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THE EFFECTS OF EMOTIONAL AROUSAL ON DECISION MAKING

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"The unexamined life is not worth living."

Socrates, Athens, 469 BC - 399 BC

"Pleasure is the only thing worth having a theory about."

The Picture of Dorian Gray, Oscar Wilde, 1890

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SUMMARY

It is increasingly recognised that affect plays a crucial role in decision making. This thesis investigates the extent to which arousal is an important, and neglected, factor in decision making under risk. Arousal level was manipulated on two gambling tasks via (1) muscle-tension-induced (MTI) arousal and (2) increased magnitude (and quality) of monetary reinforcement. On the Iowa Gambling Task (IGT), a commonly used neuropsychological tool involving reward contingency learning, both arousal-induction methods led to impaired performance. These results are discussed in terms of inconsistencies with Somatic Marker Hypothesis (SMH) predictions regarding task-relevant arousal, and background somatic state, and have important implications for future use of the IGT. On the Explicit Gambling Task (EGT), a novel probabilistic gambling task without involvement of reward contingency learning, increased arousal led to higher risk-taking where the choice of probabilities was most extreme. The EGT results have important implications for gambling tasks generally and are consistent with the interpretation of the detrimental arousal effects on the IGT as partly attributable to increased risk-taking. Effects of MTI arousal were also found on a Sexual Decision Making Questionnaire, and this is believed to be the first study to report an effect of non-specific arousal on sexual behaviour intentions. The findings in this thesis are discussed in terms of the SMH, micro-economic theory, misattribution of arousal and the commonly used distinction between affective and deliberative models of information processing and decision-making. It is thus concluded that arousal (which may be non-specific, non-valenced, task–relevant or incidental) is an important factor in the relative shift in balance between 'cold' deliberative cognitive (S2) processes, which may better take account of long-term considerations, and 'hot' emotional (S1) processes more concerned with immediate reward (or avoidance of punishment). Increased arousal may therefore increase the tendency to engage a pre-potent response (as opposed to a more deliberate one), leading to behaviour which is more stimulus-bound and impulsive.

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CHAPTER ONE

LITERATURE REVIEW: REASON, PASSION AND DECISION MAKING

Decision-making characterises most moments of our life, whether it be choosing between competing options based on known consequences, trying to assess risk in a novel situation, deciding whether to go with a 'gut instinct' for reasons we can't easily explain, or trying to exert willpower when choosing between a tempting 'here and now' option over a possibly wiser, long term alternative. This chapter provides an overview of the history of research of emotional influences on decision making. It can be seen that the focus has moved from a traditional view of the rational and dispassionate individual, with optimal decision making as an unemotional process, to a recognition of the crucial role of emotion in decision making. The many influences of emotion on decision making, both advantageous and maladaptive will be described, together with research which suggests that emotional arousal, rather than specific mood may be a more appropriate research focus.

1.1 Cognitive Evaluation (and expected emotions)

Traditionally, in ancient philosophy, it was believed that efficient decision-making involved suppression of the emotions in favour of rational calculation. Aristotle, for example, believed that 'the passions' could only cloud logical judgement, whilst Plato conceptualised behaviour as a chariot driven by the two opposing horses of reason and passion: Reason was a horse driven by rationality alone while Passion was a horse driven by irrationality, appetite and emotion, needing to be reined in constantly (cited in Elster, 1999). More recently, decision-making was studied initially from within the economic discipline. Again, decision-making was seen as an essentially cognitive process, with people evaluating different options and their outcomes dispassionately. The role of emotion was only accounted for in as much as people were proposed to consider how the decision consequences would later impact on their affective state.

1.1.1 Economic theories of decision making under risk

An important concept economic models of decision-making have attempted to address is that of decision-making under risk, or probabilistic decision-making, and for many years the Expected Utility (EU) Model was the dominant theoretical framework (e.g., von Neumann & Morgenstern, 1944). According to this model, the decision-maker is seen as a rational agent, weighing up both the desirability, or 'utility', of an option and the probability of that outcome mathematically and then deciding in favour of an option which will maximise positive emotions and minimise negative emotions. Utility theories treat the subjective values that enter into the decision-making process as fixed and invariant parameters. However, it has since been shown that people do not always decide purely in terms of mathematic reasoning but regularly show patterns of behaviour that violate the model's assumptions. As will be discussed, advances have been made to the EU model, to more realistically describe the role of expected emotions in decision-making - for example, with respect to the construction of subjective utilities, asset integration, counterfactual comparisons and non-linear probability weighting.

Kahneman and Tversky (1979) developed an alternative model to describe noted deviations from rational decision-making. Prospect Theory (Kahneman & Tversky, 1979) proposes that, when making decisions under conditions of risk, the value of a utility is determined by comparison with a contextually dependent reference point, which may be somewhat arbitrary and idiosyncratic. This reference point may be manipulated through the description of options and, thus, the way a choice is framed may lead to opposing decisions. One important result of Kahneman and Tversky's (1979) work was to demonstrate that people's attitudes toward risks concerning gains may be quite different from their attitudes toward risks concerning losses. For example, when given a choice between receiving a certain $1000 or having a 50% chance of getting $2500 they often choose the certain $1000, even though the mathematical expectation (Probability x Outcome) of the uncertain option is $1250. This behaviour is described as risk-aversion. But Kahneman & Tversky (1979) also found that the same people, when offered a certain loss of $1000 versus a 50% chance of no loss or a $2500 loss, often choose the risky alternative, exhibiting risk-seeking behaviour in the negative domain. Although not necessarily irrational, this study demonstrated an interesting asymmetry evident in human choice behaviour, which cannot be accounted for by earlier models based on purely rational choice.

The EU model postulated that a person is concerned with the final situation following the consequences of their choices. However it has been found that, when appraising the possible consequences of gambles, people respond emotionally not to the associated absolute levels of wealth but the incremental gains and losses (e.g., Markowitz, 1952; Tversky & Kahneman, 1992) Modern cognitive-appraisal models of decision-making have thus abandoned the original assumption of asset integration. Another recent model which not only abandoned the concept of asset integration but more explicitly described a role of emotion in choice was that developed by Lopes (1987). Lopes (1987) proposed that decision-making under risk is a function of the two variables of aspiration level and security/potential.

