taken before the initiation of tasks followed by seven MBP, HR and SBP measurements taken during the IGT performance after each Block of 20 picks. MBPR, HRR and SBPR reactivity responses were calculated by subtracting the average of the performance MBP, HR and SBP measurements from the average of resting MBP, HR and SBP measurements.

**Procedure**

Following consent, participants sat for a 5-min resting period, and then baseline hemodynamic measurements were taken. Next, the process of calibration for eye-tracking methodology was undertaken and the IGT performed. Participants were interrupted after each Block (20 trials) and the questions related to the conceptual knowledge of the game were recorded. After the completion of the IGT task post-task hemodynamic measurements were taken. The CRT1, AOT, REI, CFC and ASI were administrated and at the end participants were debriefed. Only the Conscious-Awareness test was scored on paper. The remaining tests were administered electronically.

**Analytic strategy and scoring**

Before the initiation of the analyses, data were inspected for normality by checking for outliers, Skewness and Kurtosis, normality tests and Z-scores to ensure that the assumptions of parametric statistics were met before analyses were performed. If parametric assumptions were not met the data were log transformed, corrections used, and non-parametric tests used when appropriate.

**IGT**

Standard scoring was derived by deducting total disadvantageous card picks (A + B) from total advantageous picks (C + D). A positive score suggests a more advantageous decision-making strategy, whereas a negative score suggests a disadvantageous decision-making strategy. A repeated measures ANOVA was conducted to check the IGT performance per Block. Next, bivariate correlations between the disadvantageous decks, CRT1, AOT, REI, CFC and ASI scores were examined.

**Inspection time**
Inspection time was measured in seconds. As parametric assumptions were not met a log transformation was performed to stabilize variances. Inspection time was examined across Blocks by using 2 (deck) x 7 (Block) repeated measures ANOVAs with disadvantageous (A+B) and advantageous decks (C+D) as the dependent variables. A repeated measures t-tests were used to test the deck differences between the matching Blocks. Next, multiple regression (method Enter) tested the relative predictive strength of disadvantageous (A+B) and advantageous decks (C+D) inspection time for performance on IGT.

**Conceptual Knowledge**

Conscious awareness across Blocks was also examined as follows. Five measures of knowledge were obtained for each deck at each question period: a deck rating from −10 to 10 (Deck Rating), an estimate of the average net amount won or lost on the deck (Estimated Net) and a calculated net amount based on participant estimates of how much they would win, how often they lost, and how much that average loss was (Calculated Net). The participants were also asked which deck they would choose if they only had one choice (One Deck). In the end, participants were asked to rate how confident they are in their decision (Confidence Rating). Participants’ level of conscious knowledge was then arranged according to three levels as suggested by Maia and McClelland (2004). Level 0: the participant does not have any conscious knowledge specifying a preference for one of the two best decks. Level 1: the participant has conscious knowledge specifying a preference for one of the two best decks but does not have conscious knowledge about the outcomes of the decks that could provide a basis for that preference. Level 2: the participant has conscious knowledge specifying a preference for one of the two best decks and has conscious knowledge about the outcomes of the decks that could provide a basis for that preference (Maia & McClelland, 2004, p.16076). Overall deck ratings (CD-AB) were examined to inspect Level 1 knowledge across Blocks. Next, a 2 (deck) x 2 (value) repeated measures ANOVA examined Estimated and Calculated net values between the disadvantageous (A+B) and advantageous (C+D) decks (Level 2 knowledge). Levels of conceptual knowledge (Level, 0, 1 and 2) were examined per Block by calculating the percentage of the number of the participants that reached different levels. Finally, a 2 (deck) x 3 (knowledge) repeated measures ANOVA examined inspection time of disadvantageous (A+B) and advantageous decks (C+D) across three levels of conceptual knowledge.

**Hemodynamic measures**
As parametric assumptions were not met a log transformation was performed to stabilize variances. Three separate repeated measures ANOVAs were used to determine levels of participants’ arousal (MBPR, HRR and SBPR) per Block.

4.4. Results

Performance across Blocks was tested using a Greenhouse-Geisser adjusted repeated measures ANOVA. There was a main effect of Block condition, $F(4.26,208.68)=24.33, p<.001, \eta^2_p=.33$. Means and standard deviations are shown in Table 4.4.1. Bonferroni adjusted post hoc tests demonstrated that performance improved significantly through the Blocks of trials (excluding Block 6). Notably the nonstandard additional Blocks 6 and 7 continued to show changes in performance relative to earlier Blocks such that performance dipped in Block 6, but Block 7 was significantly better than all but Block 6.

Table 4.4.1

<table>
<thead>
<tr>
<th>Trial Block</th>
<th>IGT performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block 1</td>
<td>-3.12 (7.15)</td>
</tr>
<tr>
<td>Block 2</td>
<td>1.64 (6.53)</td>
</tr>
<tr>
<td>Block 3</td>
<td>4.12 (7.04)</td>
</tr>
<tr>
<td>Block 4</td>
<td>6.28 (7.38)</td>
</tr>
<tr>
<td>Block 5</td>
<td>7.80 (8.29)</td>
</tr>
<tr>
<td>Block 6</td>
<td>5.80 (9.12)</td>
</tr>
<tr>
<td>Block 7</td>
<td>8.78 (9.93)</td>
</tr>
</tbody>
</table>

Correlations between CRT1 scores, AOT scores, ASI scores, REI scores, CFC scores and selection of disadvantageous decks were conducted with the adjusted threshold alpha ($p<.005$) to avoid potential issues related to false positives results (see Table 4.4.2). These demonstrated the significant negative relationships between CRT1 scores and disadvantageous card selections in all but the first Block of trials. The correlations between the AOT, CFC, REI, ASI scores and selection of disadvantageous decks were not significant. This indicates that cognitive ability significantly correlates with disadvantageous deck section whereas measures of thinking disposition do not.

Table 4.4.2

Correlations between Disadvantageous card selections, CRT1 score and thinking disposition measures as a function of Trial Block.
### Eye tracking Analyses

Inspection time was analysed by conducting a 2 (Decks) x 7 (Blocks) Greenhouse-Geisser adjusted repeated measures ANOVA with log-transformed data. There was a main effect of Decks F(1.00,24.00)=7.22, p=.013, $\eta_p^2=.23$. Participants spent more time inspecting advantageous decks (M=0.75, SD=0.20) than disadvantageous decks (M=0.67, SD=0.20). Means and standard deviations are shown in table 4.4.3.

#### Table 4.4.3

<table>
<thead>
<tr>
<th>Trial Block</th>
<th>Inspection Time (C+D)</th>
<th>Inspection Time (A+B)</th>
<th>Total Inspection Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block 1</td>
<td>0.71 (0.16)</td>
<td>0.84 (0.18)</td>
<td>0.78 (0.17)</td>
</tr>
<tr>
<td>Block 2</td>
<td>0.78 (0.15)</td>
<td>0.79 (0.14)</td>
<td>0.79 (0.15)</td>
</tr>
<tr>
<td>Block 3</td>
<td>0.80 (0.16)</td>
<td>0.69 (0.18)</td>
<td>0.75 (0.17)</td>
</tr>
<tr>
<td>Block 4</td>
<td>0.80 (0.14)</td>
<td>0.61 (0.23)</td>
<td>0.71 (0.18)</td>
</tr>
<tr>
<td>Block 5</td>
<td>0.76 (0.24)</td>
<td>0.64 (0.26)</td>
<td>0.70 (0.20)</td>
</tr>
<tr>
<td>Block 6</td>
<td>0.69 (0.30)</td>
<td>0.59 (0.20)</td>
<td>0.64 (0.21)</td>
</tr>
<tr>
<td>Block 7</td>
<td>0.69 (0.29)</td>
<td>0.54 (0.22)</td>
<td>0.61 (0.20)</td>
</tr>
<tr>
<td>Total</td>
<td>0.75 (0.20)</td>
<td>0.67 (0.20)</td>
<td></td>
</tr>
</tbody>
</table>

There was a main effect of Block F(2.96,70.99)=7.07, p< .001, $\eta_p^2=.22$ with inspection time decreasing after the second block. The Bonferroni adjustment was too stringent to make 21 comparisons to examine this main effect. The alpha level was therefore adjusted to p< .005 to balance concerns related to type I and type II errors. The adjusted post hoc pairwise comparisons (Table 4.4.4) demonstrated that inspection time in Blocks 1 and 2 was significantly higher than Blocks 6 and 7 (all p< .005). Inspection time in Block 3 was significantly higher than Block 6.

---

8 Note all * are significant at p = .001, and all ** are significant at p < .001
Table 4.4.4

Mean differences (SD) in Inspection Time. Pairwise comparison across Blocks

<table>
<thead>
<tr>
<th>Block 1</th>
<th>Block 2</th>
<th>Block 3</th>
<th>Block 4</th>
<th>Block 5</th>
<th>Block 6</th>
<th>Block 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block 1</td>
<td>-0.00 (.03)</td>
<td>p&gt;.005</td>
<td>.03 (.03)</td>
<td>p&gt;.005</td>
<td>.07 (.03)</td>
<td>p&gt;.005</td>
</tr>
<tr>
<td>Block 2</td>
<td>.04 (.02)</td>
<td>p&gt;.005</td>
<td>.08 (.02)</td>
<td>p&gt;.005</td>
<td>.08 (.04)</td>
<td>p&gt;.005</td>
</tr>
<tr>
<td>Block 3</td>
<td>.04 (.02)</td>
<td>p&gt;.005</td>
<td>.05 (.04)</td>
<td>p&gt;.005</td>
<td>.11 (.03)</td>
<td>p&gt;.005</td>
</tr>
<tr>
<td>Block 4</td>
<td>.00 (.04)</td>
<td>p&gt;.005</td>
<td>.07 (.02)</td>
<td>p&gt;.005</td>
<td>.06 (.04)</td>
<td>p&gt;.005</td>
</tr>
<tr>
<td>Block 5</td>
<td>.00 (.04)</td>
<td>p&gt;.005</td>
<td>.06 (.02)</td>
<td>p&gt;.005</td>
<td>.09 (.06)</td>
<td>p&gt;.005</td>
</tr>
<tr>
<td>Block 6</td>
<td>.00 (.04)</td>
<td>p&gt;.005</td>
<td>.07 (.02)</td>
<td>p&gt;.005</td>
<td>.06 (.04)</td>
<td>p&gt;.005</td>
</tr>
<tr>
<td>Block 7</td>
<td>.00 (.04)</td>
<td>p&gt;.005</td>
<td>.06 (.02)</td>
<td>p&gt;.005</td>
<td>.09 (.06)</td>
<td>p&gt;.005</td>
</tr>
</tbody>
</table>

There was an interaction between the Decks and the Blocks F(2.84,68.18)=4.81, p=.005, \( \eta^2_p=.16 \). Bonferroni adjusted independent t-tests tested the interaction between the matching Blocks (Table 4.4.5). There was a significant interaction between Blocks 1, 4, 5 and 7 of disadvantageous and advantageous decks with Block 4, 5 and 7 showing greater increase in inspection time for advantageous Blocks (Figure 4.4.1). Means and standard deviations are shown in Table 4.4.5.

Note all * significant at p <.005

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Sensitivity: Internal
**Figure 4.4.1.** Mean inspection time for disadvantageous (AB) and advantageous (CD) decks per Block. Error bars are the standard error of the mean.

**Table 4.4.5**

*Paired t tests inspection time comparison between disadvantageous and advantageous decks per matching Blocks.*

<table>
<thead>
<tr>
<th>Fixation Blocks</th>
<th>T</th>
<th>Df</th>
<th>sig(^{10})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block 1</td>
<td>3.50</td>
<td>47</td>
<td>p = .001*</td>
</tr>
<tr>
<td>Block 2</td>
<td>-0.74</td>
<td>46</td>
<td>p = .460</td>
</tr>
<tr>
<td>Block 3</td>
<td>-2.60</td>
<td>42</td>
<td>p = .013</td>
</tr>
<tr>
<td>Block 4</td>
<td>-4.86</td>
<td>44</td>
<td>p &lt; .001*</td>
</tr>
<tr>
<td>Block 5</td>
<td>-4.12</td>
<td>34</td>
<td>p &lt; .001*</td>
</tr>
<tr>
<td>Block 6</td>
<td>-2.33</td>
<td>35</td>
<td>p = .025</td>
</tr>
<tr>
<td>Block 7</td>
<td>-2.88</td>
<td>33</td>
<td>p = .007*</td>
</tr>
</tbody>
</table>

Next, a multiple regression (Enter method) tested the relative predictive strength of inspection time for disadvantageous (A + B) (Mean=0.68, SD=0.12) and advantageous (C + D) (Mean=0.76, SD=0.15) deck picks for performance on the IGT. Data indicated that both predictors combined reliably accounted for 65% of the variability in IGT scores. The standardized beta for advantageous cards showed a positive correlation with inspection time while the disadvantageous cards showed a negative correlation. This indicated that increased inspection time of advantageous decks was associated with better overall performance in contrast while increased inspection time of disadvantageous decks was associated with poorer performance (Table 4.4.6)

**Table 4.4.6**

*Multiple Regression Analysis of Inspection Time for disadvantageous (AB) and advantageous (CD) decks as predictors (standardized and unstandardized betas) of IGT performance.*

<table>
<thead>
<tr>
<th>Predictors</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model ‘Enter.’</td>
<td>(R^2=.681, R^2_{adj}=.652)</td>
</tr>
<tr>
<td></td>
<td>(F(2, 24)= 23.50, p &lt; .001)</td>
</tr>
<tr>
<td>Inspection time (A + B)</td>
<td>(B^{11}=-114.32; \beta=-.531, p=.001)</td>
</tr>
<tr>
<td>Inspection time (C + D)</td>
<td>(B=154.44; \beta=.929, p&lt;.001)</td>
</tr>
</tbody>
</table>

\(^{10}\) Note: Bonferroni adjusted significance \(p = .007^*\)

\(^{11}\) B is unstandardized beta value and \(\beta\) is standardized coefficient

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Sensitivity: Internal
**Conceptual Knowledge Analyses**

Level 1 knowledge across Blocks was tested by conducting a Greenhouse-Geisser adjusted repeated measures ANOVA. There was a main effect of Block condition, $F(3.55,173.83)=23.68$, $p<.001$, $n_p^2=.33$. Bonferroni adjusted post hoc tests demonstrated the emergence of Level 1 knowledge after the first Block (Figure 4.4.2.). Level 1 knowledge in Block 1 was significantly lower than all Blocks (all $p<.001$).

![Figure 4.4.2.](image)

**Figure 4.4.2.** Mean deck ratings (CD-AB) as a function of Trial Block. Error bars are the standard error of the mean.

Participants’ quantitative knowledge of the task was assessed using the Estimated Net and Calculated Net measures. The Estimated Net was an estimate of the average amount won or lost on the deck while the Calculated Net was calculated from participants’ estimates of how much they would win, how often they lost, and how much that average loss was when selecting from each deck.

Quantitative knowledge of disadvantageous and advantageous decks was analysed by conducting a 2 (Deck) x 2 (Net values) Greenhouse-Geisser adjusted repeated measures ANOVA. Mean and SD is shown in table 4.4.7.

**Table 4.4.7**

*Mean (SD) of the estimated and calculated net values between the advantageous (CD) and disadvantageous (AB) decks*
### Trial Block

<table>
<thead>
<tr>
<th></th>
<th>AB</th>
<th>CD</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated net</td>
<td>267.87 (321.05)</td>
<td>287.40 (224.13)</td>
<td>277.64 (275.64)</td>
</tr>
<tr>
<td>Calculated net</td>
<td>-358.91 (200.81)</td>
<td>-116.64 (83.06)</td>
<td>-237.77 (195.44)</td>
</tr>
<tr>
<td>Total</td>
<td>-45.52 (412.52)</td>
<td>85.38 (263.64)</td>
<td></td>
</tr>
</tbody>
</table>

There was a main effect of Deck F(1.00,49.00)=226.04, p<.001, $\eta^2_p=.82$, with overall higher Net values observed for the advantageous decks than the disadvantageous decks. There was a main effect of overall Net values F(1.00,49.00)=13.12, $p=.001$, $\eta^2_p=.21$, with higher Net values observed for the estimated Net than the calculated Net values. There was an interaction between the Decks and the Net values F(2.84,68.18)=4.81, $p=.005$, $\eta^2_p=.16$. There was no difference between advantageous and disadvantageous decks in estimated value, whereas calculated Net value was lower for disadvantageous decks than advantageous decks (Figure 4.4.3.).

![Figure 4.4.3](image-url)

**Figure 4.4.3.** Mean estimate and calculated net values for disadvantageous (AB) and advantageous (CD) decks. Error bars are the standard error of the mean.

Figure 4.4.4. shows levels of conscious knowledge. The participant’s conscious knowledge about the goodness of the decks and the outcome of the decks (Level 2) started to emerge from Block 2 onwards. The percentage of the participants that did not have any conscious knowledge declined from Block 1 until Block 5. The percentage of the participants’ that reached Level 1 conscious knowledge, about the goodness of the decks was constant across the Blocks except Block 2 respectively. Finally, the percentage of participants that reached the full conceptual knowledge of the game gradually increased from Block 2 onwards and reached 34% in the last Block.
Figure 4.4.4. The percentage of the participant’s conscious levels of knowledge across Blocks.

**Inspection time and Conceptual Knowledge**

Next, differences between the inspection times of the disadvantageous/advantageous decks across different levels of conceptual knowledge was tested.

Mean decks inspection time during the different levels of conscious knowledge was analysed by conducting a 2 (Decks) x 3 (Level of Knowledge) repeated measures ANOVA with log-transformed data. Means and standard deviations are shown in Table 4.4.8.

**Table 4.4.8**

*Means (SD) of levels of knowledge for disadvantageous (AB) and advantageous (CD) decks*

<table>
<thead>
<tr>
<th>Decks</th>
<th>Level 0 Knowledge</th>
<th>Level 1 Knowledge</th>
<th>Level 2 Knowledge</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB</td>
<td>1.25 (1.10)</td>
<td>1.63 (1.06)</td>
<td>1.78 (1.53)</td>
<td>1.56 (0.23)</td>
</tr>
<tr>
<td>CD</td>
<td>1.01 (0.88)</td>
<td>2.35 (1.68)</td>
<td>4.44 (2.55)</td>
<td>2.60 (1.72)</td>
</tr>
<tr>
<td>Total</td>
<td>1.13 (0.17)</td>
<td>1.99 (0.51)</td>
<td>3.12 (1.87)</td>
<td></td>
</tr>
</tbody>
</table>

There was a main effect of Deck F(1.00,16.00)=12.66, p=.003, $\eta_p^2=.44$ with greater inspection time observed for advantageous decks than disadvantageous decks.

There was a main effect of Knowledge F(2.00,32.00)=7.99, p=.002, $\eta_p^2=.33$. The inspection time increased at different levels of knowledge. Bonferroni adjusted post hoc tests demonstrated greater inspection time during Level 2 knowledge compared to the inspection time during the Level 1 knowledge (p<.001). There were no other significant differences.

There was an interaction between deck inspection time and inspection time during different Levels of knowledge F(2.00,32.00)=23.42, p<.001, $\eta_p^2=.59$. Bonferroni adjusted post hoc tests
demonstrated that inspection time during the Levels 1 and 2 of conscious knowledge was greater for the advantageous decks compared to the disadvantageous decks. There was also a greater deck inspection time between the Levels 1 and 2 of conscious knowledge for advantageous decks compared to the disadvantageous decks (Figure 4.4.5).

**Figure 4.4.5.** Mean inspection time interaction with levels of knowledge for disadvantageous (AB) and advantageous (CD) decks. Error bars are the standard error of the mean.

**Blood Pressure Analyses**

MBPR HRR and SBPR were tested across Blocks to examine participants’ arousal during the game. MBPR per Block was tested by using a repeated measures ANOVA. The MBPR differences between the Blocks were not significant ($F(6.00,36.00)=.90$, $p=.50$). Similarly, HRR per Block was tested by using a repeated measures ANOVA. The HRR differences per Block were not significant. SBPR was also tested by using a Greenhouse-Geisser adjusted repeated measures ANOVA. Although the results indicated a significant effect of Blocks, ($F(3.78,185.26)=3.48$, $p=.010$), Bonferroni adjusted post hoc demonstrated that the differences per Block were not significant (all $p>.05$, Figure 4.4.6).
4.5. Discussion

The results from Experiment 2 demonstrated several significant results that are first summarised and then discussed in turns. Consistent with the first prediction, the Block performance analysis demonstrated that IGT performance did not reach ceiling at Block 5 and significantly improved in Block 7 after a non-significant dip in Block 6. The second prediction was partially supported. Correlations between CRT1 scores and IGT broadly replicated the findings from the control group in Simonovic et al., (2016) and the performance in healthy participants in Experiment 1 (Simonovic et al., 2017) with moderate correlations and evidence that reflective processing is implicated early in the task (after the first trial). This is in line with Brevers et al.’s. (2013) dual process account and represents unambiguous evidence of the Type II processing. In contrast to the third prediction related to thinking dispositions, correlations between measures of thinking disposition and IGT were not significant. This suggested that self-reported measures of how participants experienced their own cognitive processes did not correspond with their actual cognitive ability. The forth and the fifth predictions are also supported: Attentional focus differed between the decks whereby different inspection time indicated that both disadvantageous and advantageous decks are processed according to the ‘goodness’ and the ‘badness’ of the decks. Longer inspection time of the disadvantageous decks was observed in the first two Blocks and declined significantly after Block three while inspection time of the advantageous decks showed a slow increase from Block 1 until Block 4. A significant interaction between the decks was observed after Block 4 indicating longer inspection time of the advantageous decks. This is important because it showed that increased cognitive processing of the disadvantageous decks occurred from the beginning of the game.
but significantly declined after Block three, thus indicating less cognitive processing which is not sufficient for the deck's contingencies disambiguation. Inspection time for both decks were reliable significant predictors of IGT performance. Specifically, increased inspection time of advantageous decks predicted better overall performance, whereas inspection time of disadvantageous decks predicted poorer overall performance. This is also important because it is a clear indicator that increased inspection time of disadvantageous decks will increase the likelihood of the bad deck selection.

In terms of Maia and McCleland's (2004) measures of conscious awareness, consistent with the prediction 6, participants' knowledge of the game was evident in the second Block. Participants could specify a preference for the good decks after the first Block, that is, they reached Level 1 of conceptual knowledge. The emergence of Level 2 conceptual knowledge occurred after the second Block for some participants, who were able to express conscious knowledge about the net outcomes of the decks and choose one of the advantageous decks as their final pick until the end of the game. A good proportion of the participants initially reported no knowledge of the game albeit this gradually increased and reached ceiling at the end of the game. However, it must be noted that some participants (30%) reported no knowledge after the final Block. Overall net value was higher for the advantageous decks than disadvantageous decks. Higher net values were observed for the estimated net than the calculated net values. The interaction shows that while there was no difference in estimated net values between the decks, there were however, differences in calculated net value such that net value was lower for disadvantageous decks than advantageous decks. This indicated that participants struggle to calculate the average amount won or lost on the bad decks and this may be one of the reasons why participants often engage in risk-taking behaviour (e.g., Dunn et al., Fernie & Tunney, 2013). There was also a greater contrast between estimated and calculated values for bad decks than there are for good decks.

Prediction 7 is also supported. The results indicated that there is a close interplay between the attentional processing and conscious awareness. Overall, Level 2 of conceptual knowledge was associated with greater inspection time than Levels 0 and 1 respectively. Furthermore, greater inspection time was related to the advantageous decks on Levels 1 and 2 of conceptual knowledge comparing to the disadvantageous decks. This indicated that even though participants were aware that the disadvantageous decks are ‘bad’ they neglected to attentionally focus on the information.
Finally, prediction 8 was not supported; the results showed no effect of arousal on IGT as manifested by physiological measurements. The MBPR and the HRR differences between the Blocks were not significant. Overall SBPR results were significant, but the differences between the Block were not significant. This suggested that physiological arousal does not have an effect on IGT performance.

**Results implications**

The results are in line with previous research about the active role of attentional processing in constructing decision choices (e.g., Horstmann et al., 2009; Glaholt, & Reingold, 2011; Glockner, & Herbold, 2011; Krajbich et al., 2010; Krajbich et al., 2012). Specifically, the results support previous research that increased inspection time is related to increased cognitive processing (e.g., Ball et al., 2006; Evans & Ball, 2010; Horstmann et al., 2009; Glockner, 2007; Glockner, & Betsch, 2008; Glockner, & Herbold, 2008; Glockner, & Herbold, 2011). Most participants began the task by exploring disadvantageous decks, because they yielded substantially significant gains, and this was related to increased inspection time. After approximately the second Block feedback from encountered losses for ‘bad’ decks required a shift in strategy and a switch in decision choices. That is, participants learned to avoid the bad decks and shifted towards the more advantageous decks. This was evident in the increased inspection time of the advantageous decks. Meaning, participants cognitive processing of the advantageous decks increased the likelihood of the good cards selection. This is contrary to the SMH prediction that increased processing of the disadvantageous decks occurs later in the game and as a result of somatic markers biasing signals (e.g., Bechara et al., 1994, 1997, 2000).

The results are more in line with suggestion that Type II processes are involved in gathering information about the task that leads to learning about the multiple outcomes of decision choices and subsequently development of the decision-making strategy (e.g., Horstmann et al., 2009; Glaholt, & Reingold, 2011; Glockner, & Herbold, 2011).

Indeed, the results are in line with research evidence that a specific strategy related to the task is needed for information integration and learning, and reflection on the previous choices is needed for an optimal choice formation (Horstmann et al., 2009; Glockner, 2007; Glockner, & Herbold, 2011). However, attentional processing is necessary to initiate information collection on IGT, but it is likely that supplementary analytical processes are needed for information integration or inhibition of the previously learned ‘bad’ and ‘good’ information. This could explain significant correlations between the CRT1 and disadvantageous decks early in the
game. This supports Brevers et al.’s (2013) argument that emphasises the importance of the ‘cool’, reflective processes in information integration. However, contrary to Brevers et al.’s suggestion that the reflective processes account for IGT performance in the later Blocks, the results indicated that reflective processes arise early in the game. The evidence from the correlations between CRT1 and performance across Blocks indicated a consistent role for analytic ability in determining IGT performance after the first Block. This further indicates that explicit monitoring of deck contingencies appears early, and it is consistent with the proposition that the learning on the task is explicit (e.g., Bowman et al., 2005; Simonovic et al., 2016). Furthermore, observed correlations between the CRT1 and IGT performance in this experiment and Experiment 1 suggest that analytic ability is needed early in IGT for optimal performance (e.g., the ability to estimate and calculate gains and losses). Taken together the evidence showed the involvement of Type II processes early in the game indicating that cognitive processing guides IGT learning and performance. This is further supported by measures of conceptual knowledge.

Sufficient knowledge to guide advantageous long-term choices emerged for the majority of the participants after the first Block. Average deck ratings indicated that participants’ conceptual knowledge about the decks emerged after the second Block of trials. This is consistent with previous research that challenged SMH’s suggestion that conscious awareness of the game appears late in the game (Bowman et al., 2005, Evans et al., 2005; Fernie & Tunney, 2006, 2013; Maia & McClelland, 2004, 2005). Hence, the results are contrary to the suggestion that somatic markers reinforce learning early in the IGT (ambiguous stage) while the later stages of the task are informed by conscious knowledge and higher cognitive processes (e.g., Brand et al., 2007). Participant’s conceptual knowledge about the goodness of the decks and the outcome of the decks (Level 2) started to emerge from Block two onwards. This indicated that the conceptual knowledge related to the deck’s net value was available and participants were able to express conscious knowledge about the net outcomes of the decks. However, there is a possibility that participants’ Level 2 knowledge did not reach ceiling as shown by the inconsistencies in the estimated and calculated values computations. Participants were not able to accurately calculate the amount of money won, the amount of money lost and the amount of average loss during the game. This raises the possibility that participants’ calculations are mostly incorrect and for that reason, they are not able to retain conceptual knowledge about the calculated net values of the decks (e.g., Fernie & Tunney, 2013).
Indeed, only seventeen participants developed a full conceptual knowledge (Level 2) that emerged after the second Block and gradually increased until the last Block. The analysis of attentional processing and levels of knowledge on the sample of the participants that reached full conceptual knowledge showed overall increased inspection time of the advantageous decks from no knowledge (Level 0) to full conceptual knowledge (Level 2). Similar increases in inspection time were observed for disadvantageous decks. However, greater inspection time for advantageous decks was observed on the conceptual knowledge 0 and 2. This suggests a lack of cognitive processing of the disadvantageous decks and a possibility that even if the participants reach full conceptual knowledge level, participants’ knowledge was not fully complete. This could also indicate that attentional processing and conceptual knowledge is not sufficient to guide behaviour on the disadvantageous decks because a specific cognitive ability is required that will enable net outcome calculation. However, this notion is not directly tested in the experiment and remains to be examined. Nevertheless, this suggestion is in line with research that indicated that full conceptual knowledge involves awareness of the reward/punishment schedule where a specific cognitive ability is needed (e.g., WM capacity, analytic thinking, inhibitory capacity) to augment optimal performance and decks’ disambiguation (e.g., Bowman et al., 2005; Fellows, & Farah, 2003; Hornak et al., 2004; Turnbull et al., 2003).