Security/potential is a dispositional trait closely related to risk aversion/risk-seeking – so that security-minded individuals will focus on the worst possible outcome, whilst the potential-minded will focus on the best. Aspiration level is a situational variable encompassing the environmental opportunities and constraints present. Another modification to the EU model is a move to consider the role of counterfactual emotions. This refers to the observation that, when anticipating how we will feel about possible outcomes, we often compare decision outcomes with the alternative possibilities. For example, regret theory (Loomes & Sugden, 1982, 1986) and disappointment theory (Bell, 1982) claim that utilities reflect not simply the value of an outcome but its relative value when compared to easily-imagined counterfactual outcomes. Whilst other modern theorists have stressed the drive to protect self esteem from the possibility of regret, especially if the decision-maker is likely to receive feedback about the results of the rejected alternatives (e.g., Larrick, 1993; Larrick & Boles, 1995). Further research is necessary, however, to determine the exact effect and extent of these influences.

A further observation serving to discredit the EU model and the idea of the decision maker as a purely rational individual comes from the finding that, when making decisions under risk, the weight people place on the possible consequences of a decision and the likelihood of those consequences occurring are not directly proportional. Kahneman and Tversky (1979) proposed the non-linear probability weighting function to describe this tendency for people to over-weight small probabilities, whilst being insensitive to variations in mid-range probabilities and under-weighting moderate and high probabilities (Prelec, 1998). This violation from original economic theory can be seen in the tendency of amateur gamblers to back long-shots with only a small probability of winning. Also, in situations of uncertainty, Srull (1984) found people will tend to choose the familiar over the unfamiliar and that when they do choose the unfamiliar this results in more arousal.

1.1.2 Inter-temporal choice

A second concern in devising models of decision-making is how we evaluate decisions with a temporal aspect, i.e. decisions where the consequences are delayed. The discounted utility (DU) model, first introduced by Samuelson (1937) had been the dominant model of inter-temporal choice. An analogue to the EU model, the DU similarly took little account of emotions in decision-making and its assumptions of the individual as a rational decision-maker have also been called into question. The DU model assumes positive time discounting, i.e. that people place less weight on outcomes when they are delayed. It also assumes that we can calculate simply the utility of any delayed option by multiplying the utility by a constant discount factor. However, from both animal and human studies it is evident that the discount rates decrease as the length of the delay increases; i.e. people appear to care more about delays close in time than delays that are far in the future. Contradicting the main tenet of the DU model, in reality the discount rate is therefore not constant but varies systematically, with the rate of discounting decreasing as the utility moves further into the future - a phenomenon known as hyperbolic time discounting (for review, see Shane, Loewenstein, & O'Donoghue, 2003).

Hyperbolic time discounting can have profound implications for decision-making behaviour and may be been seen as an explanation of impulsivity. Impulsivity is the tendency for people towards instant gratification, choosing instant smaller rewards over delayed larger rewards, or the selection of larger delayed penalties over immediate smaller penalties (Ho, Mobini, Chiang, Bradshaw, & Szabadi, 1999). There is much individual variation in levels of impulsivity and although impulsivity is associated with neurological impairments, psychiatric disorders and drug addiction, (American Psychiatric Association, 2000; Bechara, Damasio, Damasio, & Anderson, 1994; Rahman, Sahakian, Cardinal, Rogers, & Robbins, 2001; Rogers et al., 1999), it is unclear why healthy people may show some degree of impulsivity. It may be due to an inability to suppress actions and/ or distorted weighting of values. Although an advance of traditional DU models, however, the concept of hyperbolic forecasting cannot explain other variables which are known to have an effect in inter-temporal choice. For example, reward-specific instances of impulsivity, and the power of current affective or motivational state and of physical proximity or sensory contact with an object to lead towards decisions of instant gratification (Hoch & Loewenstein, 1991) suggest a role of more immediate emotions that hyperbolic discounting cannot account for.

Another variable to be considered in inter-temporal decision making is the fact that desires change over time. Affective forecasting refers to the ability to predict future desires; much research suggests that, in predicting their future states and needs, people are systematically biased by their current needs. Two sources of such errors have been identified: underestimation of one's ability to adapt to circumstances and a tendency to overestimate the pleasurable impact of an event on which one is focused. (e.g., Loewenstein & Frederick, 1997). For example, non-addicts or addicts not currently craving drugs will underestimate the extent of future cravings (Loewenstein, 1999). Such biases in future predictions can have adverse consequences for decision making.

1.2 Immediate Emotions

Where economists have taken account of affect, then, they have largely focused on expected emotions, the emotions which one would anticipate experiencing in the future as a result of the decision. Immediate emotions, i.e. emotions experienced at the time of the decision-making have been ignored. However, our behaviour is strongly influenced by affective systems, systems essential for daily functioning (LeDoux, 1996; Panksepp; Rolls, 1999). As will now be discussed, recent research has highlighted how other factors can affect the quality of decisions, such as anticipation, internal deprivation states and external stimulation, affective state and incidental emotion unrelated to the decision at hand, trait personality and neurological deficits.

Emotions has be defined as a set of complex interactions between subjective and objective factors, which are mediated by neural and hormonal systems and can generate affective experience, cognitive processes and physiological adjustments, leading to expressive, adaptive and goal-directed behaviour (Kleinginna & Kleinginna, 1981). It seems likely that emotions evolved in order to best direct behaviour, to motivate us towards the most salient action (Baumeister, Vohs, DeWall, & Zhang, 2007). Schultz (2000) believes that, although originally related to biological needs, rewards have evolved to allow for more sophisticated behaviour. Such higher rewards are often based on cognitive representations and can involve objects or concepts such as power, territory, novelty, challenge and acclaim. It is now known that the classic dualistic division of reason and passion is not supported by the architecture of the brain. Not only has the prefrontal cortex, assumed in the past to be exclusively involved in complex cognition, now been shown to be an essential convergence zone for cognitive and affective information (Damasio, 1994) but, also, some sub-cortical structures once viewed as part of the emotional 'limbic system' (MacLean, 1949) are now also known to be implicated in cognitive processes. For example, the hippocampus has been shown to be critical in memory processes (e.g., Yanike, Wirth, & Suzuki, 2004) and the amygdala impacts cognitive processing by prioritising early attention to emotionally salient stimuli (Holland & Gallagher, 1999).

1.2.1 Effects of mood on decision making

Experimental manipulation of immediate affect has been found to have effects on decision-making. For example, there is a large body of research demonstrating that positive mood leads to optimism and negative mood to pessimism when assessing probabilities (Constans & Mathews, 1993; Johnson & Tversky, 1983; Mayer, Gaschke, Braverman, & Evans, 1992; Pietromonaco & Rook, 1987; Wright & Bower, 1992), and that mood influences the level of risk-taking (e.g., Grable & Roszkowski, 2008; Isen, 1997; Mano, 1992; Raghunathan & Pham, 1999; Yuen & Lee, 2003). The direction that the effect of mood takes on risk-taking has been highly inconsistent, though, as will be further discussed later in the thesis. It has also been demonstrated that affect and subsequent decision-making can be influenced by even the most minimal of cues. Factors identified as influencing immediate emotions include odour (Baron & Kalsher, 1998) crowding, sights and sounds (Gifford, 2007).

Emotions may also have indirect influences on decision-making, by impacting on judgment of expected outcomes, the emotional reactions to them and in the nature of information processing. For example, immediate emotions may also bias the interpretation of relevant information in the decision-making process. Studies have shown that negative emotions can narrow attentional focus whilst positive emotions have the opposite effect

(Ashby, Isen, & Turken, 1999; Isen, 1997); although others believe that emotions have a more emotion-specific effect that cannot be accounted for by valence alone (Niedenthal, Halberstadt, & Innes-Ker, 1999). Other research has focused on the impact of incidental emotions on the depth of information processing, reporting that negative emotions lead to more systematic processing and positive ones to relatively heuristic processing (Bodenhausen, Kramer, & Susser, 1994; Nolen-Hoeksema & Morrow, 1993), while another study found that a happy mood increased reliance on general knowledge structures relative to negative mood, but without necessarily leading to lower cognitive performance (Bless, Schwarz, Clore, Golisano, & Rabe, 1996). Some authors have stressed the role of arousal level as well as emotional valence (Bodenhausen, 1993; Mano, 1992) or have suggested that depth of processing is driven by more specific emotions rather than general valence (Bodenhausen et al., 1994). Immediate emotions can also influence people's perceptions of how they will feel about possible outcomes. As will be further discussed, when people try to predict how they will feel they often project current state onto the future and they are also poor at predicting behaviour of others who are in a different emotional state from themselves (Loewenstein, 1996).

Another indirect way in which emotions have been proposed to affect decision making is through emotion regulation. This is the idea that we are driven to behave in a way that alters our mood (Galliot & Tice, 2007). For example, people are more likely to give in to their impulses when emotionally distressed, and this tendency to decide in favour of immediate gratification over long-term benefits is not seen when people believe that this action will not improve their mood. This effect has been seen with regard to eating restraint, frivolous procrastination, and a delaying gratification computer task (Tice, Bratslavsky, & Baumeister, 2001). The authors concluded that, rather than suffering from lack of motivation or an inability to exercise self-control, when people are upset they give short-term affect regulation priority over other goals., i.e. when people want relief from bad moods they make choices which may undermine their long term well-being.

Although there is no one accepted definition, mood is generally seen as an affective state which is more sustained but of lower intensity than an emotion (although shorter term than temperament). Also, whereas an emotional response is generally experienced in response to a specific stimuli, with mood the cause is often unknown or more complex. It is often unclear to what extent an experimentally induced affective state resembles a mood versus an emotion. As will be elaborated upon in fuller detail later in the thesis, it can also be seen that experimental mood induction has lead to complex and often contradictory results in laboratory tests of decision making and that arousal level may be a neglected and crucial component.

1.2.2 Differences between 'expected' emotions and 'immediate' emotions

Whereas expected emotions, as originally considered, are an essentially cognitive phenomenon, i.e., the cool, rational process of deciding on the optimum choice to make us happy at a later time, immediate emotions refer to the affective state generated during the decision-making process. Immediate emotions can be seen to differ from expected emotions in terms of their relative insensitivity to probability, their sensitivity to timing and vividness of events, and individual perceptions of control. As described earlier, the EU model stated that a utility's sum outcome and the probability of occurrence are both processed equally when deciding upon an uncertain prospect. Psychophysiological studies of anxiety have shown, however, that probabilities have a relatively small role in emotional responses. For example, it has been found that during anticipation of a shock, psychophysiological measures correlate with the intensity of the anticipated shock but not with the probability (Monat, Averill, & Lazarus, 1972). It was also shown that arousal responses increase as the outcome approaches (Monat, 1976). Damasio (1994) explained this phenomenon by proposing that anticipatory emotions stem from mental images of possible outcomes. Such images give rise to associated emotional reactions, regardless of probabilities of occurrence. Consistent with this explanation, Sjoeberg (1998) found dissociation between intellectual judgements of risk and emotional reactions to the same risks. Also, it has been reported that the ability to generate vivid mental imagery is positively correlated with the intensity of emotional reactions, for example as seen in the intensity of salivation on imagining food (White, 1978). Thus it appears that a mental image can act as a conditioned stimulus, biasing decisions and producing the appropriate response (in this case, salivation) in the same fashion as the unconditioned stimulus (food).

The fact that there is no simple linear relationship between probability of an outcome and the associated emotions may explain the phenomenon of non-linear probability weighting described earlier. Over-weighting of small probabilities has also been found to occur more for vivid, emotion-evoking outcomes compared to more neutral outcomes (Hsee & Rottenstreich, 2004; Rottenstreich & Hsee, 2001) As the event draws closer in time, anticipatory arousal increases and one can become more biased by emotion. This was illustrated by Read and van Leeuwen (1998) in a study where participants were more likely to choose an unhealthy snack when it was to be served immediately but more likely to choose a healthy snack when it would be served further in the future.

Another factor which may account for the divergence in influence between expected and immediate emotions is temporal delay between the decision and the resulting consequences. Even when the probability and severity of the outcome does not vary, anticipatory emotions will tend to intensify as the event approaches. This was shown in a study which demonstrated increased physiological responses and self-reported anxiety as time drew closer to an anticipated electric shock (Monat, 1976). This factor was also proposed to account for the phenomenon of 'chickening out' of an event one was initially happy to take part in (Van Boven, Loewenstein, & Dunning, 2005).

Anticipatory immediate emotions also differ from expected emotions in terms of perceived control. For example, when panic-prone patients were administered with a panic provoking agent, those who knew they could reduce the concentration of the agent by turning a dial suffered less panic than those who did not, even though the former group of patients did not actually make use of the dial (Sanderson, Rapee, & Barlow, 1989).