A lack of correlation between the thinking dispositions and IGT performance indicated that the chosen measures are not related to IGT performance. Toplak et al. (2010) review suggested that since the performance on IGT is relatively independent from a cognitive ability that thinking disposition or cognitive style measures could provide a good measurement of cognitive reflective processes during the IGT performance. Toplak et al. further argued that impaired performance on IGT may be attributable to problems in Type I processes and cognitive reflective processes related to the thinking dispositions. The results from this experiment did not provide support for this argument. Instead, the results indicated that cognitive ability (as measured with CRT1) independently correlated with IGT performance thus supporting an argument that optimal IGT performance depends on individuals’ cognitive abilities (Buelow & Suhr, 2009).

Thus, the results from this experiment support the argument that there is an important role for Type II processes in deck contingences disambiguation. In this chapter, the locus of explicit attention, cognitive reflection and conscious awareness were examined as potentially important explanatory mechanisms of the Type II processes that may be implicated in learning IGT. The
results indicated that: (i) an increase in cognitive processing occurs early in the game and it differs according to the nature of the decks; (ii) similarly cognitive ability is important early in the game and it is related to disadvantageous deck’s disambiguation; (iii) conceptual knowledge is evident early in the game and it interacts with attentional processing. Thus, it could be argued that attentional processing advances conscious awareness and informs cognitive processes that facilitate learning of the task. Measures of thinking disposition were not related to learning of the disadvantageous decks’ contingencies; and physiological arousal had no effect on IGT performance. Bechara et al. (2005) argued that physiological arousal integral to the task may be beneficial compared to the physiological arousal that is not integral to the task (e.g., stress). Hence, stress can have a serious impact on the quality of decision-making. Simonovic et al. (2016) showed that stress impedes analytic thinking and disrupts learning of the task. The next chapter extends on this finding and examines the locus of explicit attention, cognitive reflection and conscious awareness under stress.
Chapter 5

Overview

This chapter addresses objective (iv) of the Thesis and details the third experiment that examines the effect of stress on attentional processing, conscious awareness and analytic thinking during the IGT. The chapter also details a systematic review which was conducted by using the PSYCHinfo and PSYCHarticles database following a strict methodological process in order to select relevant articles related to the use of IGT under stressful conditions. As discussed in Chapter 4 attentional processing, conscious awareness and analytic ability may play a more significant role early in the IGT than was previously suggested. This challenges the basic premises of SMH that unconscious biasing signals guide successful decision-making on IGT. Previous research that investigated the impact of stress on IGT has shown that stress can interfere with the learning process and increase disadvantageous card selection (e.g., Preston et al., 2007; Simonovic et al., 2016; van den Bos, Hartevelde, & Stoops, 2009). According to the SMH, emotions act as mediators between the environmental input and decision-making choices whereby stress amplified emotion interferes with learning and optimal decision-making (Reimann & Bechara 2010). Specifically, stress amplified emotion generates dysfunctional strategy during decision-making that is influenced by altered feedback of the reward and punishment processing (e.g., Starcke, Wolf, Markowitsch, & Brand, 2008). However, stress also results in limited attentional processing, reductions in executive functioning and as a result may limit cognitive resources that prompt dysfunctional strategy and inhibits learning during decision-making (e.g., Kassam, Koslov & Mendes, 2009; Simonovic et al., 2016). This challenges the SMH assumption that stress interferes with the development of somatic markers that are necessary for optimal IGT performance and instead suggests that stress affects analytic ability and shifts cognitive processes away from deliberative processing towards more automatic processing. Thus, it is important to investigate the effect of stress on cognitive processes that are involved in learning and IGT performance to explore this alternative explanation. The experiment in this chapter aims to extend Simonovic et al.’s (2016) findings related to the effect of stress on analytic processing on IGT performance. Thus, in addition to a stress manipulation replication, the extended version of CRT (CRT1, Toplak et al., 2014) was used; as was eye-tracking methodology as a measure of attentional processing; and conscious awareness test to measure cognitive penetrability of IGT. To my knowledge, this is the first experiment that examined the effect of stress on attentional
processing and conscious awareness (e.g., Maia & McClelland, 2004) during IGT performance. Blood pressure and heart rate responses to stress were examined for manipulation check.

5.1. Introduction

Stress is a significant factor that influences our daily lives. Stress arises in uncontrollable situations and epitomises a mental tension resulting from the presence of a stressor that results in a compensatory psychological and physiological response (Lovallo, 2016). Stress activates the sympathetic nervous system (SNS) and hypothalamus-pituitary-adrenal (HPA) axis (e.g., Kudielka, & Kirschbaum, 2007). The adrenal hormone cortisol indicates the activity of the HPA axis, while blood pressure and heart rate can be taken as a proxy for sympathetic activity. Research on stress emphasizes the prevalence of multiple interacting mediators that can have a severe effect on wear and tear of the brain and the body if adaptation to the demands of a situation does not occur (McEwen, 2007). Thus, inability to adapt to the demands is a large part of allostatic load/overload, where allostasis signifies the process of achieving stability through alteration of physiological output (e.g., McEwen, 2008). Furthermore, stress may lead to changes in brain regions such as PFC, amygdala and hippocampus that consequently hinder cognitive, emotional and memory processing (e.g., McEwen &. Morrison, 2013; Roman et al., 2005; Wender et al., 2000). Thus, stress may induce a far-reaching, potentially maladaptive consequences, which affect not only brain structure but also health.

According to Bechara (2004), in an ambiguous decision-making situation (high uncertainty with unknown probabilities), people are more likely to rely on intuitive ‘gut' feelings. The intuitive ‘gut feelings’ may be used as information source guiding decisions through inferred values (Bechara, 2004; Pham, 2004). This view corresponds with the SMH (see Chapter 2 for a review), whereby it is assumed that the experience of decision-making induces emotional responses that match with particular somatic states (Damasio, 1996). According to the SMH, the connection between the processing of the somatic markers and decision-making can be interrupted by stress (e.g., Reimann & Bechara, 2010). For example, a stressor may have an impact on emotional resources, whereby the inhibition of the emotional learning disrupts consistent tasks performance (e.g., Bechara et al., 2000). IGT studies have shown that stress can interfere with the learning process in healthy controls, increase risk-taking behaviour and lead to disadvantageous card selections (Miu, Heilman, & Houser, 2008; Preston et al., 2007; Robinson, Bond, & Roiser, 2015; Simonovic et al., 2016; Starcke, Agorku, & Brand, 2017; van den Bos et al., 2009). While some evidence indicates that stress is emotion-mediated and
reduces learning from somatic markers feedback thus providing support for the SMH (e.g., Starcke et al., 2017), other evidence pointed out that this disruption of the development of the somatic markers may have been because of the reduction in higher order cognitive processes (e.g., Preston et al., 2007; Simonovic et al., 2016). This evidence is not conclusive and warrants further investigation especially in the healthy population. Thus, the purpose of the current review was to evaluate the empirical studies that used Bechara et al.’s (1994) IGT and psychological stressors as variables that may influence decision-making. The review is focused on the use of IGT in stressful conditions in a healthy population.

5.2. Review methods

Studies were identified by literature research using the electronic databases such as: PsycINFO, PsycARTICLES, EBSCO Electronic Journals Service, Ovid, PubMed, Elsevier Science Direct and Google Scholar. Since this review was only concerned with the performance on IGT under stressful conditions, the focus was narrow. Electronic database searches yielded 6,761 (IGT), 623,850 (Stress), (88,439) Cognition and Emotion. These results were combined generating 179 study titles that were then filtered with key words such as ‘stress’, ‘stressors’, ‘anticipatory stress’, ‘anticipated stress’, ‘affect’, ‘emotions’, ‘uncertainty’, ‘decision-making’ and ‘cognition’; the search process summarized in Figure 5.2.1. This narrowed down the results to 19 studies. Since the inclusion criteria were strict and only involved studies that manipulated stress in healthy people and used IGT as a performance measurement, the screening and reading of relevant titles and abstracts narrowed down the results to seven studies included for the purposes of this review. Therefore 12 studies were excluded for the following reasons: participants with addictive behaviour (N=3), participants with severe cognitive and emotional impairment due to brain lesions (N=5), depressed and anxious participants and participants with any disabilities (N=4). In total, 7 studies were included in the review (Table 5.2.1.).
Figure 5.2.1. CONSORT diagram - Overview of the search process, identification of studies and data extraction

Table 5.2.1

Review findings

<table>
<thead>
<tr>
<th>Study ID and references</th>
<th>Sample size and design</th>
<th>Measures and Stress exposure</th>
<th>Main Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cella et al. (2007)</td>
<td>N=75; Male (N=23); Female (N=52). Undergraduate students; Three groups of participants (N=25). Group allocation not specified.</td>
<td>Stress in the form of time constraint of 2 seconds and 4 seconds for two groups. Bechara et al. (2000) computerised version of the IGT</td>
<td>Time constraints of 2 (group I) and 4 seconds (group II) had an impact on learning and significantly disrupted performance on IGT. Group I had the worst performance comparing to control and group 2.</td>
</tr>
<tr>
<td>Preston et al., (2007)</td>
<td>N=40; 20 Male and 20 Female students Two groups of participants (N=20). Participants</td>
<td>Anticipated speech as a stressor. The State-Trait Anxiety Inventory, the Positive and Negative Affect</td>
<td>The experimental group had greater increases in heart rate from the speech anticipation stress than the control group. The</td>
</tr>
<tr>
<td>Study</td>
<td>Participants</td>
<td>Task/Procedure</td>
<td>Findings</td>
</tr>
<tr>
<td>-------------------------------</td>
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</tr>
<tr>
<td>Santos-Ruiz et al. (2012)</td>
<td>N=40; Female students, professors, or administrative personnel. Two groups of participants (N=24) (N=16). Participants randomly allocated to groups.</td>
<td>Trier Social Stress Test adapted for a Virtual Reality Environment — TSST (VR). The Symptom Checklist SCL-90-R, the Positive and Negative Affect Schedule and computerised Iowa Gambling Task (Bechara et al., 1994). Cortisol level measurements.</td>
<td>Stress manipulation worked. Cortisol levels were significantly higher in the group with poor performance on the IGT.</td>
</tr>
<tr>
<td>Simonovic et al. (2016)</td>
<td>N=60; 29 Male and 31 Female students. Two groups of participants (N=30). Participants randomly allocated to groups.</td>
<td>Bechara et al. (1994) non-computerised version of the IGT. A modified version of Preston et al.’s (2007) anticipatory speech task. Self-assessed stress perception. Blood pressure measurements</td>
<td>The stress manipulation reduced participants’ reflective ability. The stress manipulation indirectly affected IGT scores by reducing cognitive reflection but did not have a direct effect.</td>
</tr>
<tr>
<td>Starcke, et al. (2017)</td>
<td>N=54; Undergraduate students. Gender not specified. Group numbers and allocation not specified.</td>
<td>Unsolvable anagrams as stressors. Bechara et al. (2000) computerised version of the IGT. Self-measurements of current Affect and measurements of personality used.</td>
<td>The exposure to an unsolvable anagram task led to a decrease in decision-making performance in the IGT.</td>
</tr>
<tr>
<td>van den Bos, et al. (2009)</td>
<td>N=71; 33 Male and 38 Female students. Two groups for gender comparison.</td>
<td>The TSST; cortisol level measured after stress induction. The computerised Iowa Gambling Task (Bechara et al., 1994). Cortisol level measurements.</td>
<td>High cortisol level related to poorer performance in male’s participants. Slightly elevated cortisol level lead to good performance in female’s participants</td>
</tr>
<tr>
<td>Wemm, &amp; Wulfert, (2017)</td>
<td>N= 56; 24 Male and 32 Female students; Group numbers and allocation not specified</td>
<td>The TSST; SCR and heart rate measured; Bechara et al. (2000) computerised version of the IGT</td>
<td>Participants in stress condition showed significant stress-induced increases in physiological arousal (HR and SCR) as well as negative affect. The stressed group made less advantageous decisions.</td>
</tr>
</tbody>
</table>

### 5.3. Review results

All but one study reviewed here recruited students as participants. Santos-Ruiz et al. (2012) recruited University personnel. Most of the studies used both males and female’s participants except one study that used only female participants (Santos-Ruiz et al., 2012). The differences in sample size were moderate ranging from 40 (Preston et al., 2007; Santos-Ruiz et al., 2012).
to 75 participants (Cella et al., 2007). The studies also used distinct types of stressors such as anticipatory speech (Preston et al., 2007; Simonovic et al., 2016); the TSST (Kirschbaum, et al., 1993) (Santos-Ruiz et al., 2012; van den Bos et al., 2009; Wemm, & Wulfert, 2017); time constraint (Cella et al., 2007); and unsolvable anagrams (Starcke et al., 2017). Some of the studies related an increase in heart rate variability to poor learning and less advantageous choices on IGT (Preston et al., 2007; Wemm, & Wulfert, 2017). Similarly, some studies associated higher cortisol level with poor performance (Santos-Ruiz et al., 2012) albeit only in males (van den Boss et al., 2009). The effect of time is identified as important by one study (Cella et al., 2007). Cella et al. showed that time constraints could significantly interrupt IGT performance, but it does not affect subjective experience ratings of the decks. The review results also indicate that cognitive abilities play a role in the IGT during the early trials (Simonovic et al., 2016) and later trials (Starcke et al., 2017).

Several studies presented evidence that stress can affect learning and subsequent performance on IGT (Preston et al., 2007; Simonovic et al., 2016; Starcke et al., 2017; Wemm, & Wulfert, 2017). However, there was a disagreement between the studies about the nature of the learning effect and performance during Block trials. Starcke et al., (2017) argued that the early trials of the IGT depend on emotional feedback processing, as evidenced by the performance of the control group in their study. It is evident that the participants in the experimental group (who were stressed by being presented with unsolvable anagrams) showed delayed preferences for advantageous decks. However, a claim that early trials relate to emotional feedback processing is questionable. Firstly, interactions between the groups, the Block trials and the decks were not significant which indicate that the learning curve between the groups is not different. Secondly, the experimental group may have had experienced reduced cognitive abilities in early trials, and that may be the reason for poor performance in earlier Blocks. Indeed, Simonovic et al., (2016) showed that reflective thinking may be important earlier in the game than previously suggested. The overall correlations reported in Simonovic et al.’s (2016) study suggest that reduced reflective thinking in the experimental group leads to more disadvantageous deck’s selection by Block four, while the control group had reached ceiling for most of the participants. Furthermore, the effect of stress on overall IGT performance developed through the diminished capacity for reflective thinking thus indicating an indirect effect of analytic thinking on IGT performance through stress. Although, the findings from the study were not robust, this challenge the primacy of emotion feedback learning in early trials (cf. Bechara et al., 2000).
Simonovic et al.’s (2016) study was a replication with the extension of Preston et al.’s (2007) study that induced stress by informing participants that they would deliver a speech while being videotaped and evaluated. Preston et al. (2007) demonstrated that stressed participants showed a slower learning curve on the IGT than the control group. Their results were interpreted as evidence that incidental anticipatory stress interfered with the development of somatic markers and that this may have been because of a disruption of WM (Hinson et al., 2002). Furthermore, Preston et al. (2007) suggested that the anticipatory stress shifts cognitive processes away from deliberative processing towards more automatic processing, thus impairing the ability to differentiate between the advantageous and disadvantageous choices. However, this assumption was not tested directly. Nevertheless, both Preston et al. and Simonovic et al. showed that stress impairs IGT performance by reducing deliberative thinking ability during learning to ascertain the cost and benefits of decision-making. Furthermore, the results from these studies resonate with previous research suggesting that stress reduces cognitive capacity and consequently diminishes learning of negative choices (Lighthall, Mather, & Gorlick, 2009; Petzold, Plessow, Goschke, & Kirschbaum, 2011). Nevertheless, it is difficult to rule out the possibility that stress can impair emotional feedback learning and the development of somatic markers necessary for good IGT performance. The reduced cognitive processing may be related to IGT performance, but it does not allow us to make casual claims. It could be that stress impairs the development of somatic markers and feedback learning to the extent that cognitive processing could not integrate prior consequences (from feedback) into the goal-pursuing decision-making process.

The hemodynamic measurements (cortisol, heart rate and blood pressure variability) taken in the reviewed studies indicate that stress induced physiological arousal may disrupt emotion-based learning, impede analytic thinking and interfere with learning and performance on the IGT. The results also show that reflective thinking and arousal may help participants learn from the outcome of their choices even when stressed (e.g., Santos-Ruiz et al., 2012; Simonovic et al., 2016). However, it is unclear if the cognitive abilities are responsible for the relatively poor or reliable performance in early or later trials on the IGT. It may be that stress disrupts learning by interfering with the creation of somatic markers. Conversely, it may also be that stress disrupts learning by affecting analytic cognition and conscious awareness thus reducing the cognitive capacity for Type II cognitive processing. To understand the factors that determine the early influence of deliberative thinking on IGT performance, one possibility is to investigate the attentional processing by using eye-tracking methodology (as used in Chapter
4). Such an investigation may explain the learning process and how attentional processing and control under stress affect IGT performance.

**Attention under stress**

According to dual-process approaches stressful conditions interfere with Type II processes and prompts processing of a choice to fall back to automatic processes with increased risk-taking behaviour (e.g., Coates & Herbert, 2008; Cueva et al., 2015; Porcelli, & Delgado, 2009). According to this approach, stress is mediated by the cognitive processes that have an effect on decision-making (e.g., Balleine & O'Doherty, 2010). These processes depend on the PFC functioning. By contrast the SMH posits that stress is mediated by emotion-feedback parasympathetic activity that depends on VMpfc functioning (e.g., Santos-Ruiz et al., 2012). According to this view, people learn emotion-feedback response relation regardless of outcomes. For example, high stress reactivity on IGT could be mediated by the increase in cortisol level that enhances risk-taking behaviour (e.g., van den Bos et al., 2009; Santos-Ruiz et al., 2012). However, stress also interferes with cognitive processes and increases risk-taking behaviour (Porcelli & Delgado, 2009). Porcelli and Delgado used a financial decision-making task combined with cold pressor test induced stress to examine the effect of acute stress on financial decision-making. Participants had to select between two potentially negative outcomes (loss domain) or two potentially positive outcomes (gain domain) of equal expected values but varied probability, either under normal or stressful conditions. They found that the stress condition altered decision-making by increasing risk taking. Participants in the stress condition made more risky choices in the loss domain but conservative choices in the gain domain, thus indicating that stress is mediated through decreased cognitive processing that leads to activation of automatic responses. This is in line with von Helversen and Rieskamp’s (2013) results, who conducted a study that examined the effect of stress on risk-taking on a financial decision-making task. Participants were exposed to a cold pressor task and underwent a task where they needed to make 40 choices between two gambles while inspection time (eyetracking) was measured. The gambles differed in probability of win/lose 60 times (High outcome gambles) and win/lose 30 times (Low outcome gamble). Their results showed greater inspection time to losses in the high outcome gamble, which indicated that stress increases risk taking in the loss domain but decreases risk taking in the gain domain. Thus, although is possible that stress is mediated though the emotional responses, it is also likely that stress mediation occurs through the reduced cognitive processing that activates automatic, Type I processes and possibly risk-taking behaviour.
Conversely, Pabst, Brand, and Wolf (2013) showed that this explanation warrants further investigation. Pabst et al., examined the performance of two different experimental groups that underwent the TSST and performed a modified version of the GDT. In the original GDT the goal is to maximize a starting capital of virtual money by choosing among different alternatives that consist of different combinations of dice. In the modified version the monetary amounts of gains and losses were adjusted to ensure equal increases in expected values with increasing winning and losing probabilities in gain and loss domain. Pabst et al. found that stress did not increase risk-taking behaviour in the gain domain. However, contrary to Porcelli and Delgado’s (2009) study, stressed participant in the loss domain made less risky decisions compared to controls. Taken together these results indicate that under stress, automatic processes could promote risk-avoidance and good decision-making strategy; and diminished cognitive control that results from a shift in higher cognitive to lower processing may increase risk-taking behaviour. However, the exact nature and the conditions under which stress influences risk-taking needs better understanding. For example, under stress, intuitive gut feelings may hijack or bypass the examination of Type II processes and have a direct effect on decision outcome by increasing risk-taking behaviour (Arnsten, 2009). This is consistent with the idea that stress impairs certain parts of the prefrontal cortex (related to cognitive abilities and attention control) and engages attentional control through the amygdala, thus leading to potentially unexamined, erroneous responses that would not necessarily promote risk-taking behaviour (e.g., Keinan, 1987). Thus, attentional control may be the key mechanism that needs to be examined under stress, because it is involved in the maintenance of choices direction that is affected by the task-irrelevant stimuli (Eysenck et al., 2007).

The role of attention has been acknowledged in dual-processes theories of decision-making (Dijksterhuis, Bos, Nordgren, & van Baaren, 2006). It has been found that stress heightens attentional control to mostly negative choices and increases the likelihood of the adverse preferences, even though the risk is none existent (e.g., Sapolsky, 2000). Similarly, poorer learning from punishments is also associated with stress (Cavanagh, Frank, & Allen, 2011). Cavanagh et al. induced the social stress manipulation on participants that engaged in the probabilistic learning tasks. Cavanagh et al. measured heart rate variability and cortico-striatal monitoring systems reaction. Their results indicated that stress increases attentional sensitivity for rewards and punishments, where the poor learning rate was associated with participants sensitivity to rewards and punishments. This is line with research that showed increased attention towards negative decisions that potentiate a lack of capacity for attentional
disengagement from negative choices (e.g., Ononaiye, Turpin, & Reidy, 2007; Sposari & Rapee, 2007; Sapolsky, 2000). This could be pertinent to IGT performance under stress and may explain participants’ tendency to persistently select cards from the disadvantageous decks because they are unable to disengage from negative choices and learn from the negative feedback (cf. Starcke et al., 2017). This coincides with evidence that stress reduces learning from negative feedback (e.g., Petzold et al., 2011). Petzold et al. examined learning on the probabilistic selection task after the TSST induction. Participants in the control condition used more negative feedback for learning compared to stress conditions where participants in the stress group discounted the negative feedback in favour of positive feedback. However, the positive feedback during the TSST in this study was negligible, and participants mainly relied on the negative feedback. This raises a possibility that observed effects in this study may be due the nature of the test used. Nevertheless, taken together the evidence indicate that attentional processing may be sensitive to rewards and punishments, whereby an increase in sensitivity to punishments may affect cognitive capacity for learning and optimal decision-making.

Recently some studies have employed an eye-tracking methodology to measure performance under stress (Caseras, Garner, Bradley, Mogg, 2007; Chen & Lee, 2015; Pieters & Warlop, 1999; Sanchez, Vazquez, Marker, LeMoult, & Joorman, 2013; van Herpen & Trijp, 2011). It has been suggested that time pressure increases demand on cognitive functions leading to higher inspection time but also reduces the amount of fixated information (e.g., Pieters & Warlop, 1999). The general theme that emerges from these studies is that stress reduces decision accuracy by increasing demand on attention and cognitive processes. Although it is possible that stress leads to a greater cognitive demand, it is also likely that stress enhances the effect of emotional stimuli that disrupts cognitive processing of negative material and increases the difficulty in attentional disengagement (e.g., Compton, 2000; Grillon et al., 2016; Sanchez et al., 2013). For example, Compton (2000), showed that a reduced ability to disengage attention was associated with increased emotional reactivity to a distressing film clip. Similarly, the impairment in cognitive control was related to greater inspection time of negative stimuli and associated with attentional disengagement in depressed individuals (e.g., Caseras et al., 2007; Sanchez et al., 2013). However, in certain condition stress can enhance learning because it shifts attention to potentially relevant stimuli (Herten, Otto, & Wolf, 2017). Herten et al. used the TSST and tested participants’ free recall on tasks involving the objects presented the day before. Stressed participants showed enhanced memory for central objects,
accompanied by longer inspection times and larger fixation amounts on these objects. This suggests that stress alters early attentional processing, such that memory of the perceived relevant object is enhanced. However, although there is evidence that increased attention give rise to cognitive processing, it is not clear to what extent this focused-attention recruits other EFs related to cognitive control that may be driven by attention.

Cognitive control has been shown to regulate emotional responses (e.g., Nolen-Hoeksema, 2012), but, the efficacy of cognitive control to regulate emotional responses diminishes under stress (Raio, Orerdu, Palazzolo, Shurick, & Phelps, 2013). This could be because stress affects cognitive control of goal-directed choices by reducing connectivity between ventromedial PFC and dorsolateral PFC regions linked to cognitive control (Maier, Makwana, & Hare, 2015). Goal-directed behaviour is identified as an important cognitive function and there is evidence a disruption of the Type II processes impedes goal-directed behaviour during decision-making. (Margittai et al., 2016; Schwabe & Wolf, 2009; Schwabe & Wolf, 2013; Schwabe, Tegenthoff, Höffken, & Wolf, 2010; Seehagen, Schneider, Rudolph, Ernst, & Zmuy, 2015). The prevailing themes in these studies are that a decrease in cognitive control is associated with negative choice selection (Schwabe & Wolf, 2009), behaviour adjustment (Seehagen, et al., 2015) and changes from goal-directed to automatic control of action (Margittai et al., 2016). Margittai et al. tested healthy participants that received placebo, cortisol and a drug that increases noradrenergic stimulation, before performing the original CRT (Frederick 2005). In addition, blood pressure measurements were taken. Their results showed that an increase in cortisol causes a shift from reflective (deliberate) processing towards more automatic (intuitive) processing. The results showed that cortisol mediates the engagement of different cognitive processes and complements research on the IGT that showed poor performance on the IGT is related to stress mediated, reduced capacity for reflective Type II processes (Simonovic et al., 2016). Margittai et al.’s results are also in line with research that showed higher-order top-down processes to be cortisol dependent (Schwabe & Wolf, 2009; Schwabe & Wolf, 2013; Schwabe et al., 2010). Thus, decision-making under stress can be affected by impaired cognitive control and/or increased automatic response tendency. Moreover, impaired, stress mediated cognitive processes may be responsible for the activation of automatic Type I processing that impedes a goal-directed behaviour (e.g., Seehagen et al., 2015).

Conscious awareness
As discussed in Chapter 4, another aspect of the Type II processing that may be pertinent to IGT performance is conscious awareness. Newell and Shanks (2014) argued that selective attention occurs inside of conscious awareness and there is a complex relation between the attention, executive processes and conscious awareness. However, the question whether conscious awareness is related to Type II processes as a distinctive category and if it improves decision-making is still under debate (e.g., Dijksterhuis et al. 2006; Evans, 2010; Newell & Shanks, 2014). Chen and Lee (2015) examined eye-movements and conscious awareness and measured memory of past events. Greater inspection time was observed for the stimuli that were previously experienced. Conscious awareness was also correlated with higher inspection times indicating that both measures provide good explicit measures of the past experience. This could be related to IGT learning where it was suggested that conscious awareness of the deck contingencies develops in the exploration stage through the experiences of gain and losses (Maia & McClelland, 2004. The results from the experiment in Chapter 4 support this notion and show that conscious knowledge may improve decision-making on IGT performance and it may arise early in the game. To the best of my knowledge, the impact of stress on conscious awareness during IGT performance has not been investigated yet. There is some evidence that stress affects conscious awareness by impeding attentional monitoring of the correctness of the decision choices (Reyes, Silva, Jaramillo, Rehbein, & Sackur, 2015) and impedes the processing of information during a performance on the motor task (Hardy, Mullen, Jones, 1996). Furthermore, stress may affect preconscious selective attention that decreases avoidance reaction towards negative stimuli (e.g., Roelofs, Bakvis, Hermans, van Pelt, & van Honk, 2007). This evidence implies that stress impairs conscious awareness and attentional monitoring during decision-making and may impede information processing and decrease avoidance of the negative choices because they are not sufficiently processed. This suggestion could be related to IGT performance because of the evidence that conscious awareness plays a role early in the game (e.g., Experiment 2; Maia & McClelland, 2004; Fernie & Tunney, 2006; 2013).