1.2.3 Neuroeconomics: further evidence of the role of emotion in decision making

Recently there has been a resurgence of interest in emotion amongst neuroscientists and the relatively new discipline of neuroeconomics offers a strategy for testing economic models of decision-making. Contrary to the traditional view of decision making as involving rational, unemotional cognitive processing, many recent neuroscience studies support a role of emotional neural systems in decision-making. For example an fMRI study of neural correlates of time discounting suggested that emotional limbic areas are activated in decisions involving immediate reward, versus greater frontal-parietal activity when choosing long term options. (McClure, Ericson, Laibson, Loewenstein, & Cohen, 2007) Another fMRI study of risk aversion versus risk-seeking framing effects demonstrated that this effect involved emotional processes and was mediated by the amygdala (De Martino, Kumaran, Seymour, &

Dolan, 2006). It has been reported that subjective utilities were calculated according to a context dependent reference frame and encoded by the amygdala, a structure crucial in the processing of emotions (Breiter, Aharon, Kahneman, Dale, & Shizgal, 2001), while a positive emission tomography study utilising a menu task reported that emotion systems were involved in making decisions involving subjective values, regardless of internal homeostatic influences (Arana et al., 2003).

1.2.4 Neurological Evidence

Whereas emotions were traditionally seen as an extraneous factor in decision making, either neglected or viewed as having a detrimental effect, observations of neurological patients with specific impairments of personal and social decision-making provide a dramatic example of the crucial role of emotion. The 1848 case of Phineas Gage was famously reported by Harlow (1868). Whilst using a tamping iron to compress explosives; the iron bar shot through Gage's cheekbone and out the top of his head. Gage survived the accident but a man previously described as a hard-working, shrewd planning, exemplary citizen suffered dramatic personality changes, including impulsive and disadvantageous decision-making, extremes of emotional instability and social disinhibition (Harlow, 1868). Despite intact language, memory and intellect, Harlow noted that "Gage was no longer Gage" (1868, p.327). Recent reconstruction of the skull demonstrated that iron had destroyed the ventromedial aspects of the anterior portions of both right and left frontal cortex (Damasio, Grabowski, Frank, Galaburda, & Damasio, 1994). More recently, Damasio, Bechara and colleagues have systematically studied the emotional and social behaviour of patients with damage to the same area of the prefrontal cortex (e.g., Bechara et al., 1994; Bechara, Tranel, & Damasio, 2000; Damasio, 1994; Saver & Damasio, 1991). It was observed that patients with ventromedial prefrontal (VM) lesions exhibited impaired expression and experience of emotions and, also, severe impairments of decision-making in personal and social matters – described by family as having changed personalities (Bechara et al., 1994). Bechara et al. (1994) describe how these patients act without appropriate concern for the future, repeatedly make decisions leading to negative consequences and appear not to learn from their mistakes. Such deficits appear to result from an inability to use emotion-based learning systems which provide information about the possible future outcomes of personal decisions (Damasio, 1996). These systems are thought to involve the ventromedial prefrontal cortex, the somatosensory cortices, the insula, and the basal ganglia (Damasio, 1997); Damasio, 1998), with multiple sources of peripheral feedback also influencing decision-making (Damasio, 2004). These impairments in real-life social cognition were dissociated from intact intellectual and memory abilities, normal performance in 'executive' tasks, e.g. in the Wisconsin Card Sorting Test (Milner, 1963; cited in Damasio, 1994), and intact social knowledge and processing in experimental conditions (Saver & Damasio, 1991). Shallice and Burgess (1991) also reported social and personal planning impairments in prefrontal patients with otherwise largely intact cognitive abilities.

Based on the aforementioned clinical observations, Damasio proposed that emotions are highly involved in reasoning and decision-making (1994). It is claimed that this is also supported by experimental work with the Iowa Gambling Task (IGT). The IGT was developed with the aim of simulating, in the laboratory, some of the properties of real-life decision-making. Thus, the task involves making repeated selections from 4 decks of cards, with rewards and penalties, and with participants having little knowledge regarding the contingencies involved (Bechara et al., 1994). It is believed that the processes involved in decision-making on the IGT are distinct from conventional working memory, with a study of neurological patients demonstrating a double anatomical and cognitive dissociation between the IGT and a working memory task (Bechara, Damasio, Tranel, & Anderson, 1998).

Extending upon influential early models which saw emotional experience as arising from visceral signals combined with higher perceptions of the environment, (James, 1884, 1894), Damasio (1994) proposed the somatic marker hypothesis. This proposed that bioregulatory processes adapted to act as somatic 'markers' or biasing devices, explicit or implicit, – limiting options, saving time and facilitating logical reasoning according to individual's past experience. Support for this theory largely comes from a correlation between successful IGT performance and the development of skin conductance responses (SCRs). SCRs were recorded during employment of the IGT, the aim being to provide physiological indications of autonomically–controlled somatic state changes, and it has been reported that enhanced magnitude responses are normally produced following reward or punishment (Bechara et al., 1994). In the seconds prior to card selection anticipatory SCRs were also reported, which has been interpreted by Bechara et al. (1994) as an automatic signal originating in the prefrontal ventromedial region. This early signal is proposed to cause further processing and to enable marking of the contingency with a negative bias (Bechara et al., 1994). Within the theory, the ventromedial region of the prefrontal cortex is especially critical, due to its ability to integrate signals from the body, and to reactivate learnt associations between specific stimuli and the bioregulatory states experienced.

In normal participants, anticipatory responses to the 'bad' decks were reported to continue to rise in amplitude, even before participants report any subjective awareness of the properties of the different decks (Bechara et al., 1994). VM patients experience a normal, large SCR response to loss of money, in the same way as healthy controls, demonstrating that they have intact core affect systems and still experience emotion. However, crucially, before selecting from a bad deck, they fail to show the anticipatory SCRs that develop in healthy participants (Bechara et al., 1994). This 'advance warning' effect was proposed to aid cognition through prediction of the most advantageous choice (Bechara et al., 1994), and the fact that such patients fail to develop an avoidance of poor-outcome decisions was proposed to explain their consistently poor performance, both on the IGT and in everyday decision-making. If this is the case, then the IGT may be examining a set of psychological processes, i.e. the role of emotion in cognition, which other so-called 'executive' tasks do not.