According to some evidence in the systematic review, stress interferes with the development of the somatic markers that consequently lead to poor performance or increases selection from the disadvantageous decks (e.g., Reimann & Bechara, 2010, Starcke et al., 2017; Wemm, & Wulfert, 2017). It was also indicated that stress would lead to increased reward seeking and risk taking due to alterations in dopamine firing rates and reduced executive control due to suboptimal PFC functioning later in the IGT trials (Starcke et al., 2017). Contrasting evidence
reviewed here indicates that: stress diminishes cognitive processes and may increase risk-taking behaviour; impedes goal-directed behaviour by increasing automatic processing that is associated with negative choices selection and disrupts the development of conscious awareness and selective attention. There is also evidence that stress mediated cognitive processes have an effect on decision-making. To the best of my knowledge these suggestions have not been tested in relation to IGT performance. Simonovic et al. (2016) argued that stress disrupts cognitive processes and impairs cognitive ability to differentiate between the disadvantageous and advantageous deck selections on IGT. Simonovic et al.’s mediation analysis indicated that ‘IGT performance occurs through reducing the capacity for reflective Type II thinking rather than disrupting performance via an alternative route’ (p. 653). These findings are extended in the following experiment. Attentional processing (inspection time) was examined by using an eye-tracking methodology; CRT1 (Toplak et al., 2014) was used as a measure of analytic ability; Conscious Awareness test (Maia & McClelland, 2004) was also used to examine conceptual knowledge during the game.

5.4. The Experiment

The main aims of the experiment were to first replicate Simonovic et al.’s (2016) findings by (i) examining the role of stress in delaying the optimization of deck selection; (ii) examining the effect of stress on analytic thinking and disadvantageous deck selections. Next, Simonovic et al.’s original findings were extended with the objectives and aim to: (iii) examine the differences in inspection time between the disadvantageous and between the advantageous deck selections in both conditions; (iv) examine whether stress responses inhibit the emergence of knowledge sufficient to guide choice behaviour on IGT; (v) examine whether stress responses, inspection time, reflective thinking or knowledge either individually or combined predict card selection scores. It was hypothesised that:

1. The stress manipulation will inhibit performance on the IGT and delay the elimination of disadvantageous deck selections.
2. Stress would reduce participants’ reflective ability as measured by the CRT1; this represents the first direct test of stress on an extended version of CRT1 scores in the literature.
3. CRT1 scores would significantly correlate with disadvantageous deck’s selection early in the game consistent with Simonovic et al.’s (2016) argument that higher-level cognitive processes are important early in the game.
4. There would be differences in inspection times between the disadvantageous decks and advantageous decks between the stress and the control group.

5. Stress will inhibit learning of the patterns of gains and losses (deck rating) and learning of the estimated and calculated net values, thus impeding the emergence of conscious knowledge.

6. Finally, the relationship between inspection time, conscious knowledge, CRT1 scores, stress and IGT performance was tested by using mediation analyses to extend Simonovic et al.’s previous findings and it was predicted that inspection time, conscious knowledge, CRT1 scores and SBP reactivity measure would indirectly predict IGT performance.

5.5. Method

Participants

Twenty-three male and 53 female, from the University of Derby, aged 19-56 years, were recruited and randomly allocated to stress and control groups. Participants had normal or corrected to normal vision. All participants gave informed consent, in accordance with stipulations of the local ethics committee. People under the age of 18 years old and people who reported depression, anxiety, any cardiovascular disease or high blood pressure were excluded from participation.

Materials

Stress manipulation

The study used the same anticipatory speech task as Simonovic et al. (2016, based on a modified version of Preston et al.'s 2007 anticipatory speech task). A video camera was installed that simulated recording during the experiment and participants in the experimental group were told that they would be video-recorded during their performance and they would have to summarise their experience at the end of the experiment in front of the camera. Control participants were not given a description of a speech before the task, and the camera was not present in the room.

Physiological measurement

SBP and HR responses to stress were measured to check whether the manipulation was effective. A continuous, non-invasive cardiovascular measure by Finometer (Finapres Medical
System, Amsterdam, The Netherlands) was used to measure SBP and HR in both groups. Baseline SBP and HR measurements were taken continuously for five minutes and averaged to create a baseline measurement before the initiation of tasks. After that, SBP/HR measurements were taken during the IGT performance. SBP/HR responses were calculated by subtracting the average of the performance SBP/HR measurements from the average of baseline SBP/HR measurements.

**Conscious Awareness Test**

Maia and McClelland’s (2004) Test of Awareness was used as in the previous experiment with the identical procedure.

**Eye Tracking Measurements**

Eye movements were recorded with the Eye-gaze binocular system and the identical procedure was used as in the previous experiment.

**IGT**

Bechara et al.’s (1994) computerised version of IGT was used as in previous experiments with the identical procedure.

**CRT1**

CRT1 was used as in previous experiments with the identical procedure. The Cronbach alpha for this experiment was $\alpha = .77$.

**Procedure**

Following consent, participants sat for a 5-min resting period, and then baseline SBP/HR measurements were taken. Next, they were randomly allocated to groups. The instructions regarding the presentation to the camera were only given to the experimental group, and they were shown the camera which was then switched on. The camera was not present in the room for the participants in the control group. The CRT1 was administrated followed by the IGT and SBP/HR measurements. Eye tracking measures were taken during the IGT performance. Also, conscious awareness per Block was assessed during the task. After the completion of the IGT task, participants in the experimental group were told that they would not have to give the speech at that point. Finally, participants were debriefed, and post-task SBP/HR measurements were taken.
Analytic strategy and scoring

Before the initiation of the analyses, data were inspected for normality by checking for outliers, Skewness and Kurtosis, normality tests and Z-scores to ensure that the assumptions of parametric statistics were met before analyses were performed. If parametric assumptions were not met the data were log transformed, corrections used, and non-parametric tests used when appropriate. Initial analyses focused on checking that the stress manipulation was effective: ANOVA was used to determine if SBP and HR responses differed by condition. Next, a 2 (condition) × 7 (Block) mixed ANOVAs were used to determine the effect of the manipulation on IGT scores across the seven Blocks. Standard scoring was derived by deducting total disadvantageous card picks (A + B) from total advantageous picks (C + D). As parametric assumptions were not met, a Mann–Whitney test was used to examine if there were differences in CRT1 scores between the two conditions. Bivariate correlations were examined to determine relationships between CRT1 scores and disadvantageous deck picks (A + B) during each Block, for each group separately. Fixation duration was also examined across Blocks. A 2 (condition) x 7 (Block) mixed ANOVAs were used to determine the differences in inspection time for disadvantageous and advantageous decks across Blocks. separately. Next, a 2 (condition) x 7 (Block) mixed ANOVA was used to determine the effect of manipulation on Level 1 conscious knowledge on overall deck ratings (C+D – A+B) across Blocks. In addition, 2 (condition) x 2 (decks) mixed ANOVAs were used to determine the effect of the manipulation on estimated and calculated values across the disadvantageous and advantageous decks. Finally, a bootstrapped mediation model tested the conceptual model outlined in Figure 5.6.8. All hypotheses were tested simultaneously using the ‘Process' macro for SPSS (Hayes, 2012), with 10 000 bootstrapping re-samples and bias-corrected 95% confidence intervals (CIs) for each indirect effect. In bootstrapping analyses, bias-corrected CIs that do not contain 0 signify a significant mediational effect (Preacher & Hayes, 2004, 2008). Direct effects estimate how much two cases differing on the independent variable (stress manipulation) also differ on the dependent variable (total IGT score: (C +D) - (A + B)), independent of the effect of the mediator variables (SBP responses, inspection time, CRT1 scores and conscious knowledge) on the dependent variable. Total effects are the sum of the indirect and direct effects of the independent variable (stress manipulation) on the dependent variable (IGT scores) (Hayes, 2012). Analysis was conducted using IBM SPSS 22 for Windows.

5.6. Results
**Manipulation check**

ANOVA revealed a condition (stress vs. control) effect for SBP responses, $F(1,74)=13.63$, $p<.001$, $n_p^2=.16$; responses were larger in the stress condition than in the control condition (Table 5.6.2). Further, ANOVA revealed a condition (stress vs. control) effect for HR responses $F(1,74)=4.07$, $p<.05$, $n_p^2=.05$; responses were larger in the stress condition than in the control condition (Table 5.6.2).

**Table 5.6.2**

**Mean (SD) SBP and HR at baseline and during IGT performance**

<table>
<thead>
<tr>
<th></th>
<th>SBP</th>
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<th>HR</th>
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<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>During</td>
<td>Baseline</td>
<td>During</td>
</tr>
<tr>
<td>Stress</td>
<td>122.05 (15.19)</td>
<td>139.16 (13.76)</td>
<td>80.46 (14.44)</td>
<td>85.08 (14.28)</td>
</tr>
<tr>
<td>Control</td>
<td>120.22 (8.70)</td>
<td>122.60 (7.19)</td>
<td>77.33 (7.95)</td>
<td>77.50 (8.24)</td>
</tr>
</tbody>
</table>

**IGT performance**

To determine the effect of stress manipulation on the standard IGT scoring, $(C+D) - (A+B)$ across the seven Blocks of the IGT, a 2 (Condition) x 7 (Blocks) Greenhouse-Geisser adjusted repeated measures ANOVA with log-transformed data was used (see Table 5.6.3). There was a main effect of stress manipulation $F(1,74)=58.80$, $p < .001$, $n_p^2 = .44$ such that IGT scores were significantly lower in the stress condition ($M=17.07$, $SD=43.69$) than in the control condition ($M=38.39$, $SD=46.18$).

**Table 5.6.3**

**Mean (SD) standard IGT scores per Block for control and stress group**

<table>
<thead>
<tr>
<th>Blocks</th>
<th>Stress</th>
<th>Control</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-4.05 (4.48)</td>
<td>-3.16 (8.29)</td>
<td>-3.60 (6.63)</td>
</tr>
<tr>
<td>2</td>
<td>-2.32 (6.39)</td>
<td>4.53 (8.02)</td>
<td>1.10 (7.98)</td>
</tr>
<tr>
<td>3</td>
<td>-.53 (7.56)</td>
<td>9.40 (6.94)</td>
<td>4.43 (8.77)</td>
</tr>
<tr>
<td>4</td>
<td>-.89 (6.23)</td>
<td>10.32 (7.22)</td>
<td>4.71 (8.76)</td>
</tr>
<tr>
<td>5</td>
<td>2.00 (7.45)</td>
<td>11.74 (7.70)</td>
<td>6.87 (8.99)</td>
</tr>
<tr>
<td>6</td>
<td>1.21 (7.81)</td>
<td>12.10 (7.88)</td>
<td>6.65 (9.53)</td>
</tr>
<tr>
<td>7</td>
<td>1.89 (9.21)</td>
<td>13.16 (7.70)</td>
<td>7.53 (10.16)</td>
</tr>
<tr>
<td>Total</td>
<td>-2.68 (31.15)</td>
<td>58.16 (37.47)</td>
<td></td>
</tr>
</tbody>
</table>

114
There was a main effect of Block F(4.25,314.32)=33.29, p<.001, n_p^2=.31 with IGT scores increasing after the first Block (See table 5.6.3). The Bonferroni adjustment was too stringent for 21 comparisons therefore alpha level was adjusted to p<.005 to balance concerns related to type I and type II errors. The adjusted post hoc pairwise comparisons (Table 5.6.4) demonstrated significantly lower IGT scores in Block 1 than all other Blocks (all p<.005). Furthermore, IGT scores in Block 2 were significantly lower than Blocks 4, 5, 6 and 7 (all p<.005). There were no other significant differences between Blocks.

Table 5.6.4

Mean differences (SD) in IGT Scores. Pairwise comparison across Blocks

<table>
<thead>
<tr>
<th>Block 1</th>
<th>Block 2</th>
<th>Block 3</th>
<th>Block 4</th>
<th>Block 5</th>
<th>Block 6</th>
<th>Block 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1.08)</td>
<td>(.97)</td>
<td>(.97)</td>
<td>(1.15)</td>
<td>(1.13)</td>
<td>(1.24)</td>
<td></td>
</tr>
<tr>
<td>p&lt;.005*</td>
<td>p&lt;.005*</td>
<td>p&lt;.005*</td>
<td>p&lt;.005*</td>
<td>p&lt;.005*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-3.33</td>
<td>-3.60</td>
<td>-5.76</td>
<td>-5.55</td>
<td>-6.42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(.90)</td>
<td>(.92)</td>
<td>(1.02)</td>
<td>(1.09)</td>
<td>(1.02)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>p&gt;.005</td>
<td>p&lt;.005*</td>
<td>p&lt;.005*</td>
<td>p&lt;.005*</td>
<td>p&lt;.005*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-.28 (.66)</td>
<td>-.243</td>
<td>-2.22</td>
<td>-3.09</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>p&gt;.005</td>
<td>(1.05)</td>
<td>(.98)</td>
<td>(1.04)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Block 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-2.16</td>
<td>-1.95</td>
<td>-2.81</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(.87)</td>
<td>(.87)</td>
<td>(.99)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>p&gt;.005</td>
<td>p&gt;.005</td>
<td>p&gt;.005</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-.21</td>
<td>-.66</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>(.73)</td>
<td>(.85)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>p&gt;.005</td>
<td>p&gt;.005</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Block 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Block 6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-.87</td>
<td>-.63</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(.63)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>p&gt;.005</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

There was an interaction between the IGT scores and the stress condition across blocks F(4.25,314.32)=7.44, p<.001, n_p^2=.09, on IGT score. Independent t-tests revealed that participants in the stress conditions had lower IGT scores in all but Block 1 (all significant at p<.001) compared with participants in the control condition (see Figure 5.6.2) (Alpha adjusted threshold p<.005).
Figure 5.6.2. Block and stress interaction between the groups with IGT scores as the dependent variable. Error bars are the standard error of the mean

**CRT1 performance**

A Mann–Whitney test showed differences in CRT1 scores between the two groups: participants in the stress condition had lower CRT1 scores (Median=1, IQR=5) than participants in the control condition (Median=4.5, IQR=7) U=128, p<.001, demonstrating that reflective thinking was inhibited by stress (with a large effect size, r=.72).

**Correlations between CRT1 and IGT**

Correlations between disadvantageous card selection scores (A+B) per Block revealed medium to large correlations across both conditions. Further correlations between disadvantageous card selection scores for each Block and CRT1 scores were calculated for control and stress conditions separately. Significant negative correlations between disadvantageous card selection scores and CRT1 scores were observed in Blocks three, five, six and seven in the control condition (Alpha adjusted threshold p<.005). Meaning, higher CRT1 scores were associated with better performance in those Blocks (Table 5.6.5).
Table 5.6.5
Correlations between CRT1 scores and disadvantageous card selection scores (A+B)

<table>
<thead>
<tr>
<th>Blocks12</th>
<th>Stress</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>r=-.321, p=.049</td>
<td>r=.007, p=.966</td>
</tr>
<tr>
<td>2</td>
<td>r=-.005, p=.977</td>
<td>r=-.186, p=.264</td>
</tr>
<tr>
<td>3</td>
<td>r=-.175, p=.294</td>
<td>r=-.442, p=.005*</td>
</tr>
<tr>
<td>4</td>
<td>r=-.124, p=.458</td>
<td>r=-.201, p=.227</td>
</tr>
<tr>
<td>5</td>
<td>r=-.234, p=.158</td>
<td>r=-.476, p=.003*</td>
</tr>
<tr>
<td>6</td>
<td>r=-.354, p=.029</td>
<td>r=-.519, p=.001**</td>
</tr>
<tr>
<td>7</td>
<td>r=-.327, p=.045</td>
<td>r=-.484, p=.002*</td>
</tr>
<tr>
<td>Total</td>
<td>r=-.354, p=.029</td>
<td>r=-.462, p=.003*</td>
</tr>
</tbody>
</table>

**Inspection time**

Two separate repeated measures ANOVA were conducted to test the effect of inspection time of disadvantageous decks in stress and control conditions (first analysis) and the effect of inspection time of advantageous decks in stress and control conditions (second analysis).

**Inspection time of disadvantageous decks across conditions (First analysis)**

A Greenhouse-Geisser adjusted repeated measures ANOVA with log transformed data was used to determine the effect of stress manipulation on the inspection time for disadvantageous choices (A+B) across seven Blocks of the IGT (see Table 5.6.6). There was a main effect of stress manipulation F(1,74)=89.25, p<.001, n_p^2=.54, such that longer inspection time was observed in the stress condition (M=.35, SD=.10) compared to the control condition (M=.15, SD=.07).

Table 5.6.6

Mean (SD) inspection time for disadvantageous decks per Block for control and stress group

<table>
<thead>
<tr>
<th>Blocks</th>
<th>Stress</th>
<th>Control</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

12* Significant at p<.05.

** Significant at p<.01
There was a main effect of Block, $F(4.14,306.16)=21.81, p<.001, \eta^2_p=.23$ with the inspection time increasing from Block 1 until Block 4 (See table 5.6.6). Post hoc tests were used to unpack this main effect. The Bonferroni adjustment was too stringent to make 21 comparisons between all combinations of Blocks, therefore the alpha level was adjusted to $p<.005$ to balance concerns related to type I and type II errors. The adjusted post hoc pairwise comparisons (Table 5.6.7) demonstrated that inspection time in Block 1 was significantly lower than inspection time in Blocks 2 and 3 (all $p<.005$). Inspection time in Blocks 2 and 3 was significantly higher than inspection time in Blocks 6 and 7. Furthermore, the inspection time in Block 4 was significantly higher than inspection time in Blocks 5, 6 and 7 (all $p<.005$).

**Table 5.6.7**

*Mean differences (SE) in Inspection Times (in seconds). Pairwise comparison across Blocks.*

<table>
<thead>
<tr>
<th></th>
<th>Block 1</th>
<th>Block 2</th>
<th>Block 3</th>
<th>Block 4</th>
<th>Block 5</th>
<th>Block 6</th>
<th>Block 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block 1</td>
<td>-.08 (0.02)</td>
<td>-.09 (0.02)</td>
<td>-.14 (0.03)</td>
<td>-.03 (0.02)</td>
<td>.05 (0.02)</td>
<td>.05 (0.02)</td>
<td></td>
</tr>
<tr>
<td>Block 2</td>
<td>-.01 (0.02)</td>
<td>-.05 (0.02)</td>
<td>-.04 (0.02)</td>
<td>.06 (0.18)</td>
<td>.05 (0.02)</td>
<td>.05 (0.02)</td>
<td>.13 (0.02)</td>
</tr>
<tr>
<td>Block 3</td>
<td>.10 (0.02)</td>
<td>.19 (0.02)</td>
<td>.06 (0.02)</td>
<td>.09 (0.02)</td>
<td>.08 (0.18)</td>
<td>.08 (0.05)</td>
<td></td>
</tr>
<tr>
<td>Block 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Block 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Block 6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Block 7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Finally, there was an interaction between the stress manipulation and Blocks $F(4.14,306.16)=26.16, p<.001, \eta^2_p=.26$. Bonferroni adjusted independent t-tests tested the interaction between the matching Blocks in both conditions. These revealed longer inspection time for
disadvantageous decks in the stress conditions in Blocks 2, 3, 4 and 5 compared with participants in the control condition (Figure 5.6.3) (Alpha adjusted threshold p<.005).

Figure 5.6.3. Block and stress interaction between the groups with inspection time of disadvantageous decks as the dependent variable. Error bars are the standard error of the mean.

**Inspection time of advantageous decks across conditions (Second analysis)**

A Greenhouse-Geisser adjusted repeated measures ANOVA with log transformed data was used to determine the effect of stress manipulation on the inspection time for advantageous choices (C+D) across the seven Blocks of the IGT (see Table 5.6.8). There was a main effect of stress manipulation F(1,74)= 7.52, p=.008, ηp²=.09, such that longer inspection time was observed in the control group (M=.29, SD=.10) compared to the stress group (M=.22, SD=.08).

**Table 5.6.8**

<table>
<thead>
<tr>
<th>Blocks</th>
<th>Stress (SD)</th>
<th>Control (SD)</th>
<th>Total (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.22 (0.10)</td>
<td>0.22 (0.14)</td>
<td>0.22 (0.12)</td>
</tr>
<tr>
<td>2</td>
<td>0.19 (0.10)</td>
<td>0.30 (0.14)</td>
<td>0.25 (0.13)</td>
</tr>
<tr>
<td>3</td>
<td>0.23 (0.15)</td>
<td>0.41 (0.23)</td>
<td>0.32 (0.21)</td>
</tr>
<tr>
<td>4</td>
<td>0.23 (0.16)</td>
<td>0.46 (0.30)</td>
<td>0.35 (0.27)</td>
</tr>
<tr>
<td>5</td>
<td>0.19 (0.12)</td>
<td>0.22 (0.18)</td>
<td>0.21 (0.15)</td>
</tr>
<tr>
<td>6</td>
<td>0.23 (0.15)</td>
<td>0.18 (0.16)</td>
<td>0.21 (0.16)</td>
</tr>
<tr>
<td>7</td>
<td>0.23 (0.14)</td>
<td>0.19 (0.18)</td>
<td>0.21 (0.17)</td>
</tr>
</tbody>
</table>
There was a main effect of Block, $F(3.78, 280.19)= 12.12$, $p<.001$, $\eta_p^2=.14$ with the inspection time increasing from Block 1 until Block 4 (See table 5.6.8). Post hoc tests were used to unpack this main effect. The Bonferroni adjustment was again very stringent so the alpha level was adjusted to $p< .005$ to balance concerns related to type I and type II errors. The adjusted post hoc pairwise comparisons (Table 5.6.9) demonstrated that inspection time in Block 1 was significantly slower than Blocks 3 and 4 (all $p<.005$). Furthermore, inspection time in Block 3 was significantly longer than Blocks 5 and 6 (all $p<.005$). Additionally, inspection time in Block 4 was significantly longer than Blocks 5, 6 and 7 (all $p<.005$).

Table 5.6.9

<table>
<thead>
<tr>
<th></th>
<th>Block 1</th>
<th>Block 2</th>
<th>Block 3</th>
<th>Block 4</th>
<th>Block 5</th>
<th>Block 6</th>
<th>Block 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block 1</td>
<td>-.03 (.02)</td>
<td>-.09 (.02)</td>
<td>-.13 (.03)</td>
<td>.01 (.02)</td>
<td>.01 (.02)</td>
<td>.01 (.02)</td>
<td></td>
</tr>
<tr>
<td>p &gt; .005</td>
<td>p &lt; .005*</td>
<td>p &lt; .001*</td>
<td>p &gt; .005</td>
<td>p &gt; .005</td>
<td>p &gt; .005</td>
<td>p &gt; .005</td>
<td></td>
</tr>
<tr>
<td>Block 2</td>
<td>-.07 (.02)</td>
<td>-.09 (.02)</td>
<td>-.04 (.02)</td>
<td>.11 (.03)</td>
<td>.11 (.03)</td>
<td>.10 (.03)</td>
<td></td>
</tr>
<tr>
<td>p &gt; .005</td>
<td>p &gt; .005</td>
<td>p &gt; .005</td>
<td>p &lt; .005*</td>
<td>p &lt; .005*</td>
<td>p &gt; .005</td>
<td>p &gt; .005</td>
<td></td>
</tr>
<tr>
<td>Block 3</td>
<td>-.04 (.02)</td>
<td>.14 (.03)</td>
<td>.14 (.03)</td>
<td>.14 (.03)</td>
<td>.14 (.03)</td>
<td>.14 (.03)</td>
<td></td>
</tr>
<tr>
<td>p &gt; .005</td>
<td>p &lt; .005*</td>
<td>p &lt; .005*</td>
<td>p &lt; .005*</td>
<td>p &lt; .005*</td>
<td>p &gt; .005</td>
<td>p &gt; .005</td>
<td></td>
</tr>
<tr>
<td>Block 4</td>
<td>.11 (.03)</td>
<td>.11 (.03)</td>
<td>.11 (.03)</td>
<td>.11 (.03)</td>
<td>.11 (.03)</td>
<td>.11 (.03)</td>
<td></td>
</tr>
<tr>
<td>p &gt; .005</td>
<td>p &gt; .005</td>
<td>p &gt; .005</td>
<td>p &gt; .005</td>
<td>p &gt; .005</td>
<td>p &gt; .005</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Block 5</td>
<td>.14 (.03)</td>
<td>.14 (.03)</td>
<td>.14 (.03)</td>
<td>.14 (.03)</td>
<td>.14 (.03)</td>
<td>.14 (.03)</td>
<td></td>
</tr>
<tr>
<td>p &gt; .005</td>
<td>p &gt; .005</td>
<td>p &gt; .005</td>
<td>p &gt; .005</td>
<td>p &gt; .005</td>
<td>p &gt; .005</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Block 6</td>
<td>.14 (.03)</td>
<td>.14 (.03)</td>
<td>.14 (.03)</td>
<td>.14 (.03)</td>
<td>.14 (.03)</td>
<td>.14 (.03)</td>
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</tr>
<tr>
<td>p &gt; .005</td>
<td>p &gt; .005</td>
<td>p &gt; .005</td>
<td>p &gt; .005</td>
<td>p &gt; .005</td>
<td>p &gt; .005</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Block 7</td>
<td>.00 (.01)</td>
<td>.00 (.01)</td>
<td>.00 (.01)</td>
<td>.00 (.01)</td>
<td>.00 (.01)</td>
<td>.00 (.01)</td>
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</tr>
<tr>
<td>p &gt; .005</td>
<td>p &gt; .005</td>
<td>p &gt; .005</td>
<td>p &gt; .005</td>
<td>p &gt; .005</td>
<td>p &gt; .005</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

There was an interaction between the stress manipulation and Blocks $F(3.78, 280.19)= 10.88$, $p<.001$, $\eta_p^2=.13$. Bonferroni adjusted independent t-tests tested the interaction between the matching Blocks in both conditions. These revealed longer inspection time for participants in the control condition in Blocks 2, 3 and 4 compared with participants in the stress condition (see Figure 5.6.4) (Bonferroni adjusted threshold $p<.005$).
Figure 5.6.4. Block and stress interaction between the groups with inspection time of advantageous decks as the dependent variable. Error bars are the standard error of the mean.

**Conscious awareness**

A Greenhouse-Geisser adjusted ANOVA was used to determine the effect of stress manipulation on the Level 1 knowledge (overall deck ratings, \( C + D - (A + B) \)) across the seven Blocks of the IGT (see Table 5.6.10). There was a main effect of stress manipulation \( F(1,73)=12.90, p=.001, \eta^2_p=.15 \), such that the Level 1 knowledge was lower in the stress group \( (M=-1.19, SD=6.90) \) compared to the control group \( (M=-7.61, SD=8.32) \).

**Table 5.6.10**

<table>
<thead>
<tr>
<th>Blocks</th>
<th>Stress</th>
<th>Control</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-5.84 (7.48)</td>
<td>1.37 (7.01)</td>
<td>-2.28 (8.07)</td>
</tr>
<tr>
<td>2</td>
<td>1.18 (9.36)</td>
<td>4.83 (9.62)</td>
<td>2.99 (9.13)</td>
</tr>
<tr>
<td>3</td>
<td>1.60 (8.64)</td>
<td>8.37 (8.81)</td>
<td>4.94 (9.31)</td>
</tr>
<tr>
<td>4</td>
<td>3.47 (9.28)</td>
<td>8.51 (11.15)</td>
<td>5.96 (10.49)</td>
</tr>
<tr>
<td>5</td>
<td>3.13 (8.08)</td>
<td>9.51 (11.38)</td>
<td>6.28 (10.30)</td>
</tr>
<tr>
<td>6</td>
<td>2.39 (8.27)</td>
<td>10.48 (10.65)</td>
<td>6.39 (10.30)</td>
</tr>
<tr>
<td>7</td>
<td>2.45 (8.00)</td>
<td>10.16 (10.46)</td>
<td>6.25 (10.01)</td>
</tr>
<tr>
<td>Total</td>
<td>1.19 (6.90)</td>
<td>7.61 (8.32)</td>
<td>6.25 (10.01)</td>
</tr>
</tbody>
</table>

There was a significant main effect of Block, \( F(2.75,200.67)= 26.43, p<.001, \eta^2_p=.27 \), with the level 1 Knowledge increasing from Block 1 until Block 6 (See table 5.6.10). Post hoc tests
were used to unpack this main effect. The alpha level was again adjusted to p< .005 to balance concerns related to type I and type II errors. The adjusted post hoc pairwise comparisons (Table 5.6.11) demonstrated that Level 1 Knowledge in Block 1 was significantly lower than all other Blocks (all p<.005). There were no other significant differences between Blocks.