Evidence from brain damaged patients has highlighted the necessity of understanding how emotion influences our ability to process information and motivates behaviour towards an adaptive choice amongst what, in real life, can be myriad of possible options. Almost every action we take is coloured by the value we assign to it and by the emotional consequences on ourselves or others. It is increasingly being recognised then, that emotions contribute positively to decision-making. This view meshes with everyday experience that decisions often seem to be made effortlessly and intuitively. And it has been suggested that studies investigating unconscious emotion learning systems, including those employing the IGT, can be seen as aiding our understanding of the underlying neurobiology of intuition, or our ability to listen to our 'gut feelings'(Turnbull, 2003).

Certain aspects of this theory, in particular what the IGT-associated SCRs actually represent, and how cognitively penetrable the reinforcement schedules are has since been contended (for review, see Dunn, Dalgleish, & Lawrence, 2006). However, the IGT has remained a useful and well-validated neuropsychological tool for detection and measurement of impairment in VM patients, and has been extensively applied to other pathologies associated with dysfunction of the orbitofrontal region. Examples of subjects investigated using the IGT include the neural basis of addiction (Leland, Richardson, Vankov, Grant, & Pineda, 1999), decision-making and addiction (Bechara & Damasio, 2002; Bechara, Dolan, & Hindes, 2002), decision-making in psychopaths (Schmitt, Brinkley & Newman; 1999), and the brain areas underlying impulsive aggression (Best, Williams, & Coccaro, 2002). The task has also been employed to explore the effect of a wide range of variables where personal decision-making is linked to reward in normal participants.

1.3 Maladaptive Effects of Emotion

However, although at mild to moderate levels emotions can serve to facilitate decision-making, there is plenty of anecdotal evidence that at a higher intensity they can become overwhelming, giving rise to biased, inefficient judgement and reckless, later regretted behaviour. People often report being ‘out of control’ or acting ‘in the heat of the moment’, in a way they know was not in their best interests.

Phobias represent an excellent example of the over-whelming of cognition by affect. Barlow (1988) described how patients with severe phobias, although overtly aware there is nothing to fear, cannot rationalise themselves out of the overwhelming emotional state. It seems adaptive that intensely emotional life-threatening stimuli should have the ability to override cognition and take over our attentional resources. Rolls (1999) claims that such conflict between affective response and cognitive appraisal arises from the fact that human reward and punishment systems may operate implicitly as in other animals. Unlike other animals, though, we also have the explicit ability to predict and plan ahead, and these two systems may drive behaviour in divergent ways. Turnbull (2003) has stated that, based on evidence from neurological and schizophrenic patients, there are good grounds for assuming that an over-reliance on emotion systems may be disadvantageous to cognition. The neuroleptic drugs used to treat schizophrenia are known to target the D2 dopamine system (Nishi et al., 1999), also known within psychiatry as the affect system. Similar paranoid delusions to those associated with schizophrenia are also exhibited in people with stimulant psychoses, developed after extended use of amphetamines or cocaine. As with schizophrenia, these cases of delusions are also alleviated by administration of neuroleptic drugs acting on the D2 system, although the literature has not yet accounted for exactly how this occurs. As it is only the positive symptoms of schizophrenia, the delusions, that are responsive to the neuroleptics, it seems likely that modifications to the emotion systems are somehow responsible for an inability to correctly assess available evidence, leading to the productions and maintenance of these false beliefs (Turnbull, 2003).

LeDoux (1996) distinguishes between cognitive computations, giving information about stimuli and relations between them and affective computations which yield information on the significance of that stimuli for the organism. Cognitive evaluations are proposed to come from relatively slow but sophisticated processing of more complex features of the situation via the 'high road', the thalamocortical route to the visual, auditory, somatosensory, gustatory and olfactory cortices. Emotional reactions to stimuli, however, can occur automatically, unconsciously and more rapidly than cognitive evaluations, at the early stages of perception via a 'quick and dirty' sub cortical route from the sensory thalamic structures to the amygdala. Found in the temporal lobe, the amygdala is probably the structure most implicated in emotion. It has been associated with affective behaviour, motivation, and learning (Cardinal, Parkinson, Hall, & Everitt, 2002). LeDoux (1996) believes that because of a far greater connectivity from the amygdala to the cortex compared to that in the opposite direction, the amygdala has a far greater control over the cortex, which allows rational thinking to be dominated by emotional arousal.

It has also been argued that emotions save cognitive resources, with a specific emotion triggering an adaptive universal response, e.g. anger triggering aggression and that this emotion may carry over to unrelated situations if not acted upon (Frijda, 1986; Lazarus, 1991). Panksepp (2004) has highlighted the difficultly of discerning whether one's feelings are reactions to a current decision or incidental feelings still remaining from a previous event. For example, one study found that participants who had just been shown a film where the perpetrator of a crime escaped unpunished delivered harsher justice to a perpetrator in an unrelated case, compared to participants who had watched a film where justice was seen to have been served (Goldberg, Lerner, & Tetlock, 1999). There is therefore evidence for a strong interaction between cognition and motivational systems. Another relevant example is the Read and van Leeuwen (1998) study in which it was found that hunger deprivation mediated the choice between healthy versus unhealthy snacks. It is arguable how much control we have regarding the influence of emotional carryover. It has been claimed that increasing a person's vigilance of low-moderate intensity emotions can be sufficient to lessen their impact on decision (Schwarz & Clore, 1983) . Others have argued that in decision-making, people may be unaware of a prior event having an influence (Johnson & Tversky, 1983), may have difficulty in ignoring those influences without over or under-compensating (Strack, 1992), or may actually increase their underlying arousal in the process of attempting to suppress the emotion (Gross & Levenson, 1993). Also, reducing emotional carryover through encouraging the person to attribute the emotion to an unrelated event has been found to be unsuccessful where the incidental emotion concurs with the person's dispositional state (Gasper & Clore, 1998).