**Table 5.6.11**

*Mean differences (SD) in Level 1 Knowledge. Pairwise comparison across Blocks.*

<table>
<thead>
<tr>
<th></th>
<th>Block 1</th>
<th>Block 2</th>
<th>Block 3</th>
<th>Block 4</th>
<th>Block 5</th>
<th>Block 6</th>
<th>Block 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block 1</td>
<td>5.24,</td>
<td>7.22,</td>
<td>8.22</td>
<td>8.55</td>
<td>8.67</td>
<td>8.53</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.05)</td>
<td>(1.21)</td>
<td>(1.28)</td>
<td>(1.18)</td>
<td>(1.19)</td>
<td>(1.14)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>p&lt;.005*</td>
<td>p&lt;.005*</td>
<td>p&lt;.005*</td>
<td>p&lt;.005*</td>
<td>p&lt;.005*</td>
<td>p&lt;.005*</td>
<td></td>
</tr>
<tr>
<td>Block 2</td>
<td>1.98</td>
<td>2.98</td>
<td>3.31</td>
<td>3.43</td>
<td>3.29</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.80)</td>
<td>(.95)</td>
<td>(1.00)</td>
<td>(1.01)</td>
<td>(.96)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>p&gt;.005</td>
<td>p&gt;.005</td>
<td>p&gt;.005</td>
<td>p&gt;.005</td>
<td>p&gt;.005</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Block 3</td>
<td>1.00</td>
<td>1.33</td>
<td>1.45</td>
<td>1.31</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(.58)</td>
<td>(.70)</td>
<td>(.75)</td>
<td>(.69)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>p&gt;.005</td>
<td>p&gt;.005</td>
<td>p&gt;.005</td>
<td>p&gt;.005</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Block 4</td>
<td>.33</td>
<td>.44</td>
<td>.31</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(.47)</td>
<td>(.54)</td>
<td>(.60)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>p&gt;.005</td>
<td>p&gt;.005</td>
<td>p&gt;.005</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Block 5</td>
<td>.12 (.42)</td>
<td>-.01</td>
<td>.35</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>p&gt;.005</td>
<td>(.33)</td>
<td>p&gt;.005</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Block 6</td>
<td>-.14</td>
<td>(1.44)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>p&gt;.005</td>
<td>p&gt;.005</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The Block x stress manipulation interaction F(2.75,200.67)= 1.62, p=.127, n_p^2=.02 was not significant (Figure 5.6.5).
Two separate mixed ANOVAs (one for calculated deck values and the second for estimated deck values) were used to determine the effect of stress manipulation on the deck ratings for advantageous and disadvantageous decks.

The first mixed ANOVA tested the effect of stress manipulation on the estimated deck values. There was a main effect of stress manipulation $F(1,74)=4.32, p=.041, \eta_p^2=.05$, such that participants in the stress condition estimated deck values were higher compared to the control group (see Table 5.6.12).

There was no significant main effect of decks, $F(1,74)=0.35, p=.55, \eta_p^2=.005$.

There was however, a significant deck x stress manipulation interaction $F(1,74)=8.89, p=.004, \eta_p^2=.11$. Independent t-tests revealed higher estimated values of the disadvantageous decks for participants in the stress conditions compared with participants in the control condition (see Figure 5.6.6) (Bonferroni adjusted threshold $p<.005$).
Table 5.6.12

Mean (SD) for estimated net values per deck

<table>
<thead>
<tr>
<th>Deck</th>
<th>Estimated values</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stress</td>
<td>Control</td>
</tr>
<tr>
<td>AB</td>
<td>379.23 (312.35)</td>
<td>155.56 (341.22)</td>
</tr>
<tr>
<td>CD</td>
<td>276.88 (239.80)</td>
<td>308.37 (172.90)</td>
</tr>
<tr>
<td>Total</td>
<td>328.05 (215.86)</td>
<td>231.97 (185.97)</td>
</tr>
</tbody>
</table>

Figure 5.6.6. Estimated values for advantageous and disadvantageous decks between the groups. Error bars are the standard error of the mean.

The second mixed ANOVA tested the effect of stress manipulation on the calculated deck values. There was a no significant main effect of stress manipulation F(1,74)=.11, p=.74, \( \eta_p^2 = .001 \). There was a significant main effect of deck, F(1,74)=56.16, p<.001, \( \eta_p^2 = .43 \), such that lower calculated values were observed for disadvantageous decks compared to advantageous decks (see Table 5.6.13); and there was a no significant deck x stress manipulation interaction F(2.09,154.82)=.46, p=.64, \( \eta_p^2 = .006 \) (Figure 5.6.7).
Table 5.6.13

Mean (SD) for calculated net values per deck

<table>
<thead>
<tr>
<th>Deck</th>
<th>Calculated values</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stress</td>
<td>Control</td>
</tr>
<tr>
<td>AB</td>
<td>-356.62 (329.82)</td>
<td>-365.87 (211.74)</td>
</tr>
<tr>
<td>CD</td>
<td>-165.46 (159.37)</td>
<td>-129.70 (65.84)</td>
</tr>
<tr>
<td>Total</td>
<td>-261.04 (220.95)</td>
<td>-247.79 (109.39)</td>
</tr>
</tbody>
</table>

*Figure 5.6.7*. Calculated net values for advantageous and disadvantageous decks between the groups. Error bars are the standard error of the mean.

The participant’s conscious knowledge started to emerge from Block 2 onwards in both conditions. 39% percent of the participants reached Level 1 conscious knowledge in the stress condition after the first Block, compared to 50% of the participants in the control condition. (Figure 5.6.8). However only 2% of the participants in the stress group reached Level 2 conscious knowledge after the first Block compared to 16% of the participants in the control condition. By the end of the game only 8% of the participants reached level 2 knowledge in the stress condition compared to 47% of the participants in the control conditions.
Data was first screened for the outliers and there were no issues. The data screening also indicated that the assumption of normality was not violated. For the mediation analyses, stress manipulation was an independent variable and overall IGT score was a dependent variable. CRT1 scores, inspection time, conscious knowledge and SBP reactivity were mediators. Initially, it was checked if the stress manipulation predicts chosen mediators. Stress manipulation significantly predicted all the mediators (Table 5.6.14). The results were significant for all the mediators. Further mediation analyses indicated that the direct effect of stress manipulation on IGT was not significant when controlling for mediators, \( b = 15.30 \) (SE=12.15), \( t=1.26, p=.212 \). However, there was a significant indirect effect of stress manipulation on IGT scores through CRT1, \( b=30.32 \) (SE=7.40), \( Z=4.09, p<0.001 \) and conscious knowledge, \( b=13.64 \) (SE=4.67), \( Z=2.92, p=0.003 \). Conversely, the indirect effect of stress manipulation through inspection time, \( b=3.45 \) (SE=7.07), \( Z=0.49, p=0.625 \), and SBP
reactivity, $b=-1.86$ (SE=3.50), $Z=-0.53$, $p=0.488$ was not significant. The full model of stress manipulation as a predictor of IGT scores, indirectly thorough mediators in a non-sequential pattern, is outlined in Figure 5.6.

**Table 5.6.14**

*The overall modules and effect of stress manipulation on mediators*

<table>
<thead>
<tr>
<th>Overall module</th>
<th>Stress manipulation effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRT1</td>
<td>$F(1,74)=80.35, p&lt;.001$, $R^2=.52$</td>
</tr>
<tr>
<td>SBP reactivity</td>
<td>$F(1,74)=21.54, p&lt;.001$, $R^2=.22$</td>
</tr>
<tr>
<td>Inspection time</td>
<td>$F(1,74)=90.93, p&lt;.001$, $R^2=.55$</td>
</tr>
<tr>
<td>Conscious knowledge</td>
<td>$F(1,74)=12.98, p&lt;.001$, $R^2=.15$</td>
</tr>
</tbody>
</table>

**Diagram**

Direct effect, $R^2 = 0.68$, $b = 15.68$, $t(70.00) = 1.58$, $p = 0.117$ $c'$

Total effect, $R^2 = 0.44$, $b = 60.84$, $t(74.00) = 7.70$, $p < 0.001$ $c$

Indirect effect CRT1, $b=30.32$ (SE=6.52), 95% CI [19.17, 45.90]

Indirect effect Inspection time, $b=3.45$ (SE=7.78), 95% CI [-10.21, 20.76]

Indirect effect Conscious knowledge, $b=13.64$ (SE=4.83), 95% CI [5.70, 24.93]

Indirect effect SBP reactivity, $b=-1.86$ (SE=3.21), 95% CI [-6.57, 6.79]


**Figure 5.6.9.** Model of stress manipulation as a predictor of IGT scores, mediated by SBP reactivity, inspection time, CRT1 and conscious knowledge. The confidence interval for the indirect effect is a BCa bootstrapped CI based on 10,000 samples

### 5.7. Discussion

The hypotheses related to replication of Simonovic et al.’s (2016) findings (Hypotheses 1, 2 and 3) are partially supported. The first hypothesis that the stress manipulation would inhibit IGT performance and would delay the optimisation of deck selections is supported. The stress manipulation also reduced participants’ reflective ability as measured by the CRT1. It was hypothesised that CRT1 scores would correlate in the earlier Blocks for both conditions. The hypothesis is partially supported; correlations between CRT1 scores and disadvantageous deck picks were shown in Blocks three, five, six and seven only in the control condition.

It was further hypothesised (Hypothesis 4) that there will be differences in inspection time across conditions between the disadvantageous decks and advantageous decks. That hypothesis is supported. Longer inspection time for disadvantageous decks was observed in the stress condition in Blocks two, three, four and five. Conversely, longer inspection time for advantageous decks was observed in the control condition in Blocks two, three and four. It was also hypothesised that the stress will inhibit the learning of the patterns of gains and losses (deck rating) and learning of the estimated and calculated net values (Hypothesis 5). This hypothesis is partially supported; overall, participants in the control conditions gained enough knowledge to understand the patterns of gains and losses compared to the stress condition. However, the interaction between the blocks and the decks was not significant. It was expected that participants in the stress conditions would estimate and calculate net values greater than those in the control condition. The findings only partially support this hypothesis; estimated net value was higher in the stress condition compared to the estimated net value in the control condition. There were no differences in calculated net value results between the conditions.

The emergence of Level 2 conscious awareness was evident in both conditions after the first Block. However, a higher percentage of the participants in the control group developed conscious knowledge compared to the participants in the stress conditions. This supports the hypothesis that stress interferes with the development of conscious knowledge. Finally, a mediation regression analysis was conducted to examine direct and indirect effects of the stress manipulation, SBP, inspection time, CRT1 and conscious knowledge upon IGT scores (Hypothesis 6). This analysis demonstrated the stress manipulation indirectly affected IGT
scores by reducing cognitive reflection and conscious knowledge but did not have a direct effect. These findings are discussed in turn.

**Manipulation check and IGT performance**

The results showed that the manipulation was successful as indicated by higher SBP/HR reactivity scores in the stress condition. The results showed that stressed participants selected more cards from disadvantageous decks, after the first Block, indicating that their learning was impaired. These findings support Simonovic et al.’s (2016) findings on a non-extended version of the IGT. These data are also in line with previous studies that have shown that stress impairs learning and leads to a slower elimination of disadvantageous deck selection (Preston et al., 2007; Starcke et al., 2017; Wemm & Wulfert, 2017). For example, Starcke et al. found that a stress-inducing task, unsolvable anagrams, lead to a decrease of advantageous choices on IGT. Results from the Experiment 3 in this chapter yielded similar results. Participants in the stress condition improved the IGT performance after the fourth trial compared to the participants in the control condition that improved the performance after the first trial. This is also similar to the results of Wemm and Wulfert's (2017) study that found increased heart rate responses to a stress-induced task was associated with an increased selection of disadvantageous decks.

**CRT1 results**

Participants in the stress condition had significantly lower CRT1 scores, indicating that stress reduced reflective ability. This supports Simonovic et al.’s (2016) results and indicates that analytic thinking processes are negatively affected by stress, where physiological responses to a stressor shift decision-making from deliberate and reflective processes towards automatic and habitual processes. This is also in line with Margittai et al.’s (2016) study that demonstrated higher cortisol level effect on impaired performance on the original CRT. Margittai et al. interpreted their results as direct evidence that the stress hormone cortisol biases decision-making towards automatic processing. This corresponds with research evidencing that stress disrupts the higher order control, (mediated by PFC) and allows bottom-up (automatic) control (amygdala mediated) to dominate (e.g., Arnsten, 2009; Schwabe & Wolf, 2011; Schwabe & Wolf, 2013). This further supports the dual process account of IGT where it is assumed that ‘cool’ reflective processes are important in overriding ‘hot’ processes that favour short-term gain (Brevers et al., 2013). According to Brevers et al. ‘cool’ systems are associated with monitoring options that are associated with risk and gains options. Under the circumstances
where ‘hot’ systems do not allow risk assessments of the choices, ‘cool’ systems are involved in the determination of the risk and benefits of the choices. The overall correlation between the CRT1 scores and disadvantageous deck selections scores observed in the control condition indicate that reflective processes are implicated in disambiguation of the disadvantageous deck contingencies. Correlational data further indicate that the reflective processing is significant not only in earlier trials (e.g., Simonovic et al., 2016; experiment 1 and 2) but in the later trials when participants presumably learned the rules of the task (e.g., Starcke et al., 2017). Presumably, learning shift varies from participant to participant, and it is difficult to predict a clear cut-point. The CRT1 scores in the control condition appeared to correlate with disadvantageous deck scores during the whole game. This indicates that the importance of reflective thinking emerged after the second Block and persisted until the end of the game showing less reflective participants in the control group were more likely to make a disadvantageous choice.

**Inspection time**

The overall inspection time of disadvantageous decks between the stress and the control condition was significant. Greater inspection time was observed for participants in the stress condition, particularly from Blocks two to five. This indicates that there are differences in attentional control between the two conditions and possible lack of control of the disadvantageous deck choices. This lack of control, presumably, impaired participants’ ability to disengage from the negative choices associated with disadvantageous decks in the stress condition. This is in line with previous research on the effect of stress on decision-making where an increased likelihood of the negative preferences and poor learning from punishment is associated with increased attention towards negative choices (Cavanagh et al. 2011; Ononaiye et al., 2007; Sapolsky, 2000; Sposari & Rapee, 2007). Thus, the findings indicate that stress condition inhibited participants' ability for attentional disengagement from the negative choices. However, it is not clear if the stress condition reduced participants' learning from negative feedback by ‘hijacking' cognitive control, or just increased the risk-taking behaviour through reducing individual abilities to disengage from the bad choices. Nevertheless, the second analysis related to the overall inspection time of advantageous choices between the conditions revealed that participants in the stress condition fail to maintain attentional control over advantageous decks. Greater inspection time for advantageous decks was observed in Blocks two three and four, in the control condition. This could be taken as an
indicator of participants’ awareness of the advantageousness of decks and it should not occur so early in the task according to some authors (Bechara et al., 1997, 2000; Starcke et al., 2007; 2017). Thus, it is possible that stress impaired both learnings from the positive and negative feedback of disadvantageous/advantageous decks, reduced participants' ability for attentional disengagements of disadvantageous choices and increased awareness of the advantageousness of the good decks in control group.

Conscious awareness

Sufficient knowledge to guide advantageous long-term choices emerged for most of the participants in the control condition after the first Block. Overall deck rating scores in the stress condition suggested that stress interfered with participants’ learning as they failed to develop sufficient knowledge to guide their performance compared to the control group. There were no differences in the calculated net values between the two conditions suggesting that participants’ knowledge of the advantageous/disadvantageous deck contingencies is mostly inaccurate in both groups. However, participants in the control condition were able to retain knowledge of the disadvantageous estimated deck contingencies, compared to participants in the stress condition. This indicates that stress affected participants’ knowledge of the estimated net value, whereby participants in the stress condition overestimated the average amount won or lost on disadvantageous decks. Stress also impeded participants’ development of full conceptual knowledge in the stress condition. These data are consistent with previous studies that have shown that the IGT can be performed through access to explicit, conscious knowledge (e.g., Maia, & McClelland, 2004, 2005; Fernie & Tunney, 2006; Fernie, & Tunney, 2013). Thus, while the possibility that somatic markers contribute to IGT performance cannot be ruled out, the results reliably show that stress impaired the conscious processes which are integral to IGT performance. However, it should be noted that the nature of the IGT design and the design of Maia and McClelland’s (2004) test is likely to promote some cognitive processing rather than intuitive processing because participants only need to pay attention to the punishment delivered on disadvantageous/advantageous decks to learn the IGT. Nonetheless, these data support previous research that have shown that the contention that the non-conscious intuitive signals bias decisional choices in the early stage of IGT can no longer be confidently endorsed (e.g., Bowman et al., 2005; Fernie & Tunney, 2006; Fernie, & Tunney, 2013; Maia, & McClelland, 2005).
Conceptual knowledge and inspection time of the advantageous decks emerged after the second Block. This indicated that participants in the control group had gained sufficient knowledge about the deck contingences and were more focused on the good decks. This also suggests that explicit knowledge runs in parallel with participants’ deck selection. Similar results are reported in a study that used wagering to examine conceptual awareness (Konstantinidis & Shanks, 2013). Participants were able to develop preferences towards the advantageous decks and accurately justify their preferences. Thus, it could be argued that a considerable amount of awareness activates cognitive processing about the payoff structure of the IGT that leads to an optimal decision-making strategy. This argument is in line with Newell and Shank’s (2014) suggestion that conscious awareness diverts attention to positive decisional choices and recruits cognitive processes related to goal-directed behaviour. According to this view, conscious awareness initiates executive attention that further initiates executive functioning (e.g., WM) that reflects on the specific components on the task at hand. The results from this experiment certainly indicate that conscious awareness, attentional processing and analytic ability arise early in the game, however the causality of their influence in relation to leaning IGT is yet to be established. Nevertheless, the results indicated that participants who reflect more on their responses have a higher awareness of the deck contingences and are focused more on the good decks early in the game which is an indicator of explicit Type II processing.

**Mediation analysis**

The mediation analysis revealed that learning and performance on IGT are multifaceted. The effect of stress on overall IGT performance occurs through reduced reflective and conscious capacity rather than different routes. This is in line with Preston et al.’s (2007) and Simonovic et al.’s (2016) argument that stress disrupts Type II cognitive processes. Furthermore, conceptual knowledge emerged as an additional mediator to the previously suggested reflective ability (e.g., Simonovic et al., 2016). The mediators reduced the direct effect of stress manipulation on IGT scores. However, the analysis revealed a not very strong connection between the mediators and overall IGT scores. This raises the possibility that the mediators are not strongly related to each other. Nonetheless, the data indicate that the IGT performance is not primarily dependent on emotion feedback processing and are instead compatible with the recently suggested dual process framework of decision-making (Brevers et al., 2013). However, contrary to Brevers et al.’s suggestion that the ‘hot’ processes guide successful performance, results from this experiment indicate that the Type II processes guide decision-
making on the IGT. If there is a role for emotion-feedback processing and the Type II processing early in the game, then it could be argued that a complex interaction between the different components give rise to the somatic markers. This is in line with evidence from reasoning literature that the conflict between the Type I and Type II processes can be psychophysiologicaly arousing (e.g., Evans, 2003; Kahneman & Frederick, 2005; De Neys & Glumicic, 2008; De Neys et al., 2010). Thus, it could be argued that it is not the emotion-based processing that creates the arousal, but the cognitive processing during the early stages of the task where participants’ cognitive effort is employed for learning decks contingences. If there is a lack of or insufficient cognitive processing early in the game this may create a somatic signal.

In conclusion, the results of this experiment replicate and extend previous studies that have demonstrated a link between stress and IGT performance. Moreover, the experiment demonstrated the importance of reflective cognition, attention and conscious knowledge not only in later trials but also in the earlier trials usually associated with learning the task. The results indicate that induced stress impedes analytical thinking, attentional disengagement, and development of the conscious knowledge that consequently interferes with performance on the IGT. The results of this experiment are not definitive but provide broad support for the dual-process framework of decision-making. The importance of attentional control and conscious awareness was demonstrated, (as in the previous experiment) and this accords with the hypothesis emerging from the thesis that there is a complex interplay between the cognitive processes during IGT performance. Certainly, the pattern of attentional control and cognitive reflection that guides learning observed in the previous experiment was replicated here in addition to the conscious awareness.
Chapter 6

Overview

This chapter details a summary and general discussion of the experimental results in relation to the SMH and dual-process framework. First, a summary of the empirical results is provided, and the results of each experiment are discussed in turn. Second, the methodology that is used in this Thesis is discussed and certain caveats highlighted regarding the results. Third, theoretical implications of the results and some direction for future research are discussed. Finally, a conclusion is provided in respect to the findings of this Thesis.

6.1. Summary of empirical results

SMH postulates that emotions play an important part in decision-making (e.g., Damasio, 1994). Behaviour on IGT (Bechara et al., 1994, 2000) has been interpreted as support for the SMH. Three critical assumptions have been made in support of the SMH. These are: (i) somatic markers guide decision-choices away from the bad decks as participants are able to anticipate the good and the bad options, (ii) there is a limited role for cognitive processes during IGT performance, especially during the initial stages of the task, and (iii) somatic markers bias decision-making covertly, in the absence of the awareness of deck contingencies. The systematic review with meta-analyses and the experiments described in this Thesis examined these assumptions and found little evidence in support of the SMH. There were several objectives that this thesis aimed to achieve, and these were: a) to systematically examine aSCRs evidence in support of SMH (Chapter 2), b) to test if pupil dilation can be used as an alternative measure of somatic markers and to test cognitive processes during IGT performance (Chapter 3), c) to examine explicit learning, individual differences in thinking disposition and cognitive processing during IGT performance (Chapter 4), and to examine the effect of stress on IGT performance and cognitive processing (Chapter 5). The experimental results demonstrated that the explicit processing might be very relevant during decision-making on IGT. Furthermore, the experiments provided support for the recently proposed dual-process framework of decision-making on IGT (e.g., Brevers et al., 2013).

6.1.1. Chapter 2 Results

Chapter 2 explored if there is evidence in support of the aSCRs effect on IGT performance. The systematic review and meta-analyses revealed contrasting results. The first analysis
examined the effect of overall aSCRs on IGT performance and the second analysis examined the differences in aSCRs between the disadvantageous and the advantageous decks. The first analysis provided some support for SMH with reliable results that overall aSCRs correlate with successful IGT performance. However, the second meta-analysis showed that the results were not homogeneous and indicated an absence of evidence that there is a clear distinction in aSCRs between the disadvantageous and advantageous decks. This novel finding raised the possibility that aSCRs measures cannot distinguish decisional outcomes according to the goodness and the badness of choices. This would be problematic for SMH because it challenges the underlying assumptions that somatic markers differentiate between the good and the bad choices that consequently drive future deck selections behaviour (e.g., Bechara & Damasio, 2005). The systematic review also indicated that aSCR might represent a response to reward and punishment feedback rather than a marker of how good or bad a selected option is (e.g., Suzuki et al., 2003). This suggests that anticipatory somatic markers may not be directly involved in decision-making and that the traditionally employed SCR measurements are unable to distinguish between different somatic markers signals. Furthermore, both analyses revealed small effect sizes, indicating that other factors may be important during IGT performance. For example, if there is an anticipatory signal that precedes disadvantageous deck selection then it could be argued that signal leads to a non-optimal behavioural performance (e.g., Dunn et al., 2006). Thus, these results provide some support for SMH but also raise the possibility that faster physiological measures are needed to further test the SMH.

### 6.1.2. Chapter 3 Results

In the third chapter, an eye-tracking methodology was used to measure pupil dilation as an alternative physiological marker; and a direct measure of cognitive reflection was used to examine performance on IGT. The standard interpretation of somatic markers is that future optimal choice is determined by previously encountered negative feedback during a monetary loss that biases processes of cognitive evaluation in the later trials of the game (e.g., Bechara et al., 1997, 2000). The findings from the Experiment 1 showed little support for this suggestion. These novel findings demonstrated that cognitive processing impacts on IGT performance early in the game which raises the possibility that somatic markers may be correlates of cognitive load rather than emotional feedback. Thus, evidence was found undermining the second assumption that there is a limited influence of cognitive processing early in the game. This is further demonstrated in Experiment 2 and 3; learning did not occur without cognitive evaluation of the bad choices which suggests that explicit knowledge is
important for learning and subsequent IGT performance. This also raises the possibility that the observed increase in the anticipatory pupillary responses develops from cognitive processing. Furthermore, Bechara et al.’s (1997, 1999, 2000) suggestion that the healthy participants should perform optimally on the IGT, whereby the peak of the optimal performance should be observed after the fourth trials was not supported. The results demonstrated that the performance on the IGT continues to improve after the fifth trial and this was further supported by the results from the Experiments 2 and 3 (control group). Taken together, these results provide support for recent assertions that the explicit processing occurs early in the game and guide successful IGT performance (e.g., Maia & McClelland, 2004; Fernie & Tunney, 2013; Simonovic et al., 2016). Thus, it is concluded that IGT behaviour is best explained within the dual-process framework.

6.1.3. Chapter 4 results

The third assumption of IGT behaviour in the SMH framework is that somatic markers bias decks’ selection covertly in the absences of conscious awareness and explicit processes. This was explored in chapters 3, 4 and 5. The results from Experiment 2 demonstrated several significant results that highlighted the role of Type II processes such that increased cognitive processing, explicit knowledge and cognitive reflection all have an impact on IGT performance. The results replicated findings from the Experiment 1 regarding the effect of cognitive reflection in the initial stages of the IGT. Increased cognitive processing, as measured by the inspection time, was also demonstrated for both disadvantageous and advantageous decks and these differed according to the nature of the decks. The importance of cognitive awareness was also demonstrated early in the game (from Block 2 onwards); conscious awareness had an effect on learning and performance on the task. However, it was noted that not all the participants developed Level 2 conceptual knowledge. One explanation for this behaviour is that participants’ Level 2 knowledge is not complete, and few possess accurate knowledge of the deck contingencies (e.g., Maia & McClelland, 2005).

In addition, it was found that there is an interplay between the conscious awareness and increased conscious processing such that conscious awareness alone is not enough for disambiguation of the deck contingencies. Greater cognitive processing of the advantageous decks was related to conscious awareness compared to the disadvantageous decks. This indicated that conscious awareness of disadvantageous decks alone is not sufficient for optimal performance whereby participants need to cognitively process and work out the reward and
punishment schedule to strengthen their decisional choices. Taken together these novel results add further empirical evidence to the increasing number of studies (Bowman et al., 2005, Evans et al., 2005; Fernie & Tunney, 2006, 2013; Maia & McClelland, 2004, 2005; Simonovic et al., 2016) that have reported the effect of explicit processing during learning and IGT performance. Furthermore, the results demonstrated an active role for attentional processing (as indicated by the inspection time) during the IGT, which is contrary to the suggestion that attention is determined by physiological arousal and by passively acquired information (e.g., Bechara & Damasio, 2005; Brand et al., 2007).

6.1.4. Chapter 5 results

Chapter 5 continued the exploration of cognitive processes on IGT albeit under stress. According to the SMH stress interferes with the development of somatic markers that are necessary for optimal IGT performance (e.g., Reimann & Bechara 2010; Starcke et al., 2017). Specifically, stress amplifies emotion that is not relevant to the task that alters the reward and feedback processing and generates a dysfunctional strategy during decision-making. The results of Experiment 3 do not support this contention. The results demonstrated that stress affects explicit processing such that it reduces the analytic ability, cognitive processing and conscious awareness of the bad choices. Specifically, stress reduces reflective and conscious processes that are important for disambiguation of the decks’ contingencies; this raises the possibility that insufficient cognitive processing early in the game may create a somatic signal that interferes with IGT performance No evidence was found to support the assumption that stress interferes with emotional feedback processing that impairs learning and IGT performance (cf. Starcke et al., 2017; Wemm, & Wulfert, 2017). Instead, these novel findings replicated and extended previous results that stress reduced cognitive processing lead to disadvantageous deck selection (e.g., Simonovic et al., 2016). This was demonstrated through the participants’ inability to disengage from the bad choices and through the lack of cognitive processing of the disadvantageous decks’ selection.