1.3.1 Effects of arousal on decision making

Rather than focusing on specific moods, Loewenstein has focused on the role of arousal as key in decision making. Loewenstein (1996) used the term 'visceral factors' to explain how arousal caused by motivational factors such as hunger, pain and sexual desire can affect the desirability of goods and actions and can help explain the discrepancies between behaviour and self interest. Loewenstein stated that such visceral influences on behaviour can be caused not only by temporal proximity of the decision to the individual but by physical, i.e. sensory, proximity. For example, Ariely and Loewenstein (2006) found, that when sexually aroused, participants found a wider range of stimuli sexually attractive and that sexual arousal raised the salience of sexual considerations but decreased the importance of associated ethical and health issues. Sexual arousal was also found to lead to reports of a greater tendency towards sexual forcefulness in a date rape scenario (Loewenstein, Nagin, & Paternoster, 1997). In financial tasks sexual arousal has also been found to result in increased risk-taking (Knutson, Wimmer, Kuhnen, & Winkielman, 2008) and greater discounting of future rewards (Wilson & Daly, 2004). Another study using food stimuli to induce arousal found that participants who could smell the chocolate chip cookie prize felt more optimistic about their chances of drawing a winning card and took more risks to achieve the reward than participants who merely heard a description of the cookie (Ditto, Pizarro, Epstein, Jacobson, & MacDonald, 2006).

An interesting finding in some of these studies (Ariely & Loewenstein, 2006; Ditto et al., 2006) is that affective forecasting was poor. Also referred to as the hot-cold empathy gap, this phenomenon describes how, when in a non-aroused or 'cold' state, people under-estimate the influence of affective arousal on their behaviour when in a 'hot' state (Loewenstein & Lerner, 2003). Similarly, Metcalfe and Mischel (1999) have also described a cool cognitive 'know' system and a hot emotional 'go' system which can interact to enable or undermine the individual's attempts at self control. Loewenstein (2000, p.430) states that almost all visceral factors can be associated with later regretted lapses in self-control: "hunger and dieting, sadness and impulsive suicide, anger and violence, sexual desire and sex crimes, fear and panic". Self control has also been characterised as a muscle, i.e. a limited and consumable resource (Muraven & Baumeister, 2000). Muraven and Baumeister (2000) report evidence that acts of self control, which may include coping with stress and regulating negative affect, mean that further attempts at self control are more likely to fail.

1.4 Arousal

Arousal is important in all mental functions, contributing to attention, perception, memory, emotion and problem-solving. There is no universally accepted definition of arousal but it has been described as "a condition conceived to vary in a continuum from a low point in sleep to a high point in extreme effort or intense excitement" (Duffy, 1962). Arousal involves both a physiological response (e.g., increased heart rate) and cognitive processes (e.g., appraisal of an event), and it has been described as a non specific component of motivation which reflects intensity rather than direction of motivation (Humphreys & Revelle, 1984) or the valence of affect (Whissell, Fournier, Pelland, Weir, & Makarec, 1986). It is possible that heightened arousal will lead to an increase in motivation in a range of behaviours, as directed by environmental context (Antelman & Caggiula, 1980; Brehm & Self, 1989; Katz, 1978).

Mental representations of emotion generally involve some arousal-based content (Russell & Barrett, 1999), in that people report feelings of being mentally or physically attentive, active or 'wound up' versus a feeling that the mind and body is at ease, still or sleepy. The exact role of arousal in the experience of emotion is unclear. William James (1884), and later Damasio (1994), proposed that specific emotions arise from unique patterns of somatic or visceral arousal, while Schachter and Singer (1963) proposed that emotion arises from cognitive evaluation of more generalised autonomic arousal. Research suggests that neither of these accounts is completely comprehensive, however. Different emotions have not consistently been correlated with specific visceral sensations, different measures of autonomic, cortical and somatic arousal tend not to correlate highly with one another and, also, people seem to vary in the extent to which they may have immediate, explicit access to autonomic activity (Barrett, Quigley, Bliss-Moreau, & Aronson, 2004).

Emotional reactions are typically accompanied by intense cortical arousal. During arousal, cells in the cortex and the thalamic regions which supply the cortex become more sensitive, with action potentials occurring at a faster, out of sync rate, in which some cells are driven especially strongly by salient incoming stimuli (LeDoux, 1996). Controlled by working memory, cognitive tasks become specifically focused on the emotionally arousing situation. It is generally accepted that there is an optimal level (Hebb, 1955; Yerkes & Dodson, 1908) – with too little arousal we would fail to pay attention to important stimuli, whilst too much arousal would lead us to become anxious and unproductive. A high level of arousal can be advantageous in a dangerous situation, helping us to stay alert to relevant details, but can also be a distraction when we wish to focus on other things and have difficulty in 'turning off' this level of arousal, this being the detrimental nature of anxiety. Inverted u-shaped effects of arousal on performance and problem-solving have most commonly been explained in terms of Easterbrook's (1959) concept of relevant and irrelevant cues. With increased arousal, fewer cues are processed, thereby excluding irrelevant ones. But, as arousal increases further, cues that are relevant to the task may be left unattended. Humphreys & Revelle (1984), in an alternative explanation, proposed that arousal increases attention and persistence, but reduces the efficiency of information processing. Consistent with the Yerkes-Dodson effect, both of these theories predict that optimal arousal will vary according to the task. Few studies have experimentally manipulated arousal levels to examine its effect on human cognition, although an inverted U-shaped curve effect on memory using muscle tension induced arousal has been demonstrated (Courts, 1939; Nielson, Radtke, & Jensen, 1996; Wood & Hokanson, 1965). Also, studies on animals have found an effect of varying arousal levels on memory consolidation (for review, see Roozendaal, Castello, Vedana, Barsegyan, & McGaugh, 2008).

Ascending modulatory arousal systems involve at least five neurotransmitters projections including noradrenaline (NA), acetylcholine, dopamine (DA) serotonin (5-HT) and histamine, each appearing to play a slightly different role in arousal processes (Robbins, 1997).

Acetylcholine is produced in the pons and basal forebrain, and stimulating or blocking these acetylcholine-producing cells increases or reduces cortical arousal levels, respectively. Produced in the hypothalamus, histamine increases arousal either directly, via cortical connections, or indirectly by innervating the acetylcholine-producing cells in the basal forebrain. 5-HT producing cells in the pons and medulla are most active during waking, and connect to many brain structures, including the cerebral cortex, hippocampus, thalamus, hypothalamus and basal ganglia. 5-HT has been linked with automatic behaviours, such as chewing and pacing (Jacobs & Fornal, 1997), and Carlson (2001) has proposed that 5-HT may be involved with preventing disruption to ongoing behaviours. A role has also been shown for 5-HT in behavioural inhibition, with 5-HT depletion causing impulsive responses (Gray, 1987).

The DA system appears to play a role in behavioural activation, whether cognitive or motor. The mesolimbic DA system, innervating the nucleus accumbens and the ventral striatum, plays a role in incentive motivation, with its main function being to activate behaviour in the presence of cues which signal reward. It is also believed that mesolimbic dopamine is involved in anticipatory motivation or in the concept of 'wanting', (versus sensory pleasure, or 'liking', which is dissociable and for which the related substrates are more diffuse, both neurochemically and anatomically) (Berridge, 2004, 2007; Berridge, Robinson, & Aldridge, 2009). This is seen, for example, in the evidence that rewarding, and potentially addictive, stimulant drugs are partly mediated in this area (Koob, Sanna, & Bloom, 1998). Also, DA agonists acting on the ventral striatum increase responding to reward-predicting cues (Robbins et al., 1989), whilst DA depletion in this area has been shown to decrease locomotor activity in novel environments or in the presence of food (Koob, Riley, Smith, & Robbins, 1978). The mesostriatal DA system innervating the dorsal striatum energises behaviour, both relatively novel acts and well-established behaviours such as feeding and drinking (Dunnett & Robbins, 1992). These effects are reported especially in the performance of skilled responses in reaction time experiments. Research using DA depletion suggest mesostriatal DA is involved in preparing motor responses, which is consistent with Parkinson's disease symptoms associated with striatal DA loss (Brown & Robbins, 1991) Also, studies of L-Dopa withdrawal in Parkinson's disease patients suggest it plays a role in cognitive functions such as planning and set-switching (Lange et al., 1992).

Whilst DA often appears to involve higher level, more 'executive', aspects of cognition and behavioural activation, NA is more related to stress, novelty and sensory alerting. The largest NA producing nucleus within the ascending reticular activating system is the locus coeruleus, located in the brain stem. The locus coeruleus releases NA into a huge number of brain areas, including the cerebral cortex, thalamus, hippocampus, midbrain, brainstem, cerebellum and spinal cord {Foote, 1983}. Areas involved in attention receive particularly dense innervation, e.g. the parietal cortex, pulvinar nucleus, superior colliculus.

The spontaneous activity of NA cells in the locus coeruleus changes dramatically depending on the animal's state of sleep or waking, and the NA cells have been shown to fire at any stimulus which elicits an orienting response (Aston-Jones & Bloom, 1981). Based on these findings, Aston-Jones et al proposed that the primary action of cortical NA is to mediate attention. This is consistent with a study in rats which found that lesions resulting in severely depleted NA levels in prefrontal cortex impaired reaction times and the ability for discrimination, but only when bursts of white noise were played during the delay period (Carli, Robbins, Evenden, & Everitt, 1983). NA may, therefore, help focus attention on task relevant behaviours by attenuating the influence of distracting stimuli. A related human study found that distracting noise played during an arithmetic task resulted in higher concentration of NA in urine levels in a high level condition, but not in a low effort condition (Tafalla & Evans, 1997). This suggests that NA is not recruited in tasks requiring low attention and, thus, arousal can affect the level of performance.

Although research on the regulation and function of the arousal systems has traditionally focused on the individual systems, in recent years there has been an emerging emphasis on the possibility that ascending arousal systems may interact (Briand, Gritton, Howe, Young, & Sarter, 2007; Guiard, El Mansari, Merali, & Blier, 2008; Robbins, Clark, Clarke, & Roberts, 2006). Currently, research is still relatively scarce, however.

1.5 Summary and Thesis Direction

This literature review has attempted to provide an overview of the history of research on the effects of emotion on decision making. Although now recognised that emotion is a crucial component of everyday advantageous decision making, it can be seen that emotion also has the potential to drive behaviour away from that which would be considered ideal. Also, and as will be elaborated on further within the thesis, where the effects of mood on decision making have been studied the results have often been inconsistent. More recent research on arousal and 'visceral', or appetitive factors, suggest that arousal may be an important factor in determining emotional influences on decision making, and the focus on specific mood effects on decision making may have left this topic neglected.

This thesis will therefore investigate the role of emotional arousal on decision making, and on risk-taking in particular. (Details of methodology and a summary of experiments are provided in Chapter Two). Measuring risk was chosen as the focus in this thesis, since risk is an inherent part of much everyday decision making activity; we make trade-offs daily between choices which offer more sure outcomes and those which offer greater gains along with the prospect of uncertainty. Examples in the human world could cover all sorts of situations, for example weighing up high return high risk stocks investment against a safe but low interest building society option, deciding whether to chance running across the road in a brief break amongst busy traffic or take the more time consuming option of walking to the nearest pedestrian crossing, opting for an operation which could increase quality of life but carries the potential for life threatening complications, to deciding whether the potential for a rewarding relationship with someone found attractive is worth the potential embarrassment of social rejection. Trimpop offered a definition which covers the nature of risk taking as explored from multiple perspectives: "Risk taking is any consciously or non-consciously controlled behaviour with a perceived uncertainty about its outcome, and/ or about its possible benefits or costs for the physical, economic or psycho/social well-being of oneself or others" (Trimpop, 1994, p. 9).

Exploring the effects of arousal on decision-making and risk-taking has important implications for both everyday decision making and for the interpretation of laboratory testing. Also, understanding the move from controlled to more disordered decision-making may have important implications for real-world decision making, addictive behaviour and pathological gambling.

CHAPTER TWO

AN INTRODUCTION TO THE GAMBLING TASKS, THE AROUSAL MANIPULATIONS AND THE EXPERIMENTS.

This chapter introduces the two gambling tasks which form the basis of most research in this thesis. One is the Iowa Gambling Task (IGT) (Bechara et al, 1994), a well-validated task which was developed to simulate real-world decision making, and which has been extensively applied to both neurological and healthy populations (for a review, see Dunn et al., 2006). The IGT involves learning the reward and punishment schedules of card decks. The other task, the Explicit Gambling Task (EGT), is a novel gambling task with no strategy learning; all the information necessary to make the choice is explicitly available and there are minimal demands on working memory. The explicit task, therefore, allows for a clearer examination of risk-taking, with the task design allowing for the separate manipulation of probability and outcome. This chapter will describe the background and procedure of the Iowa Gambling Task and will report the piloting of the EGT (Experiment 1). The arousal induction methods will be described and the thesis experiments outlined.