The main results from this Thesis can be summarised thus; explicit processing and explicit knowledge determine successful IGT performance. Type II processes play a significant role in learning and IGT performance. Participant performance is not optimal and continues to improve; and even a small amount of stress can interfere with performance because it hinders cognitive processes.
6.2. Methodology

6.2.1. Systematic review

Systematic review and meta-analyses provide very useful data synthesis (e.g., Bartolucci & Hillegass, 2010). However, it must be noted that despite many benefits, systematic reviews require access to a wide range of databases and peer-reviewed journals, which can be problematic and very expensive. This can sometimes undermine the objectivity of the search and retrieval process that could introduce a bias to the review processes. The systematic review in this Thesis aspired to be as objective as possible. Three independent reviewers had to reach an agreement about the studies’ inclusion criteria and the overall quality of the studies. This process presumably minimized the risk of inconsistent screening and increased the objectivity of the quality of the screening process. Another potential issue with meta-analyses is data availability as well as methodological diversity. To account for this issue, some of the authors were contacted directly and asked to provide additional information through personal correspondence. Although, most of the additional information was obtained, some of the authors (e.g., Denburg et al., 2006) were not able to provide meaningful data to be included in the meta-analyses. Nevertheless, the systematic review and meta-analyses provided a very good synthesis of the data and decision-making research should consider implementing these methods in the future.

6.2.2. Eye-tracking methodology

Changes in pupillary responses have been increasingly used as measures of cognitive and emotional effort (e.g., Fiedler & Glockner, 2012; Hewig et al., 2011; Preuschoff et al., 2011). The interpretation of pupillary responses varies according to the nature of the tasks used to assess decision-making (e.g., Costa & Rudebeck, 2016; Jepma & Nieuwenhuis, 2011; van Stegeren, 2008). The level of a task complexity may increase cognitive processing mode or elicit emotional responses to a triggered stimulus that is reflected by an increase in pupillary responses (e.g., de Gee et al., 2014; Preuschoff et al., 2011; Satterthwaite et al., 2007; Shiv et al., 2005). The results from the Experiment 1 demonstrated that anticipatory pupillary responses could be sensitive to the differences in the advantageousness of the deck contingences. It was argued that this might represent a somatic marker, although a possibility that this was due to cognitive processing could not be excluded. It has to be noted that the raw pupillary data contained some missing values and it was difficult to extract more meaningful information. Since it was not possible to ‘clean’ the data by using specialised software’s,
measures of pupillary responses were not processed with software that is usually recommended for quadric interpolation of the raw data (e.g., Satterthwaite et al., 2007). Therefore, the analysis of pupillary response measures in Experiment 1 was relatively narrow and further applications of the pupillary response methodologies are necessary to more fully explore the utility of this measure in investigating the IGT and the SMH.

Increased inspection time effect was associated with increased cognitive processing during the task performance that differed according to the nature of the decks in the Experiments 2 and 3. This is in line with evidence that associated longer inspection time with increased reasoning processing (e.g., Ball et al., 2003, 2006; Glockner, 2007; Glockner, & Betsch, 2008; Horstmann et al., 2009). However, it is not clear if an increase in inspection time reflected actual cognitive processing during IGT. Some evidence indicates that fixation duration acts as an external memory space that reduces demands on WM, and therefore can be taken as an indicator of cognitive processing (e.g., Droll & Hayhoe, 2007). Different evidence however indicates that decision-making on the complex tasks that involve working-memory processes could also be revealed though an increase in inspection time (e.g., Aivar, Hayhoe, Chizk, & Mruczek, 2005). Hence, decision complexity could increase the demand on WM processes, leading to longer inspection time that has an effect on learning (e.g., Bialkova & van Trijp, 2011; Fiedler & Glöckner, 2012). This contention is in line with the results from the Experiments 2 and 3 of this Thesis. It was evident that participants’ processing of the disadvantageous decks occurs early in the game and this probably increased demand for cognitive processing. This could also explain the early correlations between the cognitive reflection and disadvantageous deck selection. Thus, it could be argued that increased inspection reflects reasoning processes, but also captures the learning effect that is driven by the properties of the task demands.

6.2.3. CRT1

CRT1 (Toplak et al., 2014) was a very strong predictor of IGT performance in all the experiments. This is a strong indication that increased cognitive reflection is needed for disambiguation of the disadvantageous decks’ contingencies. This suggests that either: a) participants do not engage in deep thinking enough and are unwilling to invest cognitive effort during the IGT performance (e.g., Toplak et al., 2011, 2014); or b) that participants lack analytic ability and numerical skills (e.g., Stupple et al., 2013, 2017) to calculate frequencies of rewards and punishments of the disadvantageous decks. It could be argued that early attentional processing in the game reflects information collection and learning on IGT, whereby
supplementary analytical processes are needed for information integration and calculation of the learned outcomes. It has to be noted that the CRT1 is not the only extended version of the original CRT that could have been used in this Thesis (e.g., Primi, Morsanyi, Chiesi, Donati, & Hamilton, 2016; Thomson, & Oppenheimer, 2016). The CRT1 measure was chosen because it is a potent measure of cognitive reflection that is associated with decision biases and responses time (e.g., Alos-Ferrrer et al., 2016), cognitive skills (Corgnet et al., 2016) and analytic reasoning styles (e.g., Hertzog et al., 2017; Rinaldi et al., 2017; Ring et al., 2016) that may be important for IGT performance (e.g., Simonovic et al., 2016). The replication of these Thesis findings with a wider range of CRT tasks could provide further insight into cognitive processes related to IGT performance.

6.2.4. Conscious awareness

Maia and McClelland’s (2004) conscious awareness test was a reliable predictor of IGT performance. Level 1 and Level 2 conceptual knowledge emerged early in the game and influenced IGT performance above the chance. Thus, conceptual knowledge after the second Block was sufficient to guide successful decision-making in the Experiments 2 and 3. This is in line with previous research that used this measure and demonstrated similar results (e.g., Maia & McClelland, 2004, 2005, Fernie & Tunney, 2013). Note, however, that the participants were not asked to verbalize their reports because of the possibility that the verbal reports may not be sufficiently reliable and sensitive instruments for measuring awareness (e.g., Persaud et al., 2007; Newell & Shanks, 2014). Thus, only the quantified measures were used because of the suggestion that this meet reliability criterion, sensitivity criteria and a stringent insight criterion related to conscious awareness (e.g., Newell & Shanks, 2014). However, it has to be noted that even the use of stringent criteria may be elusive because it is difficult to obtain measures of conscious awareness that are simultaneously exclusive and exhaustive (e.g., Velmans, 2009). Nevertheless, in addition to the results obtained from the CRT1 measure and inspection time, conscious awareness during IGT performance clearly indicates a role for explicit knowledge and Type II processes early in IGT. Furthermore, the results also indicate that there is a complex interplay within the Type II processes. Conscious awareness was associated with increased processing effort (inspection time) and it could be argued that conscious awareness may facilitate Type II processing (e.g., Shea, & Frith, 2016).
6.2.5. Thinking disposition measures

There is some evidence that individual differences related to sensitivity to rewards and
punishment and measures of personality, behavioural activation and inhibition, neuroticism
and sensation seeking could have an effect on IGT performance (e.g., Buelow & Suhr, 2013;
Carter & Pasqualini, 2004; Franken & Muris, 2005; Hooper, Luciana, Wahlstrom, Conklin &
Yarger, 2008; Mardaga & Hansenne, 2012). The thinking disposition measures used in this
Thesis demonstrated non-significant results. This suggests that self-reported measures of how
participants experienced their own cognitive processes did not correspond with their actual
cognitive ability. The REI, AOT and CFC are often employed as measures of the reflective
processes that are important for collection and generation of the alternative answers during
decision-making (e.g., Evans & Stanovich, 2013; Toplak et al., 2010). One of the reasons why
these measures were not related to IGT performance could be the structure of the IGT. Learning
the IGT occurs through the experience of direct gains and losses, where the occurrence of losses
is sporadic and needs to be remembered and calculated. Hence greater processing of the
punishment schedule is needed than the integration of consistent rewards for optimal IGT
performance (Harman, 2011). Another reason why these self-reported measures of thinking
disposition yielded non-significant results could be motivational biases in explicit self-reports
and social-desirability bias (e.g., Dunn et al., 2006, Newell & Shanks, 2014). Newell and
Shanks (2014) propose that reliable explicit self-reports need to be relevant to the task in order
to provide a valid measure of and individual self-reported insight. Self-reported measures of
sensitivity to rewards, punishments and types of personality have been found to correlate with
IGT performance (e.g., Carter & Pasqualini, 2004; Franken & Muris, 2005; Guillaume et
al.,2012) and could be further investigated as they may be the sources of individual
differences variability in IGT performance.

6.2.6. Blood pressure

The measurement of the arterial pressure waveform on the finger with the Finometer (Finapres
Medical System, Amsterdam, The Netherlands) was effective. The Finometer has become an
accepted technology widely used in different areas of research such as autonomic control of
cardiovascular function, hypertension, pharmacology, psychophysiology and decision-making
(Evers et al., 2013; Huisman et al., 2002; Schutte et al., 2003; Schwabe, Bohringer, Chatterjee,
& Schachinger, 2008). Finometer measurement fulfils the accuracy requirement for blood
pressure and heart rate variability because it has upgraded filtering software (Schutte, Huisman,
van Rooyen, & Schutte, 2004). Heart rate and blood pressure were successfully measured in previous studies that tested IGT performance (e.g., Crone et al., 2004; Preston et al., 2007) and the measure obtained from Experiments 2 and 3 further contribute to the understanding of the physiological arousal during IGT performance. It has to be noted that due to equipment failure (a certain part of the equipment that enables a direct connection to the IGT software was missing), it was not possible to obtain more specific measurement (e.g., anticipatory heart rate or blood pressure measurements) related to the IGT performance. Nevertheless, this methodology could be used as an alternative tool that measures somatic markers (e.g., Crone et al., 2004).

6.3. Theories

Damasio’s (1994) suggestion that somatic markers increase sensitivity to different possible outcomes during the IGT that may be captured through physiological measures is not fully supported. It is possible that an individual employs a conscious strategy based upon the idea that outcomes that have occurred recently become less probable in the future. SMH proposes that decision-making first involves mapping the currently experienced situation to knowledge about emotional responses in previously experienced similar situations. This previous knowledge is assumed to be unconscious. The second set of processes involves explicit recall of relevant facts pertaining to the consequences of previous choices, and the activation of relevant reasoning strategies. In this case, the relevant knowledge and processes are assumed to be largely available to conscious awareness. This suggestion maps on the dual-process framework of decision-making where the role of Type I processes can be then conceptualized as a two-step process: a) unconscious knowledge and previous experience are first marked with the somatic markers; b) this signal is then used to further influence explicit knowledge. However, the problem for the SMH results from the claim that early stages of the task depend mainly on unconscious anticipatory signals that guide learning and performance on the task.

The claim that anticipatory somatic markers guide deck selection on the IGT prior to the development of conscious knowledge and without the explicit processing early in the game is central to the SMH. This version of the SMH has been used in the majority of the published studies that have examined IGT performance. Several authors challenged these assumptions by showing that knowledge of the deck's contingencies and cognitive processing occurs early in the game (e.g., Maia & McClelland, 2004, 2005; Fernie, & Tunney, 2006, 2013; Simonovic et al., 2016). The Experiments in Chapters 3, 4 and 5, have extended these challenges and
demonstrated that conscious knowledge and explicit processing of the deck contingencies is the critical component of the learning and performance. Without explicitly processing information that disadvantageous decks are bad and that the alternatives are qualitatively different, participants did not learn to select advantageously. Results from the Experiment 1 left open the possibility that differential somatic markers could be of a cognitive nature. This indicates that somatic markers reflect cognitive load or cognitive demand, that is instigated by conscious knowledge and explicit processing early in the game. If somatic markers do not precede conscious knowledge and explicit processing, then it is also possible that they occur as a result of knowledge and early cognitive processing but not as a covert bias that feeds into knowledge development. The importance of the early cognitive processing and the emergence of conscious knowledge demonstrated in Experiments 2 and 3 support such a contention which is further supported by the evidence about the importance of the executive component of WM in IGT selection (e.g., Hinson et al, 2003; Jameson et al, 2004).

Another concern for the interpretation of IGT behaviour in relation to the SMH is that a substantial proportion of the healthy participants do not perform optimally on the task and select disadvantageously (e.g., Dunn et al., 2006; Steingroever et al., 2013). Bechara and Damasio (2002) and Bechara et al. (2001, 2002) reported that between 30 and 40% of the healthy population does not behave advantageously. This is also reported in further studies (e.g., Bowman & Turnbull, 2003; Evans et al, 2004; Crone et al, 2005). The results from the experiments in this Thesis demonstrated that optimal performance did not reach ceiling after Block 4 and improved with additional trials. These results are problematic for SMH as it has been argued that non-optimal performance of the healthy population raises a question about the ecological validity of the IGT (e.g., Dunn et al., 2006). If healthy participants do not learn to select from the advantageous decks but presumably have no emotional impairment in decision-making, then the efficacy of the IGT as a test of such functioning is uncertain. For example, the variability in healthy participants’ performance complicates the interpretation of IGT data. The differences in performance between the clinical and the healthy population may be due to intact decision-making ability in the clinical population or it may be due to poor performance in healthy control (e.g., Steingroever et al., 2013). Furthermore, if a considerable number of healthy population perform disadvantageously on IGT, and presumably do not demonstrate any decision-making deficit in real life, it is not clear to what extent IGT measures real-life decision-making (e.g., Dunn et al., 2006). Thus, a possible re-evaluation of IGT is
needed in order to be accepted as a valid tool that measures decision-making deficit in a clinical population.

Taken together the results from these experiments and the systematic review indicate that it is difficult to avoid concluding that either: a) IGT is not an adequate experimental paradigm for the demonstration of somatic markers; b) currently employed SCR measurements do not adequately capture somatic markers; or c) somatic markers are a part of the processing system that underlies Type I intuitive processing. These conclusions do not, of course, denote that there is no such thing as a somatic marker. For example, Osumi and Ohira (2010), used the Ultimatum Game and demonstrated the presence of somatic markers by using pulse-rate deceleration and functional magnetic resonance imaging scan (fMRI). They found that the brain activation differences in right insular activation were related to pulse-rate deceleration reactivity that was attributable to decision-making whether to reject or accept an offer. Thus, the study showed a clear connection between the brain processes, physiological responses and decision-making with an important role for somatic markers in mapping decisional choices. Clearly, the SMH deserves further investigation but it is also clear the IGT behaviour is difficult to explain within the SMH framework (e.g., Brevers et al., 2013; Dunn et al., 2006; Turnbull et al., 2014).

As discussed in Chapter 1, Brevers et al.’s (2013) dual process framework could provide a better explanation of IGT behaviour than the SMH. According to this view, emotion is related to ‘hot’ processing that guides successful decision-making. The ‘hot’ system is laden with affective tags or ‘gut feelings’, these are dependent on previous experience and can be regulated by the ‘cool’ processes. However, this framework is yet to receive empirical support and it needs conceptual clarification. For example, the ‘cool’ systems resemble the classification of Type II processes that map on the ‘traditional’ dual-process framework in decision-making (e.g., Evans & Stanovich, 2013). Similarly, the ‘hot’ systems map onto the Type I processes, but they are conceptually different. According to Brevers et al.’s account, the ‘hot’ systems operate through ‘slow and controlled processes and allow to hold on to a mental representation for contemplation and self-reflection during decision-making’ (p. 2). Hence, some properties of the Type II processes (e.g., slow and controlled processing) are integrated within the ‘hot’ systems. Conversely, according to Evans and Stanovich (2013), Type I processes are automatic, fast and include affective components. Hence, Type I process reflect intuitive and affect-laden processes that operate without deliberative and conscious thinking (e.g., Glockner & Witteman, 2010; Sadler-Smith, 2008). According to this perspective, intuition as affective
arousal might influence reaction to a decision choice based on the previously successful behavioural options during the task in hand or based on previous knowledge experienced from a similar task (Glockner & Witteman, 2010). Hence, the affective reaction is established by the personal importance of the decision in hand and by the conflict that emerges from different parts of information that informs the decisional choice (e.g., Pfister & Bohm, 2008). According to this view covert, affective arousal is often accompanied by the emerging interpretation of choices that enters cognitive awareness and further necessitates cognitive processing. Conversely, Brevers et al. do not assume covert bias for the affective arousal, and instead propose that ‘hot’ systems regulate emotional response, whereby emotion not integral to the decision-making may ‘hijack’ the ‘hot’ systems that consequently require intervention from the ‘cool’ systems although this is not explicit. Thus, this conceptualisation suggests a conflict between the ‘hot’ and ‘cold’ systems that are presumably mediated by affective emotional arousal.

A different account of IGT behaviour could be that: a) somatic markers represent an affective arousal to a decision choice; b) an imprecise somatic marker signal triggers Type I processing; c) both Type I and Type II processes operate on a continuum during decision-making; and d) Type II processes need to occasionally intervene during decision-making to disambiguate decision-choices. According to dual-process models, Type I processes are closely related to the processing of affective information (e.g., Kahneman & Frederick, 2002). Thus, affective information could play an important role in that is used as a signal to avoid or approach a stimulus (e.g., Clore, Gasper, & Garvin, 2001). However, the affective signal plays no role in learning and it just leads to the activation of the cognitive processes that then act upon the decision choice (e.g., Pfister & Bohm, 2008). Thus, Type I processes integrate affective signals with previous experience (this might include affective and cognitive parts of the previous experience) to transfer the experience into awareness (e.g., Glockner & Witteman, 2010). This contention is in line with research evidence demonstrating that dual-process conflict during logical and reasoning tasks create arousal (Stupple & Ball, 2008; De Neys & Glumicic, 2008) whereby, emotional/intuitive ‘gut’ feeling, signals conflict and triggers Type II processes. According to this view emotion often accompanies emerging awareness where the cognitive interpretation and processing of the arousing stimuli is then needed to provide an optimal choice. Hence, from this perspective Type I and Type II processes are relatively independent, share important features with one another and operate in parallel (e.g., Evers et al., 2013).
perspective could certainly account for the experimental results in this Thesis and could explain the early explicit processing during IGT performance.

Notably, the IGT is a complex task and the aforementioned arguments raise the question of how explicit learning guides successful IGT performance. For example, attentional processing could be proportionally distributed to all relevant outcomes according to the importance of rewards and punishments, thus determining what information enters analytic processes (e.g., Glockner & Witteman, 2010). Results from the Experiment 2 support this argument. Increased inspection time of the disadvantageous decks was observed early- in Blocks 1 and 2, and presumably informed further analytic processing that increased optimal learning of the bad deck contingencies - which could then shift selection towards the more advantageous decks. This is also in line with the results from Experiment 3. However, the Experiment 3 demonstrated that attention (increased inspection time) could be also focused on the specific but non-optimal criteria, which are then used as a starting point for the subsequent choices (e.g., Wilson, 2002). Stress impaired participants’ ability to disengage from the negative choices associated with disadvantageous decks. Furthermore, decoupling conscious awareness of the positive and negative ratings showed that conceptual knowledge of the nature of the disadvantageous decks is strongly related to overall optimal decision-making on IGT. Such differentiation between deck ratings suggests that accumulative losses encountered from the disadvantageous decks are a major driving force in IGT decision-making (e.g., Turnbull et al., 2014). Thus, the key to optimal IGT performance could be to explicitly learn and process disadvantageous decks contingencies. This is in line with Dunn et al.’s (2006) review results and the experimental results in this Thesis support this contention.

6.4. Future directions

The IGT is still used as a test of decision-making despite some difficulties in explaining cognitive processes that occur early in the game. This Thesis has made an important contribution to an understanding of explicit processes important for learning and subsequent performance during IGT decision-making. As well as highlighting the importance of using the faster methodology for capturing emotion-cognitive processes, increasing IGT trials could improve performance. Contributions have also been made in relation to the specific cognitive processes involved during IGT learning and performance. Furthermore, the results indicate that stress not only impacts emotional feedback processing but also explicit processing that is important for learning and IGT performance. Moreover, the dual-process framework could
provide a better and more parsimonious account of IGT decision-making than the SMH, which raises the possibility that somatic markers could be explained through the mechanisms of the affective components of the Type I processes.

The work on the Thesis has nevertheless generated questions as well as answers about IGT behaviour and its relationship with the SMH and dual-process theories. An important follow-up analysis would be to measure pupillary responses between the trials according to the anticipatory and feedback nature of the choice outcomes. This could provide further insight into emotion-cognitive processes during learning and if positive or negative outcomes of the decks guide successful learning and performance during the game. In terms of the future action, data from the Experiment 1 could be ‘cleaned’ with the required software to provide such an analysis. If somatic markers map onto Type I processes, some faster IGT-like measures could be used (e.g., BLINK, Peatfield, Turnbull, Parkinson, & Intriligator, 2011) to examine the effect of Type I processes on IGT performance. The BLINK model incorporates parameters of recency, attention and response consistency and could provide a useful insight into the fast and associative system that presumably contributes to learning and decision-making (e.g., Gigerenzer, 2004).

Several studies on emotion, reasoning and cognitive processing have indicated that the distinction between the ‘hot’ and the ‘cold systems is an oversimplification of possible complex interaction between the affective and cognitive pathways during decision-making (e.g., Gray, Braver, & Raichle, 2002; Greene, Nystrom, Engell, Darley, & Cohen, 2004; Hinson et al., 2006). Previous studies on IGT have shown that WM load disrupts the formation of somatic markers (e.g., Hinson et al., 2002; Jameson et al., 2004). A useful follow up study would measure different inspection times and whether cognitive load disrupts cognitive processes before and/or after fixation on the decision options. This would allow examination of whether poor decision-making results from interference with cognitive processes that are needed for learning and subsequent IGT performance. In addition, these measurements could be used to examine responses to the frequencies of rewards and punishments between the decks. This will allow for a closer examination of the disadvantageous decks as the successful performance on IGT mostly relies on disadvantageous decks disambiguation (e.g., Dunn et al., 2006; Turnbull et al., 2014).

Blood pressure and heart rate measures could be also used as an alternative somatic marker (e.g., Crone et al., 2004; Preston et al., 2007). The measures used in this Thesis were relatively
broad and it would be useful to measure physiological arousal to the specific outcome selection. It would be also useful to examine physiological arousal to decks’ selection separately. This will allow close inspection of the choices and if more risky decisions follow prior losses or prior gains from a specific deck (e.g., Silva & Gross, 2004). This could be then matched with conscious awareness measures and different cognitive reflection measures. Furthermore, different CRT measures could be inspected more closely for the correct and incorrect answers, because of the suggestion that not all the participants provide normatively intuitive responses (e.g., Stupple et al., 2017). Inspection time of the CRT1 responses is warranted as it will allow examination of the type of processing that could be related to IGT performance.

The effects of stress on explicit processing and explicit knowledge needs further replication especially in relation to CRT1. CRT1 was only administrated under stress and before the IGT (experiment 3). This was important because it revealed the participant’s capacity for Type 2 processing under stress, however it also raised methodological questions. There is, however a possibility that: a) this limited the predictability of CRT1; and b) this increased Type II processing in the control condition that may account for good IGT performance. In future experiments CRT1 could be administered before and after the stress manipulation to examine baseline vs stress CRT1 change. One way to understand successful learning and performance on the IGT is to examine whether participants are able to learn over time to inhibit the lose-shift pattern of responding to the disadvantageous decks following punishment. IGT studies have shown that stress can hinder learning and decision-making through disrupting emotional or deliberative processes (e.g., Preston et al., 2007; Simonovic et al., 2016; Starcke et al., 2017). Certain techniques (e.g., Mindfulness and Self-Compassion techniques) of stress reduction could be used to alleviate stress and to increase attention during the task performance. For example, mindfulness meditation and compassionate imagery have been associated with reductions in the size and duration of stress responses (e.g., Rockliff, Gilbert, McEwan, Lightman & Glover, 2008; Zeidan, Johnson, Diamond, David, & Goolkasian, 2010). The eye-tracking could include both the measurement of pupil dilation as an index of somatic markers and for participant gaze to be recorded to track the focus of their attention. This could provide insight into how decisions and learning take place in stressful circumstances and thus allow for more optimal decision-making under pressure; and this could lead exploring how these techniques could be used in everyday stressful situations (e.g., surgery).

Finally, it would be useful to explore alternative theoretical accounts of both SMH and dual-process framework. For example, according to the free-energy principle, for an organism to
maintain its organization as an adaptive living system, it needs to minimize its information-theoretic free-energy in its interactions with the environment (Friston & Stephan, 2007). This minimization can be achieved by predicting or anticipating sensory input (use of sensory acquired information) or by changing the environment (use of cognitively acquired information) to match what is anticipated (Clark, 2016). Thus, this type of predictive coding can be used to minimize prediction errors. Related to IGT performance, it is possible that higher order cognitive processes generate predictions during the task, that are matched with sensory information and result in prediction-errors about the goodness or badness of the deck. It is possible that individuals performing the IGT, need to adjust to, or get in tune with, their internal state to perform more optimally on IGT. Thus, interoception, defined as the sense of the physiological condition of the body (Craig, 2003), may play a role in IGT.

There has been increasing theoretical interest in the possibility that attentional control and internal bodily awareness (interoception) are connected to activity in the brain areas (e.g., insula, and cingulate cortex) that may help the optimization of the decision-making (e.g., Barttfeld et al., 2013; Craig, 2003; Kirk, Downar, & Montague, 2011). For example, participants’ heart rate perception accuracy correlates highly with optimal performance in decision-making tasks (Kirk et al., 2011). Pertinent to IGT performance, it may be that individuals paying attention to their internal bodily state make fewer errors than the individuals paying less attention to their internal state because they are attending to the present moment and use their bodily perception to infer the current causes of sensation. Thus, interoception may provide an explanation as to why some healthy participants fail to improve their performance on the IGT selecting more cards from disadvantageous than from advantageous decks. A future study could compare participants with accurate vs. inaccurate cardiac perception and sustained attention with respect to their IGT performance. Awareness of the Breath and a Body Scan could be used to assess hear-beat perception (e.g., Ehlers & Breuer, 1992; Schandry, 1982) and eye-tracking methodology to examine sustained attention. This may show whether varying access to somatic feedback among different individuals is responsible for differences in performance on the IGT and whether a relation between sustained attention and accurate cardiac perception increases IGT performance.

6.5. Conclusion
The role for anticipatory markers appears not to be in accordance with expectation stemming from SMH. Damasio (1994) argued that somatic markers help decision-making by diverting decisional choices from the bad or risky choices. However, the evidence points out that the largest somatic markers appear just before an individual makes the wrong decision (e.g., Bechara et al., 1996, 1997). Thus, the most obvious conclusion would be that the somatic markers indicate metacognitive uncertainty related to the choice. The SMH is an intriguing idea that needs clearer specification and more supportive evidence. The Dual-process framework could help to reintroduce the idea that emotion-laden processes are part of the intuitive Type I processes. Hence, the dual-process framework may integrate affective aspects of Type I processes with cognitive reasoning whereby intuitive processing captures decision-processes that reflects imprecise somatic marker signal that triggers Type II processing.

This Thesis has examined specific SMH assumptions and concluded that they could not be supported by a detailed examination of behaviour during the IGT performance. The importance of explicit processing during early stages of the game violates SMH assumptions and could be best explained within the dual-process framework. When somatic activities are measured by using pupil dilation, there is some evidence for the anticipatory function of the somatic markers; however, these somatic markers can be correlates of cognitive load or cognitive demand, rather than emotion feedback. This raises the possibility that either somatic markers do not play a significant role in learning IGT or that the IGT does not offer a complete test of SMH (e.g., Dunn et al., 2006). Hence, a caution is warranted when the IGT is used as a diagnostic tool from which to conclude deficient VMpfc functioning or myopic decision-making. To conclude, learning in a complex environment, such as the IGT, is determined based on explicitly processed information that helps learning and optimal performance. Full comprehension of the explicit processes is necessary to understand how learning on the IGT occurs.
References


Outcomes, Chiappelli F, Caldeira Brant XM, Neagos N, Oluwadara O, Ramchandani M (eds), 17–33. DOI: 10.1007/978-3-642-05025-1_2, © Sper-Verlag Berlin Heidelberg 2010.


Bechara, A., Tranel, D., Damasio, H., & Damasio, A. R. (1996). Failure to respond autonomically to anticipated future outcomes following damage to prefrontal cortex. *Cerebral Cortex*, 6(2), 215-225


**APPENDIX A**

A.1. Experiment 1, Ethics form

This form is for University members of staff and PhD students making applications to the Psychology Research Ethics Committee (PREC). Complete this form and submit it by email to the Chair and Deputy Chair of PREC. Information about submission and approval processes, deadlines, and meeting dates is given at http://www.derby.ac.uk/science/psychology/psychology-ethics-committee/

Once approval has been given, you will be eligible to commence data collection.

<table>
<thead>
<tr>
<th>1. Name:</th>
<th>Boban Simonovic</th>
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<tr>
<td>2. School/ Research Centre (if internal applicant)</td>
<td>Science / Centre for Psychological Research</td>
</tr>
</tbody>
</table>
| 3. Contact Information | Email: B.Simonovic@derby.ac.uk  
Site/Room no (if applicable): N301 |
| 4. Position: | Postgraduate researcher |
| 5a. Name of supervisor (Director of Studies) if you are PhD student: | Dr. Edward Stupple |
| 5b. Supervisor (Director of Studies) signature of consent: | I have reviewed this application and approve its submission: |
| 6. Title or topic area of proposed study | Eye-movements and decision making: Effects of intuitive and reflective thinking on decision making under ambiguous and uncertain conditions |
| 7. What are the aims and objectives of your study? | The aim of the proposed study is to investigate decision making performance in healthy individuals by using Iowa Gambling Task (IGT) and an eye-tracker monitor.  
Objectives: |

To examine thinking disposition among healthy participants related to decision making under uncertain conditions.

To examine somatic markers and attention using an eye-tracker (i.e. pupil dilation, number of fixations and mean fixation time) in relation to
advantageous/disadvantageous decision-making patterns during the IGT performance.

To examine which blocks of the IGT are related to learning/performance phase of the task, and how this relates to thinking dispositions of the healthy participants.

8. Brief review of relevant literature and rationale for study

Learning, making decisions and information management in uncertain or ambiguous situations is a key function in everyday life. Every simple decision has a potentially perplexing array of options that needs to be evaluated for making a best optimal decision. Damasio (1996) developed the Somatic Marker Hypothesis (SMH) in order to explain optimal decision making. The theory postulates that the foundation of optimal decision-making rests on the positive or negative emotional reactions to prior outcomes of choices, rather than rational, cognitive calculation of gains and losses. It is assumed that the emotional reactions guide decision making by creating positive or negative somatic markers. Bechara, Damasio, Damasio and Anderson (1994) developed The Iowa Gambling Task (IGT) that is often used as an experimental tool for assessing SMH. It is argued that the IGT resembles real life decision making, and it is characterised by the uncertainty of punishment and reward outcomes. When performing the IGT, participants have to choose among four decks of cards with different frequencies of gains and losses in order to learn to select from the most advantageous card decks to obtain the greatest gains. Research evidence from the patients with lesions of limbic structures, neurological diseases or psychological disorders have emphasised the importance of emotional processes in deciding advantageously during the IGT performance. In contrast, analytic thinking was regarded as having much less importance. Early evidence suggested that developing somatic markers should help people making the right decision and avoid taking a risky choice (e.g., Bechara et al., 1994). However, contrasting evidence discovered that the largest somatic marker occurs just before making the erroneous decision (e.g., Bierman, Destrebecqz & Cleeremans, 2005).

While research has identified the effectiveness of the IGT in clinical research, Steingroever, Wetzelsa, Horstmann, Neumann and Wagenmakers (2013) have called for greater scrutiny of the performance of healthy controls on the IGT. Steingroever et al. indicated that there is a substantial individual variability during the performance of healthy participants whereby, individual choices are driven by frequency of losses rather than the long-term outcome of the decks. This challenges the assumption that the performance of healthy participants is optimal.

Previous research further indicated that implicit processing (e.g., processing the feedback of previous trials and associated emotional responses) may significantly contribute to advantageous decision making in the IGT (e.g., Bechara et al., 1994). However, a dual process account of IGT performance, presented by Brevers et al., (2013) emphasises a deficit in “cool” reflective processes among pathological gamblers in contrast to healthy controls. They also argue that the hyperactive emotional processing can ‘hijack’ the reflective mechanism that detects problematic future outcomes from disadvantageous decks and thus lead to disadvantageous card selections. This suggestion needs further examination among healthy participants. Furthermore, on the basis of dual-process model of self—regulation,
executive functions depend on the integrity of ‘cool’ and ‘hot’ neural systems. A ‘cool’ executive function includes analytical thinking and problem-solving disposition while ‘hot’ executive functions include regulation of emotional responses and inhibition of impulsive reaction. There is also a suggestion that the IGT comprises learning and performance phase, however determining the point to delineate learning and performance phases is somewhat controversial. For example, Schiebener, Zamarian, Delazer, and Brand (2011) suggest that the learning phase includes the first 40 trials; Bechara and Damasio (1997) suggest 50 trials; and Preston et al., (2007) argue for 60 trials This distinction needs further examination especially within a healthy population.

The relationship between optimal decision making in the IGT and experiential, affective reactions has been demonstrated in studies using skin-conductance response (e.g., Bechara, Damasio, Damasio, & Lee, 1999; Bechara, Damasio, Tranel, & Damasio, 1997). In order to clarify the role of intuitive (experiential) and analytical reasoning systems during the IGT, an investigation of somatic reaction to potential options before actually making a choice is needed. One simple indicator of autonomic nervous system activation is pupil size variation. Research indicates that there is a relation between the pupil size and affective and cognitive processing of the information (Bierman, Cleeremans, van Ditzhuyzen, & van Gaal, 2004). By using pupil size as a somatic marker, it is possible to differentiate between somatic markers on potential options and provide a relatively clearer picture about the role of implicit learning during the decision-making task. Thus, using an eye-tracker will provide a clearer distinction between reflections on positively and negatively marked options during the IGT. Furthermore, previous research suggests that using an eye-tracker may be useful for understanding a complex interplay between experiential and executive functions processes, information searching and implicit learning (Horstmann, Ahlgrimm, & Glockner, 2009; Bierman et al., 2004). Therefore, an eye-tracker can potentially be a very useful tool in providing evidence about the involvements of intuitive or analytical reasoning during the task.

Additionally, behavioural strategies and executive functions in healthy participants need stronger methodological measures that can tease out the processes involved in decision-making. The proposed study will test aspects of dual process account of IGT performance in healthy participants by using an eye-tracker. Furthermore, the study aims to examine critical thinking aptitude and disposition by using measures that can possibly explain types of processing in decision making, i.e. extended version of the Cognitive Reflection Test (Toplak, West & Stanovich, 2014).

An eye-tracker will measure pupil size which will be used as a somatic marker. It is expected that pupil size decreases at the beginning of the task when making disadvantageous choices. The use of an eye-tracker will help to differentiate between somatic reactions on each viable option before deciding. Pupil dilation refers to the difference in pupil size between periods
of task processing and periods of rests. Based on the previous research an increase in pupil size should be demonstrated when looking at the disadvantageous decks (e.g., Bierman et al., 2004). Furthermore, number of fixation and mean fixation duration will be investigated. Mean fixation duration refers to the average duration of single fixation in a decision. Research indicates that executive processes are associated with longer fixations, whereas more intuitive processing is accompanied by shorter fixations (Horstmann et al., 2009). Single fixations will be categorized according to Horstmann et al.’s suggestion in short (<150 ms), medium (≥150 and < 500 ms) and long (≥ 500 ms) fixation durations resulting in the variable time category.

9. Outline of study design and methods

The present study is a quantitative experimental research that will be conducted on-campus. Eye-movements will be recorded using the Eye-gaze binocular system (Tobii-X2-30), with remote binocular sampling rate of 30 Hz and an accuracy of about 0.45°. The first administrated task (CRT) will measure participants’ tendency to engage in reflective thinking followed by the IGT task. Bechara et al.’s (1994) computerised version of IGT will be used for the purpose of this study. The equipment and the material will be stored in room (T038) where the experiment will take place. The IGT involves virtual money and participants will not risk their own money. Non-clinical, student population will be recruited via the university website and student forums. Participants under the age of 18 years old will not be allowed to participate in this study. Participants will be asked for general demographic information. Following briefing and informed consent the researcher will explain the rules of the task, what is involved and what kind of measurements will be taken during the performance.

This study will test a somatic markers account based on pupil dilation variation. The numbers of disadvantageous/advantageous picks will be calculated and correlated to individual variations in pupil dilations. Furthermore, participants’ cognitive disposition abilities and type of processing during the IGT performance will be assessed. The study will comprise 110 participants who will each perform the task once. The IGT involves four decks of cards (A, B, C and D) and the game consists of 100 trials that is usually broken down to 5 blocks of 20. In the IGT, following each selection, a specified amount of fictitious money is awarded. However, at certain times, losses of different fixed amounts occur. Two decks of cards, C and D, are advantageous, as they result in small immediate gains, but also very small losses and will therefore return greater money in the long run, than that which is given out. The other two decks (decks A and B) produce high immediate gains. However, because very high losses occur at certain times, more money will be lost than gained (disadvantageous decks). Participants are required to learn to avoid bad decks by following their hunches and guesses, and by using feedback from previous trials. The IGT involves virtual money and participants will not risk their own money. However, a cash prize reward will be offered for the first and
the second highest score (£70/30) on the game in order to facilitate recruitment and increase motivation for participation in this study. The role of incentives in motivating experiment participation has been widely documented and shows that money may be more effective than non-cash incentives (e.g., Church 1993; Groves, Presser, Dipko 2004; Singer, & Couper, 2008). Cumulative scores for the gambling task will be calculated by adding the total net scores from all trials.

The IGT task will be extended to 140 trials to examine the transition from learning to performance phase during the task. It is predicted that there will be strong correlation between the performance in the latter trials of the IGT and measures of analytic thinking.

The dependent variables in this study are the pupil dilation and the CRT scores. Firstly, it is hypothesised that participants will have larger pupil dilation when looking at disadvantageous decks (i.e. A and B). Secondly, it is hypothesised that participants have higher number of long fixation at advantageous decks (i.e. C and D). And lastly, participants who are more reflective will perform better on IGT than participants who are less reflective. Pupil dilation will be calculated as peak pupil dilation scores, that is, the maximum increase of pupil size from baseline (measured at blank screen and fixation cross before each decision) in the same time period. Pupil dilation will be measured as radius in mm. Single fixations will be categorized in short (< 150 ms), medium (≥ 150 and < 500 ms) and long (≥ 500 ms) fixation durations resulting in the variable time category.

Pupil dilation will be regressed to average mean with standard deviation scores. Then ANOVA will be used to determine if pupil dilation variability increased between the baseline measurement and task measurement. Separate linear regression will be used to see is there a relationship between the eye tracking measurements and Cognitive Reflection Test (CRT). Separate ANOVA’s will be used to determine the effect of reflective thinking (CRT), pupil dilation and periods of fixation on IGT scores during the learning and performance phase. Finally, multiple regression will be conducted to determine to what extent CRT scores pupil dilation and periods of fixation will predict IGT scores in the learning and performance phases of the IGT.

10. Sample: Please provide a detailed description of the study sample, covering selection, number, age, and if appropriate, inclusion and exclusion criteria.

Participants will be recruited at the University by using e-mails and by contacting various student groups. A study-related announcements and recruitments materials (such as invitations to participate) will be handed in classrooms (with collaboration and approval of the lecturers) or outside classrooms. GPower software was used in order to determine the number of participants needed to detect medium effect sizes. Thus, for moderate effect sizes (d= 0.5, Alpha= 0.05, Power= 0.80) a total number of 110 participants is sufficient (both...
males and females). Participants under the age of 18 years old will not be allowed to participate in the study. An opportunity samples (student participants) will be recruited for this study. Participants with previous knowledge of the IGT or the CRT, and participants with a history of brain injury will be excluded from the study. Participants will be asked about their general health, history of brain injuries and familiarity with the task prior to commencement of the experiment.

11. Are payments or rewards/incentives going to be made to the participants? If so, please give details below.

Participation points will be given for face-to-face participation (2 points).

Do you intend to give Participation Points for taking part in your study? Yes (Delete as appropriate)

12. What resources will you require? (e.g., questionnaires, equipment, for example video camera, specialised software; if questionnaires are to be used please give full details here).

Extended version of the Cognitive Reflection Test will be used (CRT, Toplak, West & Stanovich, 2014). This will offer a measure of reflective thinking that can evaluate individual differences in reflective processing among participants engaging with the IGT. This test is constructed to measure peoples’ aptitude to engage in reflective thinking whereby the more reflective you are the more likely you are to inhibit initial response to a problem (heuristically derived) and engage in finding an alternative solution to a problem.

The scales are publicly available and there are no copyright issues.

Bechara et al., (1994) computerised Iowa Gambling Task (IGT) is frequently used as an experimental task in the decision-making research, and the University holds a copy of the IGT that will be used in this study.

http://www.millisecond.com/download/library/IowaGamblingTask/
The use of the Eye gaze binocular system (Tobii-X2-30) will be undertaken after supervised training and the equipment used will be located in psychology laboratories.

13. References Give the references for any sources cited in the sections on rationale, methods etc.


14. Ethical Considerations Please indicate how you intend to address each of the following in your study. Points a-i relate particularly to projects involving human participants. Guidance to completing this section of the form is provided at the end of the document.

a. Consent
The participants will be fully informed about the goals and purpose of the study prior to giving consent, as well as known risks attached. The participants will be asked to fill out formal consent form, once they have agreed to take part in the experiment (see appendices).

b. Deception
No deception will occur at any time.

c. **Debriefing**

At the end of the experiment the participants will be provided with full written debrief where they will be informed about the purpose of the study, and they will be provided with contact information for future correspondence and additional information’s (i.e. researcher email, student service centre).

d. **Withdrawal from the investigation**

Prior to the experiment, the participants will be fully informed that their participation is voluntary, and that they are allowed to withdraw from the experiment at any time and any answers they had given up to that point would be deleted. If they decide to withdraw their data after they had taken the experiment, they will be allowed to do so within the time limit of four weeks from the day that they completed the experiment (the email address of the researcher will be provided with the debrief document).

e. **Confidentiality**

To provide anonymity and confidentiality participants will be asked to create a unique code, which will be a combination of the last two letters of their favourite film and the last two digits of their mobile number. They will be asked not to reveal any personal details. Participants will be asked to leave their email addresses if they wish to opt in to the prize for the best task performance. It will be explained that the email address is only for contacting the highest scorers on the gambling game and that it will be deleted immediately after the prize has been awarded.

f. **Protection of participants**

There is no deception involved and participants will be assured anonymity. No lasting harm will occur as a result of this experiment. Participants under the age of 18 years old and participants with a history of brain injury will not be allowed to participate in the study. Research will be conducted during office hours and the researcher will adhere to the BPS Guidelines for Ethical Practice for conducting laboratory experiments.
g. Observation research [complete if applicable]
Not applicable

h. Giving advice
I will only be providing the relevant information in regard to the experiment and the phenomenon in question. If participants are concerned about anything else, they will be advised to contact the student services at University of Derby. Furthermore, the researcher will act in accordance with both the BPS ethical principles and adhere to the codes of conduct outlined by the University of Derby to ensure ethical conduct and knowledge development.

i. Research undertaken in public places [complete if applicable]
Not applicable

j. Data protection
The experimental data will be password protected and stored on external drive. The data collected will be accessible only to the researcher and his supervisors. All paper data collected will be stored in a secure locked cabinet, in a locked room.

k. Animal Rights [complete if applicable]
Not applicable

l. Environmental protection [complete if applicable]
Not applicable
15. Have/do you intend to request clearance from any other body/organisation? 
Yes/No (please circle as appropriate)

If Yes – please give details below.

16. All projects have an element of risk which should be assessed before any project is undertaken.

Have the activities associated with this research project been risk assessed? Yes □ No □

17. Declaration: The information supplied is accurate to the best of my knowledge and belief. I understand my obligations and the rights of the participants. I agree to act at all times in accordance with University of Derby Ethical Policy for conducting research with human participants. □
A.2. Ethical Approval

Approval Letter: Psychology Research Ethics Committee

University of Derby

Date: 15th October 2014

Dr Frances A. Maratos
Chair, Psychology Research Ethics Committee, University of Derby

Dear Bob,

Ethics Ref No: 25-14-BS

Thank you for submitting this revised application to the Psychology Research Ethics Committee.

I have now reviewed the revised documents you sent following the feedback you received on your initial application, and I am satisfied that all of the issues raised have been dealt with. The application can now therefore be approved.

The following documents have now been re-reviewed:

1. Revised Ethics application form
2. Revised IGT Instructions
3. Revised invitation to participate
4. Revised debrief

If any changes to the study described in the application or supporting documentation is necessary, you must notify the committee and may be required to make a resubmission of the application.

Good luck with the study.

Yours sincerely

F. A. Maratos

Frances A. Maratos
A.3. Materials

Toplak et al. (2014) extended version of the CRT

This is removed for copyright reasons Please see the original paper

‘IGT instructions and procedure (Bechara et al., 1994) adopted for the computerised version

This is removed for copyright reasons Please see the original paper


INVITATION TO PARTICIPATE

My name is Boban Simonovic. I am a postgraduate researcher studying for a PhD award at the University of Derby. As part of my research I am interested in decision making under uncertain conditions.

The aim of the present research is to explore people’s decision-making abilities under uncertainty. A computer gambling game is involved. If you decide to participate in this research, you will be asked to complete the gambling game and a series of problem solving tasks. During the study we will be using an eye tracker device as a monitoring tool to measure gaze direction and pupil dilation.
The experiment should take no more than forty-five minutes. You will play the gambling game with virtual money. You are, however, encouraged to play the game to the best of your ability. You will receive two participation points for taking the part in this study.

Participation is voluntary, and all information recorded will remain anonymous and confidential. Data recorded for this study will not be used for any other purpose than the study itself. Data will be stored in accordance with data protection laws and University of Derby data collection and storage policies. Please note that you may withdraw your consent for participation at any time during the study. If you choose to withdraw your data after taking the part, please contact the researcher (see below) using your unique code. Withdrawal from the study will result in all participant information being destroyed and will not be included in any analysis. Participant withdrawal is available up to 4 weeks after participation.

To ensure anonymity of the data you will be asked to create your unique reference number. Once you have completed the experiment, please keep a note of your reference number and quote it in any future correspondence. You will be asked to give your email address. This will be used for contact purposes only if you are a winner of a cash prize. Email addresses will be deleted immediately after the scores have been assessed.

Please note no harm will occur as a result of this experiment. To avoid and reduce any unnecessary risks, for example, if you feel depressed or anxious, you should not to take part in this research. Please note that the Iowa Gambling Task and the Cognitive Reflection Test will be used in this study. If you are familiar with these tasks you are advised not to take part in this study.

**Exclusion criteria: People under the age of 18 years old. People with a history of brain injuries.**

Please do not hesitate to contact me at any time before during and after you made your decision to participate

Researcher contact e-mail: B.Simonovic@derby.ac.uk
CONSENT FORM

Date: ______________________

Personal Reference Number: __________________________

(Last two letters of your favourite film and last two digits of your mobile number):

This research is about people’s decision-making abilities under uncertainty. Please note that you are under no obligation to complete the experiment and you can withdraw at any time during the process. Participation is voluntary, and all information recorded will remain anonymous and confidential. Data recorded for this study will not be used for any other purpose than the study itself. Withdrawal from the study will result in all participant information being destroyed and not included in analysis. Participant withdrawal is available up to 4 weeks after the day of participation. You will need to use your unique personal reference number in order to send the request for data deletion.

Contact e-mail B.Simonovic@derby.ac.uk,

What will participation involve? - It involves a computer gambling game and problem solving tasks while having your eye-movements tracked. It will take approximately about 45 minutes to complete the experiment.

As an informed participant of this research I understand that:

1. My participation is voluntary, and I may cease to take part in this research at any time.
2. I am aware of what my participation involves.
3. I understand that all my additional questions about the experiment will be satisfactorily answered.

I have read and understood the above and give consent to participate.

Participant signature_________________________________

Researcher signature_________________________________

Date____________________________________

DEBRIEF

Thank you for taking the time to participate in this experiment. The aim of this research was to investigate uncertainty and decision making.

Evidence suggests that decisions can be made based on strategic or intuitive assessments of risk and both can be used interchangeably depending on the context of the situation. In the case of the gambling game you have just completed the initial ambiguity of the task did not provide adequate cues for strategic decisions making, perhaps leading you to rely on your ‘gut feelings’. There is evidence that this gambling task is comprised of two phases (learning and performance) that differ in terms of the involvement of either intuitive or strategic reasoning. The evidence is not conclusive, and the purpose of this study was to shed more light on this topic. Furthermore, this study investigated the relationship between people’s thinking dispositions, and gambling scores during the learning and performance phase.
Your eye gaze and pupil dilation were monitored during the experiment because an increase of pupil dilation and numbers of fixations may have a relationship with decision making. This assumption is based on the Somatic Marker Hypothesis which postulate that affective somatic states may be associated with prior decisions outcomes that are used to guide future decisions. For example, if you made a choice followed by a negative outcome, an emotional reaction becomes associated with that choice. Once the emotional reaction is sufficiently well established, the reaction occurs before a choice is made. If your pupil was small, that suggests that you intuitively ‘knew’ which decks were bad even if you didn’t have any conscious awareness of it. Please bear in mind that pupil dilatation does not have any effects on your health, and is completely normal.

Hopefully your participation will make significant contribution in further clarification of these phenomena.

Please bear in mind that the data collected will only be used for this research, and will be stored and safeguarded on a removable disc by the researcher for a minimum of 6 years. Please keep your reference number safe for further correspondence, and bear in mind that you can withdraw your data up to 4 weeks after participation. Please bear in mind that in order to secure your anonymity, your email will be deleted. For any further question please feel free to contact me or the Supervisor of this research Dr Edward Stupple.

Researcher contact e-mail: B.Simonovic@derby.ac.uk

Supervisor contact e-mail: E.J.N.Stupple@derby.ac.uk

Please feel free to contact student service centre if this study has raised any issues or concerns

Student service centre: University of Derby, Kedleston Road, Derby, DE22 1GB.

T: +44 (0)1332 590500
F: +44 (0)1332 294861
If you are interested in this topic, the article below may provide more information regarding people’s thinking disposition on decision making, following link about the eye tracking measurements and Somatic Markers Hypothesis.


APPENDIX B

B.1. Experiment 1, Ethics form

This form is for University members of staff and PhD students making applications to the Psychology Research Ethics Committee (PREC). Complete this form and submit it by email to the Chair and Deputy Chair of PREC. Information about submission and approval processes, deadlines, and meeting dates is given at http://www.derby.ac.uk/science/psychology/psychology-ethics-committee/

Once approval has been given, you will be eligible to commence data collection.

<table>
<thead>
<tr>
<th>1. Name:</th>
<th>Boban Simonovic</th>
<th>2. School/ Research Centre (if internal applicant)</th>
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| 3. Contact Information | Email: B.Simonovic@derby.ac.uk | Site/Room no (if applicable): N301 | Tel No. 07426322112 |

| 4. Position: | Postgraduate researcher |

If applicable:

5a. Name of supervisor (Director of Studies) if you are PhD student: Dr. Edward Stupple

5b. Supervisor (Director of Studies) signature of consent:

I have reviewed this application and approve its submission:

6. Title or topic area of proposed study

**Effects of intuitive and reflective thinking on decision making under ambiguous and uncertain conditions**

7. What are the aims and objectives of your study?

The aim of the proposed study is to investigate decision making performances in healthy individuals by using Iowa Gambling Task (IGT).

Objectives:
To examine thinking attitude and disposition in healthy participants related to decision making under uncertain conditions.

To examine physiological responses (i.e. blood pressure, heart rate variability) in relation to advantageous/disadvantageous decision-making patterns during the IGT performance.

To examine which blocks of the IGT are related to learning/performance phase of the task, and how this relates to thinking dispositions of the healthy participants

8. Brief review of relevant literature and rationale for study

Making decisions in uncertain or ambiguous situations is a key function in everyday life. The complexity of everyday life compels quick decision making, often under stressful conditions and many situations that require decisions to be made elicit stress responses themselves. The decision whether to take a risky choice that may have extensive financial consequences or to choose between several alternatives that offer different rewards or punishment are stress-eliciting situations. In these kind of situations it is of great importance for an individual to remain calm under pressure, with relatively sound judgment, to decide advantageously. Thus, stress and decision making are intricately connected and the influence that stress has on the quality of a decision is of special interest in decision making research. Bechara, Damasio, Damasio and Anderson (1994) developed The Iowa Gambling Task (IGT) that is often used as an experimental task and a clinical assessment tool in decision making research. It is argued that the IGT resembles decision making in real life and it is characterised by the uncertainty of punishment and reward outcomes. In the IGT participants have to choose among four decks of cards with different frequencies of gains and losses in order to learn to select from the most advantageous card decks to obtain the greatest gains. Research evidence from the patients with lesions of limbic structures, neurological diseases or psychological disorders have emphasised the importance of emotional processes in deciding advantageously during IGT performance. In contrast, analytic thinking was regarded as having much less importance. While research has identified the effectiveness of the IGT in clinical research, Steingroever, Wetzelsa, Horstmann, Neumann and Wagenmakers (2013) have called for greater scrutiny of the performance of healthy controls on the IGT. Steingroever et al. indicated that the performance of healthy participants is characterised by substantial individual variability whereby individual choices are driven by frequency of losses rather than the long-term outcome of the decks. This challenges the assumptions that performance of the healthy participants is optimal. On the other hand, IGT studies have shown there is a relationship between the hormone cortisol and disadvantageous behavioural patterns (e.g., Santos-Ruiz et al., 2012), but these studies did not measure other physiological responses that may be relevant for decision making.

Early research indicated that implicit processing (e.g., processing the feedback of previous trials and associated emotional responses) may significantly contribute to advantageous decision making in the IGT (e.g., Bechara et al., 1994). However, a dual process account of IGT performance, presented by Brevers et al., (2013) emphasises a deficit in “cool”
reflective processes among pathological gamblers in contrast to healthy controls. They also argue that hyperactive emotional processing can ‘hijack’ the reflective mechanism that detects problematic future outcomes from disadvantageous decks and thus lead to disadvantageous card selections. This suggestion needs further examination among healthy participants. Furthermore, on the basis of dual-process model of self—regulation, executive functions depend on the integrity of ‘cool’ and ‘hot’ neural systems where a ‘cool’ executive function includes analytical thinking and problem solving disposition while ‘hot’ executive functions include regulation of emotional responses and inhibition of impulsive reaction. There is also a suggestion that the IGT comprises learning and performance phase, however it is difficult to pin point which blocks relate to learning/performance phase. This distinction needs further examination especially within a healthy population.

It has also been shown that behavioural changes, leading to disadvantageous card selection may occur from an increase in cortisol whereby such an increase affects neural circuits in the prefrontal cortex which are important for analytical thinking (e.g., Santos-Ruiz et al., 2012). This conclusion is based on studies that measured cortisol reactivity to stress but did not measure other physiological responses that may be relevant for decision making. For instance, the effect of blood pressure and heart rate variability on decision making whereby elevated blood pressure (BP) reactivity leads to decreased cognitive performance, remain unexamined but may offer a more dynamic measure of the physiological response during decision making. Additionally, behavioural strategies and executive functions in healthy participants are in need of strong methodological measures that can tease out the processes involved in decision-making. The proposed study will test aspects of dual process account of IGT performance in healthy participants, examine components of executive functions and examine critical thinking aptitude and disposition by using measures that can possibly explain types of processing in decision making, i.e. extended version of the Cognitive Reflection Test (Stupple, Hunt, & Steel, in prep), Rational-Experiential Inventory (REI, Epstein, Pacini, Denes-Raj & Heier 1996) active open-minded thinking (AOT, Haran, Ritov, & Mellers, 2013), the consideration of future consequences (CFC, Strathman, Gleicher, Boninger, & Edwards, 1994) and Anxiety Sensitivity Index (ASI, Reiss, Peterson, Gursky, & McNally, 1986). In addition, this study aims to assess participants’ level of knowledge throughout the game, by using a sensitive test of awareness in the form of a structured questionnaire (e.g., Maia & McClelland, 2004). An eye tracker will measure pupil size dilation in order to differentiate between the positive and negative somatic markers. It is expected that pupil size and increase in the beginning of the task when making disadvantageous choices. In addition, blood pressure reactivity and heart rate variability measures will be taken, and Anxiety Sensitivity Index will be measured in order to examine physiological responses during decision-making processes and participants’ anxiety sensitivity level. This study will follow National Institute for Health and Clinical Excellence (NICE, 2011) guidelines in order to have an operational definition for high blood pressure as an exclusion criterion for this study participation. According to NICE 120/80 mmHG is ideal RESTING blood pressure while 140/90 mmHG and higher may be a reason for concern. Thus, participants with a blood pressure higher than 140/90 mmHG will not be allowed to enter the study and advised to maybe visit their GP as a precaution. No guidance, however, exists for high blood pressure levels during mental stress studies but a systolic blood pressure of over 200mmHg is considered high during exercise (AHA, 2010) and so will be used to operationalize high BP during the study; it is very unlikely that any
participant’s blood pressure will reach this level, but the study will be stopped if it reaches this level. Heart rate variability (HRV) is calculated based on variation of time in milliseconds between two heartbeats. HRV is a relatively new method for assessing, for example, stress. What makes HRV interesting is the fact that it can reflect changes in stress while other physiological parameters, like blood pressure, are still in normal or accepted ranges. For the purposes of this study standards of measurements and physiological interpretation are adopted from the Task Force of The European Society of Cardiology and The North American Society of Pacing and Electrophysiology (1996). In the situation where HRV is related to emotional arousal the Task Force suggests the use of Frequency domain methods. This method assigns bands of frequency and then counts the number of NN (beat-to-beat) intervals that match each band. The bands are typically high frequency (HF) from 0.15 to 0.4 Hz, low frequency (LF) from 0.04 to 0.15 Hz and the very low frequency (VLF) from 0.0033 to 0.04 Hz.

9. Outline of study design and methods

The present study is a quantitative experimental research that will be conducted on-campus. The equipment and the material will be stored in room (T038) where the experiment will take place. Bechara et al.’s (1994) computerised version of IGT will be used for the purpose of this study. The IGT involves virtual money and participants will not risk their own money. Healthy students will be recruited via the university website and student forums. Participants under the age of 18 years old will not be allowed to participate in this study. Participants will be asked for general demographic information. Participants with the history of cardiovascular disorders or history of high blood pressure will not be allowed to participate. Furthermore, if a participant has a very high blood pressure before (e.g., higher than the operational definition for exclusion) or during the experiment they will be informed about this, advised to stop, or not to participate in the experiment, and informed that they might want to visit their GP as a precaution (See Appendices). Since the exact cause of the increase in blood pressure can be hard to pin down (e.g., smoking, lack of physical activity, genetics, too much alcohol or salt consumptions) and it is beyond the expertise of the researcher, participants will only be advised not to take part in the study, and possibly visit their GP as a precautionary measure. The researcher will also emphasize that there may be no reason for a major concern, and that his advice should only be considered as a safeguard measure. Following briefing and informed consent the researcher will explain the rules of the task, what is involved and what kind of measurements are taken during the performance. Continuous, non-invasive cardiovascular measure by Finometer (Finapres Medical System) with the interval of four minutes will be used in the study. The Finometer will measure blood pressure and heart rate variability. In addition, eye-movements will be recorded using the Eye-gaze binocular system (Tobii-X2-30). Participants will be asked to sit for five minutes (resting period), baseline blood pressure and heart rate variability measurements will be taken three times before the tasks engagement. The first administrated task (CRT)
will measure participants’ tendency to engage in reflective thinking followed by REI, AOT, CFC and ASI. REI will measure participants’ rational and experiential thinking styles while AOT will tap into participants’ tendency to weigh new evidence against a favoured belief and to consider carefully different options in forming a decision. CFC measures the extent to which people consider distant versus immediate consequences of potential behaviour. ASI measures beliefs that anxiety experiences have negative implication. The order of the administrated task will be counterbalanced by using the ABCD, ACDB, ADBC, ... DABC layout. After that the participants will engage in IGT. During the IGT performance, participants will be asked questions related to cognitive awareness, after the first 20 trials and then every 10 trials. At the end a post cardiovascular measurement will be undertaken to make sure they are back to normal task followed by debrief. If the blood pressure shows further increase or doesn’t show any sign of decreasing, the participant will be informed and possibly advised to contact their GP or even University doctor (in the cases of immediate concern).

This study will assess the importance of reflective thinking and intuitive responses among healthy participants completing the IGT. A between-group (intuitive vs. reflective) design will measure participants' cognitive abilities, abilities to inhibit emotional reaction and type of processing during the IGT performance. The study will comprise 110 participants who will perform the task once. The IGT involves four decks of cards (e.g., A, B, C and D) and the game consists of 100 trials. In the IGT, following each selection, a specified amount of fictitious money is awarded. However, at certain times, losses of different fixed amounts occur. Two decks of cards, C and D, are advantageous, as they result in small immediate gains, but also very small losses and will therefore return more money in the long run, than that which is given out. The other two decks (decks A and B) produce high immediate gains, however, because very high losses occur at certain times, more money will be lost than gained (disadvantageous decks). Because it is impossible to calculate the best option from the beginning of the task, subjects have to learn to avoid bad decks by following their hunches and guesses, and by using feedback from previous trials. The IGT involves virtual money and participants will not risk their own money. Cumulative scores for the gambling task will be calculated by adding the total net scores from all trials.

The IGT task will be extended to 140 trials to pin down learning and performance phases during the task. It is predicted that in healthy subjects, the performance in the latter trials of the IGT, will be more strongly correlated with measures of analytic thinking.

The dependent variable in this study is the cumulative score on IGT and it is hypothesised that participants who are more reflective, critical and plan strategically will learn more quickly and perform better on IGT than participants who are less reflective, critical and rely on intuition. BP reactivity will be calculated by subtracting the of the performance measurements from the average of baseline measurements. Then ANOVA will be used to determine if systolic, diastolic BP and heart rate variability increased between the baseline measurement and task measurement. Separate linear regressions will be used to see is there
a relationship between the physiological measurements (e.g., eye movement), anxiety sensitivity index (ASI) and thinking style. Separate ANOVA’s will be used to determine the effect of reflective thinking (CRT), thinking style (REI) planning (AOT) consideration of future consequences (CFC) on IGT scores during the learning and performance phase. Finally, multiple regression will be conducted to determine to what extent CRT scores, REI scores AOT scores CFC scores, ASI scores, blood pressure and heart rate variability will predict IGT scores in the learning and performance phases of the IGT.

10. Sample: Please provide a detailed description of the study sample, covering selection, number, age, and if appropriate, inclusion and exclusion criteria.

Participants will be recruited at the University by using e-mails and by contacting various student groups. GPower software was used in order to determine the number of participants needed to detect medium effect sizes. Thus for moderate effect sizes (d= 0.5, Alpha= 0.05, Power= 0.80) a total number of 110 participants is sufficient (both males and females). Participants under the age of 18 years old will not be allowed to participate in the study. Participants with the history of cardiovascular disorders or history of high blood pressure will not be allowed to participate in the study. Furthermore, if a participant has a very high blood pressure during the experiment they will be informed about such event advised to stop the experiment and informed that they might want to visit their GP.

11. Are payments or rewards/incentives going to be made to the participants? If so, please give details below.

There will be two rewards offered to the participants. Participants can choose if they want to receive 4 participation points or 2 participation points and a £5 voucher for participation in this study. This will be explained in the invitation to participate.

Do you intend to give Participation Points for taking part in your study? Yes (Delete as appropriate)
Five quantitative tests will be used for the purpose of this study:

**Extended version of the Cognitive Reflection Test** will be used (CRT, Toplak, West & Stanovich, 2014). This will offer a measure of reflective thinking that can evaluate individual differences in reflective processing among participants engaging with the IGT. This test is constructed to measure peoples’ aptitude to engage in reflective thinking whereby the more reflective you are the more likely you are to inhibit initial response to a problem (heuristically derived) and engage in finding an alternative solution to a problem.

**Pacini et al., (1996) Rational-Experiential Inventory (REI)**, measures rational and experiential thinking styles. The REI measures the two independent processing modes with two factors: Need for Cognition (rational measure) and Faith in Intuition (experiential measure). Several studies have confirmed that the REI is a reliable measure of individual difference in information processing, and that the two independent thinking styles measured account for a substantial amount of variance that is not addressed by other personality theories (i.e. Norris, & Epstein, 2011).

**Haran et al., (2011) Active Open-minded Thinking Scale (AOT)** is based on Stanovich and West’s (2007) scale and is designed to capture thinkers’ desire to be more informed before making an estimate or prediction, and their higher attention to information already acquired may further improve their estimation performance.

**Strathman et al., (1994) consideration of future consequences (CFC)** measures the extent to which people consider distant versus immediate consequences of potential behaviour. This may be very important for the participants engaging in the IGT, since in order to maximize their profit participants’ need to encompass into strategy future consequences (punishment/reward).

**Reiss et al., (1986) Anxiety Sensitivity Index (ASI)**, measures beliefs that anxiety experiences have negative implication. People who believe that anxiety has few or no negative effects may be able to cope with a relatively high level of exposure to anxiety-provoking stimuli. In contrast, people who believe that anxiety has terrible effects, tend to have anxiety reactions that grow in anticipation of severe consequences. Anxiety sensitivity therefore implies a tendency to show exaggerated and prolonged reactions to anxiety-provoking stimuli. Research indicated that the performance of healthy participants is
characterized by substantial individual variability whereby individual choices are driven by frequency of losses rather than the long-term outcome of the decks. However, one of the reason for the participants’ non-optimal performance may be sensitivity to punishments and rewards that may lead anxiety sensitive participants to a disadvantageous decision making.

Maia & McClelland (2004) Test of Awareness, measures raise of the conscious knowledge of the advantageous strategy as early as participants behave advantageously in the IGT. This sensitivity test encompasses 5 questions in total with question 3 having 4 additional sub questions.

These scales are available and there are no copyright issues.

Bechara et al., (1994) computerised Iowa Gambling Task (IGT) is frequently used as an experimental task in the decision making research, and the University holds a copy of the IGT that will be used in this study.

The use of the Finometer (Finapres Medical System) will be undertaken after supervised training and the equipment used will be located in psychology laboratories. Research will be conducted during office hours and the researcher will adhere to the BPS Guidelines for Ethical Practice for conducting laboratory experiments.

The use of the Eye gaze binocular system (Tobii-X2-30) will be undertaken after supervised training and the equipment used will be located in psychology laboratories.

13. References Give the references for any sources cited in the sections on rationale, methods etc.


14. Ethical Considerations Please indicate how you intend to address each of the following in your study. Points a-i relate particularly to projects involving human participants. Guidance to completing this section of the form is provided at the end of the document.
a. **Consent**

The participants will be informed about the goals and purpose of the study, as well as known and unknown risks attached. The participants will be asked to fill out formal consent form, once they have agreed to take part in the experiment (see appendices).

b. **Deception**

*Not applicable*

c. **Debriefing**

At the end of the experiment the participants will be provided with full written debrief where they will be informed about the purpose of the study, what to do if they experience higher blood pressure than usual after the study (i.e. contact their GP) and they will be provided with contact information for future correspondence and additional information’s (i.e. researcher email, student service centre).

d. **Withdrawal from the investigation**

Prior to the experiment, the participants will be fully informed that their participation is voluntary, and that they are allowed to withdraw from the experiment at any time and any answers they had given up to that point would be deleted (email address of the researcher will be provided with the debrief document). If they decide to withdraw their data after they had taken the experiment, they will be allowed to do so within the time limit of four weeks from the day that they had completed the experiment.

e. **Confidentiality**
To provide anonymity and confidentiality participants will be asked to create a unique code, which will be a combination of the last two letters of their favourite film and the last two digits of their mobile number.

They will be asked not to reveal any personal details. Participants will be asked to leave their email addresses for contact purposes if they are eligible for a reward. However, it will be explained that the email address is only for contacting the highest scorers on the gambling game and that it will be deleted immediately upon data summary and prize been rewarded. The experimental data will be password protected and stored on external drive. The data collected will be accessible only to the researcher and his supervisors. All paper data collected will be stored in a secure locked cabinet, in a locked room.

**f. Protection of participants**

There is no deception involved and participants will be assured anonymity. 'No lasting harm will occur as a result of this experiment’. Participants under the age of 18 years old will not be allowed to participate in the study. Participants with the history of cardio vascular disorders or history of high blood pressure will not be allowed to participate in the study. Furthermore, if a participant has a very high blood pressure during the experiment they will be informed about such event advised to stop the experiment and informed that they might want to visit their GP.

**g. Observation research [complete if applicable]**

Not applicable

**h. Giving advice**

I will only be providing the relevant information in regards to the experiment and the phenomenon in question. If participants are concerned about anything else they will be advised to contact the student services at University of Derby. Furthermore, The researcher will act in accordance with both the BPS ethical principles and adhere to the codes of conduct outlined by the University of Derby to ensure ethical conduct and knowledge development.

**i. Research undertaken in public places [complete if applicable]**

Not applicable
j. Data protection
The experimental data will be password protected and stored on external drive. The data collected will be accessible only to the researcher and his supervisors. All paper data collected will be stored in a secure locked cabinet, in a locked room.

k. Animal Rights [complete if applicable]
Not applicable

l. Environmental protection [complete if applicable]
Not applicable

15. Have/do you intend to request clearance from any other body/organisation? Yes/No (please circle as appropriate)

If Yes – please give details below.

16. All projects have an element of risk which should be assessed before any project is undertaken.

Have the activities associated with this research project been risk assessed? Yes ☒ No ❌

17. Declaration: The information supplied is accurate to the best of my knowledge and belief. I understand my obligations and the rights of the participants. I agree to act at
all times in accordance with University of Derby Ethical Policy for conducting research with human participants.

**B.2. Ethical Approval**

*Approval Letter: Psychology Research Ethics Committee*

*University of Derby*

Date: 15\textsuperscript{th} October 2014

Dr Frances A. Maratos  
Chair, Psychology Research Ethics Committee, University of Derby

Dear Bob,

*Ethics Ref No: 25-14-BS*

Thank you for submitting this revised application to the Psychology Research Ethics Committee.
I have now reviewed the revised documents you sent following the feedback you received on your initial application, and I am satisfied that all of the issues raised have been dealt with. The application can now therefore be approved.

The following documents have now been re-reviewed:

1. Revised Ethics application form
2. Revised IGT Instructions
3. Revised invitation to participate
4. Revised debrief

If any changes to the study described in the application or supporting documentation is necessary, you must notify the committee and may be required to make a resubmission of the application.

Good luck with the study.

Yours sincerely

F. A. Maratos

Frances A. Maratos
B.3. Materials

Eye gaze binocular system (Tobii-X2-30).

Finometer (Finapres Medical System, Amsterdam, Netherlands).

Toplak et al. (2014) extended version of the CRT

This is removed for copyright reasons Please see the original paper


This is removed for copyright reasons Please see the original paper

Haran et al., (2011) Active Open-minded Thinking Scale (AOT)

This is removed for copyright reasons Please see the original paper

This is removed for copyright reasons Please see the original paper

Reiss et al., (1986) Anxiety Sensitivity Index (ASI)

This is removed for copyright reasons Please see the original paper

This is removed for copyright reasons Please see the original paper

IGT instructions and procedure (Bechara et al., 1994) adopted for the computerised version

This is removed for copyright reasons Please see the original paper

INVITATION TO PARTICIPATE

My name is Boban Simonovic and I’m a postgraduate researcher at the University of Derby. As part of my research I’m interested in learning more about decision making under uncertain conditions.

The aim of the present research is to explore people’s decision-making abilities under uncertainty. A computer gambling game is involved. If you decide to participate in this research, you will be asked to complete this gambling game and several questionnaires. Your blood pressure will be measured during this process and you may experience slight pressure and discomfort on your arm. In addition, we will use an eye tracker device as a monitoring tool that measure gaze direction.

The experiment will take no more than 70 minutes. You will play the gambling game with virtual money. However, you are encouraged to play the game naturally to the best of your ability. You can also choose to receive four participation point or two participations and a £5 voucher for participating in this study. Participation is voluntary, and all information recorded will remain anonymous and confidential. Data recorded for this study will not be used for any
other purpose than the study itself. Data will be stored in accordance with data protection laws and University of Derby data collection and storage policies.

Please note that you may withdraw your participation at any time during the study without consequences. If you choose to withdraw your data after taking part please contact the researcher (see below) using your unique code. To provide anonymity of the data you will be asked to create your unique reference number. Once you have completed the experiment keep a note of your reference number and use it for any future correspondence. You will be asked to give your email addresses for contact purposes if you are eligible for a reward.

Email addresses will be used only for contacting the highest scorers on the gambling game and it will be deleted immediately upon data summary. Withdrawal from the study will result in all participant information being destroyed and not included in analysis. Participant withdrawal is available up to 4 weeks after participation.

Please note no harm will occur as a result of this experiment. However, to avoid and reduce any unnecessary risks, if you feel depressed or anxious, be advised not to take part in the present research.

Furthermore, people under the age of 18 years old and people who suffered from any form of cardiovascular disorders or high blood pressure are not allowed to take part in the experiment.

Please note that if during the experiment we notice that your blood pressure is higher than normal you will be informed and possibly advised to contact your GP.

Please do not hesitate to contact me at any time before during and after you made your decision to participate.

Researcher contact e-mail: B.Simonovic@derby.ac.uk

Supervisor contact e-mail: E.J.N.Stupple@derby.ac.uk
CONSENT FORM

Name:

Date:

Personal Reference Number

(Last two letters of your favourite film and last two digits of your mobile number):

This research is about people’s decision-making abilities under uncertainty. Please note that you are under no obligation to complete the experiment and you are not going to be penalised if you decide to withdraw during the process. Participation is voluntary, and all information recorded will remain anonymous and confidential. Data recorded for this study will not be used for any other purpose than the study itself. Withdrawal from the study will result in all participant information being destroyed and not included in analysis. Participant withdrawal is available up to 4 weeks after participation. You will need to use your unique personal reference number in order to send the request for data deletion. Contact e-mail B.Simonovic@derby.ac.uk.

What will participation involve? - It involves computer gambling game and answering questionnaires, while having your eye-movements and blood pressure activity monitored. It will take approximately about 70 minutes to complete the experiment.

As an informed participant of this research I understand that:

4. My participation is voluntary, and I may cease to take part in this research at any time, without penalty.

5. I am aware of what my participation involves.

6. I understand that all my additional questions about the experiment will be satisfactorily answered.

7. I’m aware that I can chose between the two rewards for this study: a) 4 participation points or b) 2 participation points and a £5 voucher.
Can you please select your reward by choosing between the two options?

I would like to receive:

a) 4 participation points  
b) 2 participation points and a £5 voucher

I have read and understood the above and give consent to participate.

Participant signature_________________________________
Participant email _________________________________  
Researcher signature_________________________________
Date____________________________________________

DEBRIEF

Thank you for taking the time to participate in this experiment. Can you please confirm which of the two rewards you like to receive: a) 4 participation points or b) 2 participation points and a £5 voucher?

The aim of this research was to investigate the uncertain context of decision making. Evidence suggests that decisions can be made based on strategic or intuitive assessments of risk and both are used interchangeably depending on the context of the situation. In the case of the gambling game, that you have just completed the initial ambiguity of the task did not provide adequate cues for strategic decisions making, perhaps leading you to rely on your ‘gut feelings’. There is evidence that this gambling task is comprised of two phases (learning and performance) that differ on the involvement of either intuitive or strategic reasoning. The evidence is not conclusive, and the purpose of this study was to shed more light on this topic. Furthermore, this
study investigated the relationship between people’s thinking dispositions, thinking style, consideration of future consequences on gambling scores during the learning and performance phase.

Your eye gaze was monitored during the experiment because an increase of pupil dilation may have an effect on decision making. This assumption is based on the Somatic Marker Hypothesis which postulate that affective somatic states may be associated with prior decisions outcomes that are used to guide future decisions. For example, if you made a choice followed by a negative outcome, an emotional reaction becomes associated with that choice. Once the emotional reaction is sufficiently well established, the reaction occurs before a choice is made. If your pupil was slightly dilated, it is plausible that intuitively, you 'knew’ which decks were bad even if you didn’t have any conscious awareness of it. Please bear in mind that your pupil dilatation will not have any effects on your health, and is completely normal.

Your blood pressure was monitored during the experiment because of the previous suggestions that an increase of the blood pressure may have an effect on decision making. Please bear in mind that if your blood pressure was slightly higher than usual this will not have any lasting effects on your health. However if you experience any unusual and persistent activity with your blood pressure (higher than normal) please contact your GP.

Hopefully your participation will make significant contribution in further clarification of these phenomena.

Please bear in mind that the data collected will only be used for this research, and will be stored and safeguarded on a removable disc by the researcher until after awarding of the academic degree (September 2016). Please keep your reference number safe for further correspondence, and bear in mind that you can withdraw your data up to 4 weeks after participation. For any further question please feel free to contact me or the Supervisor of this research Dr Edward Stupple

Researcher contact e-mail: B.Simonovic@derby.ac.uk

Supervisor contact e-mail: E.J.N.Stupple@derby.ac.uk

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If you are interested in this topic, the article below may provide more information regarding people’s thinking disposition on decision making, following link about the blood pressure.


http://www.nhs.uk/conditions/blood-pressure-(high)/Pages/Introduction.aspx

Please bear in mind that you can always contact me or my supervisor if you have any additional questions or concerns about the study.

**Physiological measurements instructions**

Hello,

This study involves blood pressure and eye-tracking measurements. Eye tracking involves a non-invasive tracking of your gaze that will in no circumstance cause you any harm. We will use the eye-gaze monitor in this study (shows the eye-tracker). Before we start the device needs to be calibrated. Please follow the instructions as they appear on the computer screen and focus on the green dots as they appear. This should take no longer than 1 minute. Please let me know if you experience any discomfort? Before we start, let me provide you with information regarding blood pressure and inclusion/exclusion criteria for this study. This study will follow National Institute for Health and Clinical Excellence (NICE, 2011) guidelines in order to have an operational definition for high blood pressure. According to NICE 120/80 mmHG is ideal blood pressure while 140/90 mmHG and higher may be a reason for concern. People under the age of 18 years old and people who have suffered from any form of cardiovascular disorders or high blood pressure are not allowed to take part in the experiment. This is the Finometer that will be used for blood pressure measurement. Before we start I will take three baseline measurements. If the baseline measurements indicate that you have a very high blood pressure it is my duty to inform you about this and advise you not to participate in the
experiment. Since the exact cause of the increase in blood pressure can be hard to pin down (e.g., smoking, lack of physical activity, genetics, too much alcohol or salt consumption) and it is beyond my expertise, you will be advised to visit your GP as a precautionary measure. There may be no reason for concern, and the advice should be considered as a safeguarding measure. Please note that if during the experiment I notice that your blood pressure is higher than normal you will be informed and may be advised to contact your GP. Please note that there may be some increase in blood pressure during the experiment, but this will go back to normal at the end. At the end of the study I will take measurements to make sure that your blood pressure is back to normal.

Do you have any questions you would like to ask?
### APPENDIX C

#### C.1. Experiment 3, Ethics form

This form is for University members of staff and PhD students making applications to the Psychology Research Ethics Committee (PREC). Complete this form and submit it by email to the Chair and Deputy Chair of PREC. Information about submission and approval processes, deadlines, and meeting dates is given at [http://www.derby.ac.uk/science/psychology/psychology-ethics-committee/](http://www.derby.ac.uk/science/psychology/psychology-ethics-committee/)

Once approval has been given, you will be eligible to commence data collection.

<table>
<thead>
<tr>
<th>1. Name:</th>
<th>Boban Simonovic</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. School/ Research Centre (if internal applicant):</td>
<td>EHS</td>
</tr>
<tr>
<td>3. Contact Information:</td>
<td>Email: <a href="mailto:B.Simonovic@derby.ac.uk">B.Simonovic@derby.ac.uk</a></td>
</tr>
<tr>
<td></td>
<td>Site/Room no (if applicable): N301</td>
</tr>
<tr>
<td></td>
<td>Tel No. 07426322112</td>
</tr>
<tr>
<td>4. Position:</td>
<td>Postgraduate researcher</td>
</tr>
<tr>
<td>If applicable:</td>
<td>5a. Name of supervisor (Director of Studies) if you are PhD student: Dr. Edward Stupple</td>
</tr>
<tr>
<td></td>
<td>5b. Supervisor (Director of Studies) signature of consent: I have reviewed this application and approve its submission:</td>
</tr>
<tr>
<td>6. Title or topic area of proposed study:</td>
<td>Stress and risky decision making under ambiguous and uncertain conditions</td>
</tr>
<tr>
<td>7. What are the aims and objectives of your study?:</td>
<td>The aim of the proposed study is to investigate decision making performances in healthy individuals by using Iowa Gambling Task (IGT).</td>
</tr>
<tr>
<td></td>
<td>Objectives: To examine thinking attitude and disposition among healthy participants related to decision making under stress.</td>
</tr>
</tbody>
</table>
To examine physiological responses (i.e. blood pressure, heart rate variability) in relation to advantageous/disadvantageous decision-making patterns during the IGT performance under stress.

To examine intuitive responses and conscious awareness during IGT performance by using an eye tracker

8. Brief review of relevant literature and rationale for study

The complexity of everyday life compels quick decision making, often under stressful conditions and many situations that require decisions to be made elicit stress responses themselves. The decision whether to take a risky choice that may have extensive financial consequences or to choose between several alternatives that offer different rewards or punishment are stress-eliciting situations. In these situations it is of great importance for an individual to remain calm under pressure, with relatively sound judgment, to decide advantageously. Thus, stress and decision making are intricately connected and the influence that stress has on the quality of a decision is of special interest in decision making research. Stress often accompanies decision making tasks and research suggests that this may alter both the cognitive and emotional processes involved in risky decision-making (Schwabe & Wolf, 2009). Bechara, Damasio, Damasio and Anderson (1994) developed The Iowa Gambling Task (IGT) that is often used as an experimental task and a clinical assessment tool in decision making research. It is argued that the IGT resembles decision making in real life and it is characterised by the uncertainty of punishment and reward outcomes. In the IGT participants have to choose among four decks of cards with different frequencies of gains and losses in order to learn to select from the most advantageous card decks to obtain the greatest gains. Research evidence from the patients with lesions of limbic structures, neurological diseases or psychological disorders have emphasised the importance of emotional processes in deciding advantageously during IGT performance. In contrast, analytic thinking was regarded as having much less importance. Early research indicated that implicit processing (e.g., processing the feedback of previous trials and associated emotional responses) may significantly contribute to advantageous decision making in the IGT (e.g., Bechara et al., 1994). However, a dual process account of IGT performance, presented by Brevers et al., (2013) emphasises a deficit in “cool” reflective processes among pathological gamblers in contrast to healthy controls. They also argue that hyperactive emotional processing can ‘hijack’ the reflective mechanism that detects problematic future outcomes from disadvantageous decks and thus lead to disadvantageous card selections. This suggestion needs further examination among healthy participants On the basis of dual-process model of self—regulation, executive functions depend on the integrity of ‘cool’ and ‘hot’ neural systems where a ‘cool’ executive function includes analytical thinking and problem solving disposition while ‘hot’ executive functions include regulation of emotional responses and inhibition of impulsive reaction. There is also a possibility that the learning mechanisms involved in the IGT provide a large number of sources for different types of intuition (i.e. intuition as affective arousal; intuition as mere feelings of liking and disliking; intuition as a
‘gut feeling’ where critical thinking regulates emotional responses) (Glockner, & Witteman, 2010). Furthermore, the core property of intuitive processes is that they partially operate automatically without conscious control and they ‘record’ a surprising amount of information (Evans, 2008). Recent systematic review suggests that currently employed physiological measurements (e.g., skin conductance measurements) are not providing sufficient data in order to make a distinction between different types of intuitive responses (Simonovic et al. 2016 in prep). The review results suggested that the use of an eye-tracker may help to differentiate between somatic reactions during the task. This is particularly important because the anticipatory SCR captured during the IGT performance may represent a part of a broader response complex such as attentional orienting areas of focus or risk-taking behaviour that can be easily encapsulated by eye-tracking measurements.

IGT studies have also shown that stress can interfere with the learning process in healthy controls, increase risk-taking behaviour and lead to disadvantageous card selections (e.g., Preston et al., 2007; Santos-Ruiz et al., 2012). Preston et al. (2007) induced stress by informing participants that they would deliver a speech while being videotaped and evaluated, and demonstrated that stressed participants showed a slower learning curve on the IGT than the control group. It has also been shown that behavioural changes, leading to disadvantageous card selection may occur from an increase in cortisol whereby such an increase affects neural circuits in the prefrontal cortex which are important for analytical thinking (e.g., Santos-Ruiz et al., 2012). This conclusion is based on studies that measured cortisol reactivity to stress but did not measure other physiological responses that may be relevant for decision making. For instance, the effect of blood pressure and heart rate variability on decision making whereby elevated blood pressure (BP) reactivity leads to decreased cognitive performance, remain unexamined but may offer a more dynamic measure of the physiological response during decision making. Additionally, behavioural strategies and executive functions in healthy participants are in need of strong methodological measures that can tease out the processes involved in decision-making. The proposed study will test aspects of dual process account of IGT performance in healthy participants, examine components of executive functions and examine critical thinking aptitude and disposition by using measures that can possibly explain types of processing in decision making, i.e., extended version of the Cognitive Reflection Test (Toplak, West, & Stanovich, 2014), Rational-Experiential Inventory (REI, Epstein, Pacini, Denes-Raj & Heier 1996) active open-minded thinking (AOT, Haran, Ritov, & Mellers, 2013), the consideration of future consequences (CFC, Strathman, Gleicher, Boninger, & Edwards, 1994) and Anxiety Sensitivity Index (ASI, Reiss, Peterson, Gursky, & McNally, 1986). In addition, this study aims to assess participants’ level of knowledge throughout the game, by using a sensitive test of awareness in the form of a structured questionnaire (e.g., Maia & McClelland, 2004). An eye tracker will measure number of fixation and mean fixation duration. Mean fixation duration refers to the average duration of single fixation in a decision. Research indicates that executive processes go along with longer fixations, whereas more intuitive processing is accompanied by shorter fixations (Horstmann, Ahlgrimm, & Glockner, 2009). Single fixations will be categorized according to Horstmann et al.’s suggestion in short (< 150 ms), medium (≥ 150 and < 500 ms) and long (≥ 500 ms) fixation durations resulting in the variable time category.
In addition, blood pressure reactivity and heart rate variability measures will be taken, and Anxiety Sensitivity Index will be measured in order to examine physiological responses during decision-making processes and participants’ anxiety sensitivity level. This study will follow National Institute for Health and Clinical Excellence (NICE, 2011) guidelines in order to have an operational definition for high blood pressure as an exclusion criterion for this study participation. According to NICE 120/80 mmHG is ideal RESTING blood pressure while 140/90 mmHG and higher may be a reason for concern. Thus, participants with a blood pressure higher than 140/90 mmHG will not be allowed to enter the study and advised to maybe visit their GP as a precaution. No guidance, however, exists for high blood pressure levels during mental stress studies but a systolic blood pressure of over 200mmHg is considered high during exercise (AHA, 2010) and so will be used to operationalize high BP during the study; it is very unlikely that any participant’s blood pressure will reach this level but the study will be stopped if it reaches this level. Heart rate variability (HRV) is calculated based on variation of time in milliseconds between two heartbeats. HRV is a relatively new method for assessing, for example, stress. What makes HRV interesting is the fact that it can reflect changes in stress while other physiological parameters, like blood pressure, are still in normal or accepted ranges. For the purposes of this study standards of measurements and physiological interpretation are adopted from the Task Force of The European Society of Cardiology and The North American Society of Pacing and Electrophysiology (1996). In the situation where HRV is related to emotional arousal the Task Force suggests the use of Frequency domain methods. This method assigns bands of frequency and then counts the number of NN (beat-to-beat) intervals that match each band. The bands are typically high frequency (HF) from 0.15 to 0.4 Hz, low frequency (LF) from 0.04 to 0.15 Hz and the very low frequency (VLF) from 0.0033 to 0.04 Hz.

9. Outline of study design and methods

The present study is a quantitative experimental research that will be conducted on-campus. The equipment and the material will be stored in room (T037) where the experiment will take place. Bechara et al.’s (1994) computerised version of IGT will be used for the purpose of this study. The IGT involves virtual money and participants will not risk their own money. Healthy students will be recruited via the university website and student forums. Participants under the age of 18 years old will not be allowed to participate in this study. Participants will be asked for general demographic information. Participants with the history of cardiovascular disorders or history of high blood pressure will not be allowed to participate. Furthermore, if a participant has a very high blood pressure before (e.g., higher than the operational definition for exclusion) or during the experiment they will be informed about this, advised to stop, or not to participate in the experiment, and informed that they might want to visit their GP as a precaution (See Appendices). Since the exact cause of the increase in blood
pressure can be hard to pin down (e.g., smoking, lack of physical activity, genetics, too much alcohol or salt consumptions) and it is beyond the expertise of the researcher, participants will only be advised not to take part in the study, and possibly visit their GP as a precautious measure. The researcher will also emphasize that there may be no reason for a major concern, and that his advice should only be considered as a safeguard measure. Following briefing and informed consent the researcher will explain the rules of the task, what is involved and what kind of measurements are taken during the performance. Then, the experimental group will be informed that the whole process will be recorded on camera and that they will need to report their experience at the end of the experiment in front of the camera (based on Preston et al’s 2007 study). Both groups will receive information’s about the procedure and context of the task. Continuous, non-invasive cardiovascular measure by Finometer (Finapres Medical System) with the interval of four minutes will be used in the study. The Finometer will measure blood pressure and heart rate variability. In addition, eye-movements will be recorded using the Eye-gaze binocular system (Tobii-X2-30), with remote binocular sampling rate of 30 Hz and an accuracy of about 0.45°. Participants will be asked to sit for five minutes (resting period), baseline blood pressure and heart rate variability measurements will be taken three times before the tasks engagement. The first administrated task (CRT) will measure participants’ tendency to engage in reflective thinking followed by REI, AOT, CFC and ASI. REI will measure participants’ rational and experiential thinking styles while AOT will tap into participants’ tendency to weigh new evidence against a favoured belief and to consider carefully different options in forming a decision. CFC measures the extent to which people consider distant versus immediate consequences of potential behaviour. ASI measures beliefs that anxiety experiences have negative implication. The order of the administrated task will be counterbalanced by using the ABCD, ACDB, ADBC, ... DABC layout. After that the participants will engage in IGT. During the IGT performance, participants will be asked questions related to cognitive awareness, after the first 20 trials and then every 20 trials). Participants in the experimental group will be informed that they do not have to report their experience after they finished all the tasks. At the end a post cardiovascular measurement will be undertaken to make sure they are back to normal task followed by debrief. If the blood pressure shows further increase or doesn’t show any sign of decreasing, the participant will be informed and possibly advised to contact their GP or even University doctor (in the cases of immediate concern).

This study will assess the importance of reflective thinking and intuitive responses among healthy participants completing the IGT. A between-group (stress vs. control) design will measure participants' cognitive abilities, abilities to inhibit emotional reaction and type of processing during the IGT performance. The study will comprise 110 participants who will perform the task once. The IGT involves four decks of cards (e.g., A, B, C and D) and the game consists of 100 trials. In the IGT, following each selection, a specified amount of fictitious money is awarded. However, at certain times, losses of different fixed amounts occur. Two decks of cards, C and D, are advantageous, as they result in small immediate gains, but also very small losses and will therefore return more money in the long run, than that which is given out. The other two decks (decks A and B) produce high immediate gains, however, because very high losses occur at certain times, more money will be lost than gained (disadvantageous decks). Because it is impossible to calculate the best option from the beginning of the task, subjects have to learn to avoid bad decks by following their hunches and guesses, and by using feedback from previous trials. The IGT involves virtual money and
participants will not risk their own money. Cumulative scores for the gambling task will be calculated by adding the total net scores from all trials.

The IGT task will be extended to 140 trials to pin down learning and performance phases during the task. It is predicted that in control group, the performance in the latter trials of the IGT, will be more strongly correlated with measures of analytic thinking. It is hypothesised that the stress manipulation will inhibit performance on the IGT and delay the elimination of disadvantageous deck selections. It was also predicted that stress would reduce participants' reflective ability as measured by the CRT.

The dependent variable in this study is the number of disadvantageous card selection and it is hypothesised that participants in control group who are more reflective, critical and plan strategically will learn more quickly and perform better on IGT than participants in the stress group who are less reflective, critical and rely on intuition. BP reactivity will be calculated by subtracting the average of the performance measurements from the average of baseline measurements. Then ANOVA will be used to determine if systolic, diastolic BP and heart rate variability increased between the baseline measurement and task measurement. Separate linear regressions will be used to see is there a relationship between the physiological measurements (e.g., eye movement), anxiety sensitivity index (ASI) and thinking style. Separate ANOVA’s will be used to determine the effect of reflective thinking (CRT), thinking style (REI) planning (AOT) consideration of future consequences (CFC) on IGT scores during the learning and performance phase. Multiple regression will be conducted to determine to what extent CRT scores, REI scores AOT scores CFC scores, ASI scores, blood pressure and heart rate variability will predict IGT scores in the learning and performance phases of the IGT. Finally, multiple regression will be conducted to determine to what extent CRT scores number of fixation and periods of fixation will predict IGT scores in the learning and performance phases of the IGT.

10. Sample: Please provide a detailed description of the study sample, covering selection, number, age, and if appropriate, inclusion and exclusion criteria.

Participants will be recruited at the University by using e-mails and by contacting various student groups. GPower software was used in order to determine the number of participants needed to detect medium effect sizes. Thus, for moderate effect sizes (d= 0.5, Alpha= 0.05, Power= 0.80) a total number of 110 participants is sufficient (both males and females). Participants under the age of 18 years old will not be allowed to participate in the study. Participants with the history of cardiovascular disorders or history of high blood pressure will not be allowed to participate in the study. Furthermore, if a participant has a very high blood pressure during the experiment they will be informed about such event advised to stop the experiment and informed that they might want to visit their GP.
11. Are payments or rewards/incentives going to be made to the participants? If so, please give details below.

Participants will receive 4 participation points. All participants will have the option to be entered into a prize draw to win a £75 Amazon voucher. This will be explained in the invitation to participate.

Do you intend to give Participation Points for taking part in your study? Yes (Delete as appropriate)

12. What resources will you require? (e.g., questionnaires, equipment, for example video camera, specialised software; if questionnaires are to be used please give full details here).

Five quantitative tests will be used for the purpose of this study:

**Extended version of the Cognitive Reflection Test will be used** (CRT, Toplak, West & Stanovich, 2014). This will offer a measure of reflective thinking that can evaluate individual differences in reflective processing among participants engaging with the IGT. This test is constructed to measure peoples’ aptitude to engage in reflective thinking whereby the more reflective you are the more likely you are to inhibit initial response to a problem (heuristically derived) and engage in finding an alternative solution to a problem.

**Pacini et al., (1996) Rational-Experiential Inventory (REI)**, measures rational and experiential thinking styles. The REI measures the two independent processing modes with two factors: Need for Cognition (rational measure) and Faith in Intuition (experiential measure). Several studies have confirmed that the REI is a reliable measure of individual difference in information processing, and that the two independent thinking styles measured account for a substantial amount of variance that is not addressed by other personality theories (i.e. Norris, & Epstein, 2011).

**Haran et al., (2011) Active Open-minded Thinking Scale (AOT)** is based on Stanovich and West’s (2007) scale and is designed to capture thinkers’ desire to be more informed before making an estimate or prediction, and their higher attention to information already acquired may further improve their estimation performance.
Strathman et al., (1994) consideration of future consequences (CFC) measures the extent to which people consider distant versus immediate consequences of potential behaviour. This may be very important for the participants engaging in the IGT, since in order to maximize their profit participants’ need to encompass into strategy future consequences (punishment/reward).

Reiss et al., (1986) Anxiety Sensitivity Index (ASI), measures beliefs that anxiety experiences have negative implication. People who believe that anxiety has few or no negative effects may be able to cope with a relatively high level of exposure to anxiety-provoking stimuli. In contrast, people who believe that anxiety has terrible effects, tend to have anxiety reactions that grow in anticipation of severe consequences. Anxiety sensitivity therefore implies a tendency to show exaggerated and prolonged reactions to anxiety-provoking stimuli. Research indicated that the performance of healthy participants is characterized by substantial individual variability whereby individual choices are driven by frequency of losses rather than the long-term outcome of the decks. However one of the reason for the participants’ non-optimal performance may be sensitivity to punishments and rewards that may lead anxiety sensitive participants to a disadvantageous decision making.

Maia & McClelland (2004) Test of Awareness, measures raise of the conscious knowledge of the advantageous strategy as early as participants behave advantageously in the IGT. This sensitivity test encompasses 5 question in total with question 3 having 4 additional sub questions.

These scales are available and there are no copyright issues.

Bechara et al., (1994) computerised Iowa Gambling Task (IGT) is frequently used as an experimental task in the decision making research, and the University holds a copy of the IGT that will be used in this study.

The use of the Finometer (Finapres Medical System) will be undertaken after supervised training and the equipment used will be located in psychology laboratories. Research will be conducted during office hours and the researcher will adhere to the BPS Guidelines for Ethical Practice for conducting laboratory experiments.

The use of the Eye gaze binocular system (Tobii-X2-30) will be undertaken after supervised training and the equipment used will be located in psychology laboratories.
13. References Give the references for any sources cited in the sections on rationale, methods etc.


14. Ethical Considerations Please indicate how you intend to address each of the following in your study. Points a-i relate particularly to projects involving human participants. Guidance to completing this section of the form is provided at the end of the document.

a. Consent
The participants will be informed about the goals and purpose of the study, as well as known and unknown risks attached. The participants will be asked to fill out formal consent form, once they have agreed to take part in the experiment (see appendices)

b. Deception
Not applicable

c. Debriefing
At the end of the experiment the participants will be provided with full written debrief where they will be informed about the purpose of the study, what to do if they experience higher
d. Withdrawal from the investigation
Prior to the experiment, the participants will be fully informed that their participation is voluntary, about camera recording (experimental group) and that they are allowed to withdraw from the experiment at any time and any answers they had given up to that point would be deleted (email address of the researcher will be provided with the debrief document). If they decide to withdraw their data after they had taken the experiment, they will be allowed to do so within the time limit of four weeks from the day that they had completed the experiment.

e. Confidentiality
To provide anonymity and confidentiality participants will be asked to create a unique code, which will be a combination of the last two letters of their favourite film and the last two digits of their mobile number.

They will be asked not to reveal any personal details. Participants will be asked to leave their email addresses for contact purposes if they are eligible for a reward. However, it will be explained that the email address is only for contacting the highest scorers on the gambling game and that it will be deleted immediately upon data summary and prize been rewarded. The experimental data will be password protected and stored on external drive. The data collected will be accessible only to the researcher and his supervisors. All paper data collected will be stored in a secure locked cabinet, in a locked room.

f. Protection of participants
There is no deception involved and participants will be assured anonymity. ‘No harm will occur as a result of this experiment’. Participants under the age of 18 years old will not be allowed to participate in the study. Participants with the history of cardiovascular disorders or history of high blood pressure will not be allowed to participate in the study. Furthermore, if a participant has a very high blood pressure during the experiment they will be informed about such event advised to stop the experiment and informed that they might want to visit their GP.
g. Observation research [complete if applicable]

Not applicable

h. Giving advice

I will only be providing the relevant information in regards to the experiment and the phenomenon in question. If participants are concerned about anything else they will be advised to contact the student services at University of Derby. Furthermore, The researcher will act in accordance with both the BPS ethical principles and adhere to the codes of conduct outlined by the University of Derby to ensure ethical conduct and knowledge development

i. Research undertaken in public places [complete if applicable]

Not applicable

j. Data protection

The experimental data will be password protected and stored on external drive The data collected will be accessible only to the researcher and his supervisors. All paper data collected will be stored in a secure locked cabinet, in a locked room.

k. Animal Rights [complete if applicable]

Not applicable

l. Environmental protection [complete if applicable]

Not applicable

15. Have/do you intend to request clearance from any other body/organisation?

Yes/No (please circle as appropriate)
16. All projects have an element of risk which should be assessed before any project is undertaken.

Have the activities associated with this research project been risk assessed? Yes X No □

17. Declaration: The information supplied is accurate to the best of my knowledge and belief. I understand my obligations and the rights of the participants. I agree to act at all times in accordance with University of Derby Ethical Policy for conducting research with human participants. X
C.2. Ethical Approval

Approval Letter: Psychology Research Ethics Committee

University of Derby

Date: 30\textsuperscript{th} May 2016

Dr Frances Maratos
Chair, Psychology Research Ethics Committee, University of Derby

Dear Boban,

Ethics Ref No: 42-15-BS

Thank you for submitting this revised application to the Psychology Research Ethics Committee.

I have now reviewed the revised documents you sent following the feedback you received on your initial application, and I am satisfied that all of the issues raised have been dealt with. The application can now therefore be approved.

The following documents have now been re-reviewed:

1. Ethics application form
2. Invitation to Participate
3. Consent Sheet
4. Debrief
5. Questionnaire Materials

If any changes to the study described in the application or supporting documentation is necessary, you must notify the committee and may be required to make a resubmission of the application.
Please note ethical approval for application 42-15-BS is valid for a period of 5 years i.e. 30\textsuperscript{th} May 2021.

Good luck with the study.

Yours sincerely

Frances Maratos

Dr Frances Maratos
C.3. Materials

Eye gaze binocular system (Tobii-X2-30).

Finometer (Finapres Medical System, Amsterdam, Netherlands).

Toplak et al. (2014) extended version of the CRT

This is removed for copyright reasons Please see the original paper


This is removed for copyright reasons Please see the original paper

IGT instructions and procedure (Bechara et al., 1994) adopted for the computerised version

This is removed for copyright reasons Please see the original paper

INVITATION TO PARTICIPATE

My name is Boban Simonovic and I’m a postgraduate researcher at the University of Derby. As part of my research I’m interested in learning more about decision making under uncertain conditions.

The aim of the present research is to explore people’s decision-making abilities under uncertainty. A computer gambling game is involved. If you decide to participate in this research, you will be asked to complete this gambling game and several questionnaires. Your blood pressure will be measured during this process and you may experience slight pressure and discomfort on your arm. In addition, we will use an eye tracker device as a monitoring tool that measure gaze direction.

The experiment will take no more than 70 minutes. You will play the gambling game with virtual money. However, you are encouraged to play the game naturally to the best of your ability. You will receive four participation point for participating in this study. In addition, all participants have the option to be entered into a prize draw to win a £75 Amazon voucher. Participation is voluntary, and all information recorded will remain anonymous and
confidential. Data recorded for this study will not be used for any other purpose than the study itself. Data will be stored in accordance with data protection laws and University of Derby data collection and storage policies.

Please note that you may withdraw your participation at any time during the study without consequences. If you choose to withdraw your data after taking part please contact the researcher (see below) using your unique code. To provide anonymity of the data you will be asked to create your unique reference number. Once you have completed the experiment keep a note of your reference number and use it for any future correspondence. You will be asked to give your email addresses for contact purposes if you are eligible for a reward.

Email addresses will be used only for contacting the highest scorers on the gambling game and it will be deleted immediately upon data summary. Withdrawal from the study will result in all participant information being destroyed and not included in analysis. Participant withdrawal is available up to 4 weeks after participation.

Please note no harm will occur as a result of this experiment. However, to avoid and reduce any unnecessary risks, if you feel depressed or anxious, be advised not to take part in the present research.

Furthermore, people under the age of 18 years old and people who suffered from any form of cardiovascular disorders or high blood pressure are not allowed to take part in the experiment.

Please note that if during the experiment we notice that your blood pressure is higher than normal you will be informed and possibly advised to contact your GP.

Please do not hesitate to contact me at any time before during and after you made your decision to participate

Researcher contact e-mail: B.Simonovic@derby.ac.uk

Supervisor contact e-mail: E.J.N.Stupple@derby.ac.uk
INVITATION TO PARTICIPATE (experimental group)

My name is Boban Simonovic and I’m a postgraduate researcher at the University of Derby. As part of my research I’m interested in learning more about decision making under uncertain conditions.

The aim of the present research is to explore people’s decision-making abilities under uncertainty. A computer gambling game is involved. If you decide to participate in this research, you will be asked to complete this gambling game and several questionnaires. Your blood pressure will be measured during this process and you may experience slight pressure and discomfort on your arm. In addition, we will use an eye tracker device as a monitoring tool that measure gaze direction. Please be aware that the whole process will be recorded on camera and you will need to report your experience at the end of the experiment in front of the camera.

The experiment will take no more than 70 minutes. You will play the gambling game with virtual money. However, you are encouraged to play the game naturally to the best of your ability. You will receive four participation point for participating in this study. In addition, all participants have the option to be entered into a prize draw to win a £75 Amazon voucher. Participation is voluntary and all information recorded will remain anonymous and confidential. Data recorded for this study will not be used for any other purpose than the study itself. Data will be stored in accordance with data protection laws and University of Derby data collection and storage policies.

Please note that you may withdraw your participation at any time during the study without consequences. If you choose to withdraw your data after taking part please contact the researcher (see below) using your unique code. To provide anonymity of the data you will be asked to create your unique reference number. Once you have completed the experiment keep a note of your reference number and use it for any future correspondence. You will be asked to give your email addresses for contact purposes if you are eligible for a reward.
Email addresses will be used only for contacting the highest scorers on the gambling game and it will be deleted immediately upon data summary. Withdrawal from the study will result in all participant information being destroyed and not included in analysis. Participant withdrawal is available up to 4 weeks after participation.

Please note no harm will occur as a result of this experiment. However, to avoid and reduce any unnecessary risks, if you feel depressed or anxious, be advised not to take part in the present research.

**Furthermore, people under the age of 18 years old and people who suffered from any form of cardiovascular disorders or high blood pressure are not allowed to take part in the experiment.**

**Please note that if during the experiment we notice that your blood pressure is higher than normal you will be informed and possibly advised to contact your GP.**

Please do not hesitate to contact me at any time before during and after you made your decision to participate

Researcher contact e-mail: B.Simonovic@derby.ac.uk

Supervisor contact e-mail: F.J.N.Stupple@derby.ac.uk

**CONSENT FORM**

Name:

Date:

Personal Reference Number
This research is about people’s decision-making abilities under uncertainty. Please note that you are under no obligation to complete the experiment and you are not going to be penalised if you decide to withdraw during the process. Participation is voluntary, and all information recorded will remain anonymous and confidential. Data recorded for this study will not be used for any other purpose than the study itself. Withdrawal from the study will result in all participant information being destroyed and not included in analysis. Participant withdrawal is available up to 4 weeks after participation. You will need to use your unique personal reference number in order to send the request for data deletion. Contact e-mail B.Simonovic@derby.ac.uk.

What will participation involve? - It involves computer gambling game and answering questionnaires, while having your eye-movements and blood pressure activity monitored. It will take approximately about 70 minutes to complete the experiment.

As an informed participant of this research I understand that:

8. My participation is voluntary, and I may cease to take part in this research at any time, without penalty.
9. I am aware of what my participation involves.
10. I understand that all my additional questions about the experiment will be satisfactorily answered.
11. I’m aware that I can chose between the two rewards for this study: a) 4 participation points or b) 2 participation points and a £5 voucher.

Can you please indicate if you would like to enter the prize draw:

I would like to enter the prize draw Yes/No

Email:

I have read and understood the above and give consent to participate.

Participant signature_________________________________
CONSENT FORM (Experimental group)

Name:

Date:

Personal Reference Number

(Last two letters of your favourite film and last two digits of your mobile number):

This research is about people’s decision-making abilities under uncertainty. Please note that you are under no obligation to complete the experiment and you are not going to be penalised if you decide to withdraw during the process. Participation is voluntary, and all information recorded will remain anonymous and confidential. Data recorded for this study will not be used for any other purpose than the study itself. Withdrawal from the study will result in all participant information being destroyed and not included in analysis. Participant withdrawal is available up to 4 weeks after participation. You will need to use your unique personal reference number in order to send the request for data deletion. Contact e-mail B.Simonovic@derby.ac.uk.

What will participation involve? - It involves computer gambling game and answering questionnaires, while having your eye-movements and blood pressure activity monitored. It will take approximately about 70 minutes to complete the experiment.

Please be aware that your performance will be recorded during the experiment and by signing this form you are giving your consent.
As an informed participant of this research I understand that:

a) My participation is voluntary, and I may cease to take part in this research at any time, without penalty.

b) I am aware of what my participation involves.

c) I understand that all my additional questions about the experiment will be satisfactorily answered.

d) I’m aware that I will be recorded during the experiment.

e) I’m aware that I can chose between the two rewards for this study: a) 4 participation points or b) 2 participation points and a £5 voucher.

Can you please indicate if you would like to enter the prize draw?

I would like to enter the prize draw Yes/No

Email:

I have read and understood the above and give consent to participate.

Participant signature_____________________________

Participant email _______________________________

Researcher signature_____________________________

Date_______________________________

Debrief
Thank you for taking the time to participate in this experiment. Can you please confirm which of the two rewards you like to receive: a) 4 participation points or b) 2 participation points and a £5 voucher?

The aim of this research was to investigate the uncertain context of decision making under stress. This experiment had two conditions (stress vs no stress). It was hypothesised that the stress manipulation would inhibit performance on the IGT, and would delay the elimination of disadvantageous deck selections. The stress manipulation will reduce participants' reflective ability and both strategic and intuitive assessments of risk during the game. In the case of the gambling game, that you have just completed the initial ambiguity of the task did not provide adequate cues for strategic decisions making, perhaps leading you to rely on your ‘gut feelings’. If you were under stress, you were more likely to misinterpret and learn very slowly the contingencies of the decks. Furthermore, this study investigated the relationship between people’s thinking dispositions, thinking style, consideration of future consequences on gambling scores during the learning and performance phase.

Your eye gaze was monitored during the experiment because an increase of pupil dilation may have an effect on decision making. This assumption is based on the Somatic Marker Hypothesis which postulate that affective somatic states may be associated with prior decisions outcomes that are used to guide future decisions. For example, if you made a choice followed by a negative outcome, an emotional reaction becomes associated with that choice. Once the emotional reaction is sufficiently well established, the reaction occurs before a choice is made. If your pupil was slightly dilated, it is plausible that intuitively, you ‘knew’ which decks were bad even if you didn’t have any conscious awareness of it. Please bear in mind that your pupil dilatation will not have any effects on your health, and is completely normal.

Your blood pressure was monitored during the experiment because of the previous suggestions that an increase of the blood pressure may have an effect on decision making. Please bear in mind that if your blood pressure was slightly higher than usual this will not have any lasting effects on your health. However if you experience any unusual and persistent activity with your blood pressure (higher than normal) please contact your GP.
Hopefully your participation will make significant contribution in further clarification of these phenomena.

Please bear in mind that the data collected will only be used for this research, and will be stored and safeguarded on a removable disc by the researcher until after awarding of the academic degree (September 2016). Please keep your reference number safe for further correspondence, and bear in mind that you can withdraw your data up to 4 weeks after participation. For any further question please feel free to contact me or the Supervisor of this research Dr Edward Stupple

Researcher contact e-mail: B.Simonovic@derby.ac.uk

Supervisor contact e-mail: E.J.N.Stupple@derby.ac.uk

If you are interested in this topic, the article below may provide more information regarding people’s thinking disposition on decision making, following link about the blood pressure.


http://www.nhs.uk/conditions/blood-pressure-(high)/Pages/Introduction.aspx

Please bear in mind that you can always contact me or my supervisor if you have any additional questions or concerns about the study.

Physiological measurements instructions

Hello,

This study involves blood pressure and eye tracking measurements. Eye tracking involves a non-invasive tracking of your gaze that will in no circumstance cause you any harm. We will use the eye-gaze monitor in this study (shows the eye-tracker). Before we start
the device needs to be calibrated. Please follow the instructions as they appear on the computer screen and focus on the green dots as they appear. This should take no longer than 1 minute. Please let me know if you experience any discomfort? Before we start, let me provide you with information regarding blood pressure and inclusion/exclusion criteria for this study. This study will follow National Institute for Health and Clinical Excellence (NICE, 2011) guidelines in order to have an operational definition for high blood pressure. According to NICE 120/80 mmHG is ideal blood pressure while 140/90 mmHG and higher may be a reason for concern. People under the age of 18 years old and people who have suffered from any form of cardiovascular disorders or high blood pressure are not allowed to take part in the experiment. This is the Finometer that will be used for blood pressure measurement. Before we start I will take three baseline measurements. If the baseline measurements indicate that you have a very high blood pressure it is my duty to inform you about this and advise you not to participate in the experiment. Since the exact cause of the increase in blood pressure can be hard to pin down (e.g., smoking, lack of physical activity, genetics, too much alcohol or salt consumption) and it is beyond my expertise, you will be advised to visit your GP as a precautious measure. There may be no reason for concern, and the advice should be considered as a safeguarding measure. Please note that if during the experiment I notice that your blood pressure is higher than normal you will be informed and may be advised to contact your GP. Please note that there may be some increase in blood pressure during the experiment, but this will go back to normal at the end. At the end of the study I will take measurements to make sure that your blood pressure is back to normal.

Do you have any questions you would like to ask?