2.1 The Iowa Gambling Task

The Iowa Gambling Task developed from attempts to understand the emotional deficits and everyday decision making impairments of neurological patients with damage to the ventromedial prefrontal cortex (VMPFC). As discussed in the introductory chapter, Damasio (1994) reviewed how VMPFC patients could appear unaffected with regard to cognitive skills and intellect and performed normally on neuropsychological tests, yet displayed profound decision making impairments in their social and work lives, an inability to plan for the future and an apparent inability to learn from past mistakes. Research from the Iowa laboratory (Bechara et al., 1994; Damasio, 1994) reported that VMPFC damage impairs the ability to learn on the IGT, compared to healthy controls. This behavioural deficit, or 'myopia for the future', was associated with an absence of the customary anticipatory skin conductance response which they proposed represents a 'somatic marker', differentiating the best option on the IGT (Bechara et al., 1994; Damasio, 1994). Damasio thus proposed that emotional deficits were at the heart of decision making deficits caused by VMPFC damage. By factoring in aspects of real world decision making, such as rewards and punishments and unknown consequences, it was therefore believed that the IGT could simulate everyday decision making in a way previously untapped by traditional executive tasks.

In the Iowa Gambling Task (IGT) (Bechara et al., 1994) the emphasis is on the learning of reward and punishment contingencies associated with each of four decks of cards. Money is won on each card pick, but on some cards there are also losses. Unbeknown to the players, the wins and losses on each deck adheres to a fixed schedule. Decks A and B are 'disadvantageous' decks in that although they pay out larger wins and are more attractive short-term, they also have larger or more frequent losses, leading to a long-term net loss. The 'advantageous' decks C and D, have relatively modest gains, but the penalties are also less, resulting in a net gain overall. Healthy participants playing the game generally start picking more from the short-term higher pay-out decks A and B, and then learn over the course of the 100 selections that the 'rational' and optimal strategy is to choose from the short- term low pay-out decks C and D which have higher a pay-out long term. A key feature, therefore, is that participants must forego attractive short term gains to ensure long term profit. It has been argued that the contingencies are not cognitively penetratable and that, in order to do well on the game, more intuitive or 'gut feeling' decision making must be drawn upon (Bechara et al., 1994; Bechara et al., 1997; Damasio, 1994), although the extent to which this learning is unconscious has been contended (Dunn et al., 2006; Maia & McClelland, 2004).

In the computer presentation of the (Figure 2.1) the participant sees four, physically identical card decks and, using the mouse, they make repeated card selections from any deck. After each card selection some money is won and this amount is displayed on screen. On some cards there is also a loss, which is also displayed on screen. A net win is accompanied by a smiling face and the sound of applause, while a net loss is accompanied by a sad face and a 'boo-ing' sound. The participant is given credit at the start of play and can see their running total throughout the experiment. The participant is not told how many card selections there will be and is instructed to act to maximise their winnings, generally with a hint that "some decks are worse than others but, no matter how much you find yourself losing, you can still win if you stay away from the worst decks". It has been pointed out that instructions have not always been identical (Fernie & Tunney, 2006), however IGT experiments in this thesis include this 'hint' (for full participant instructions see Appendix A).

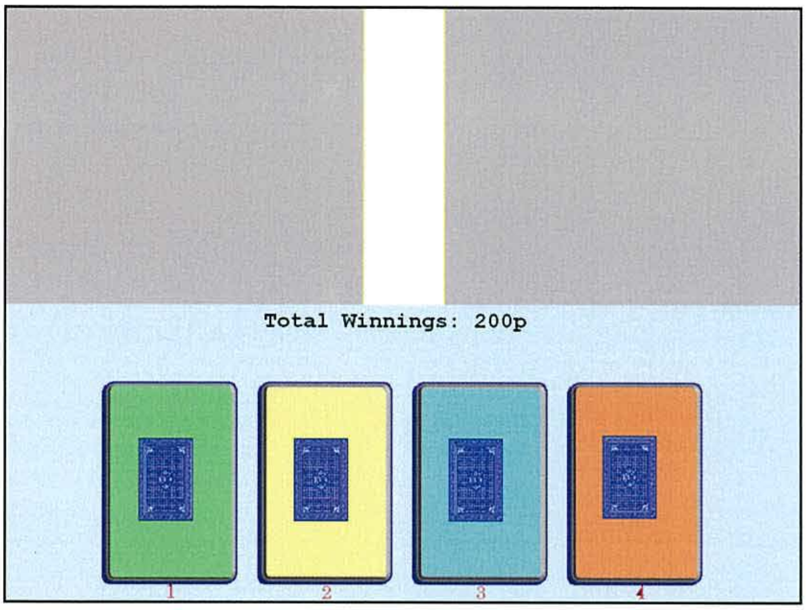


Figure 2.1a. IGT computer presentation prior to card selection

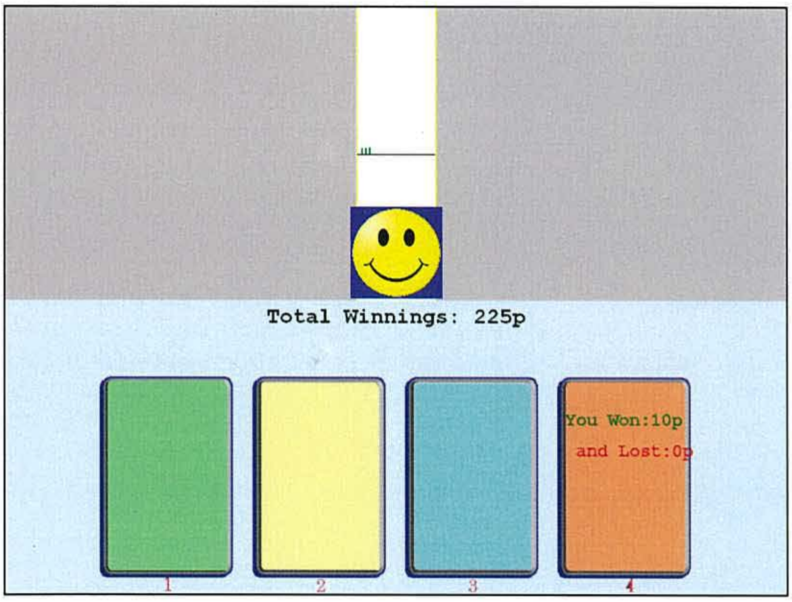


Figure 2.1b. IGT computer presentation– feedback following an overall win

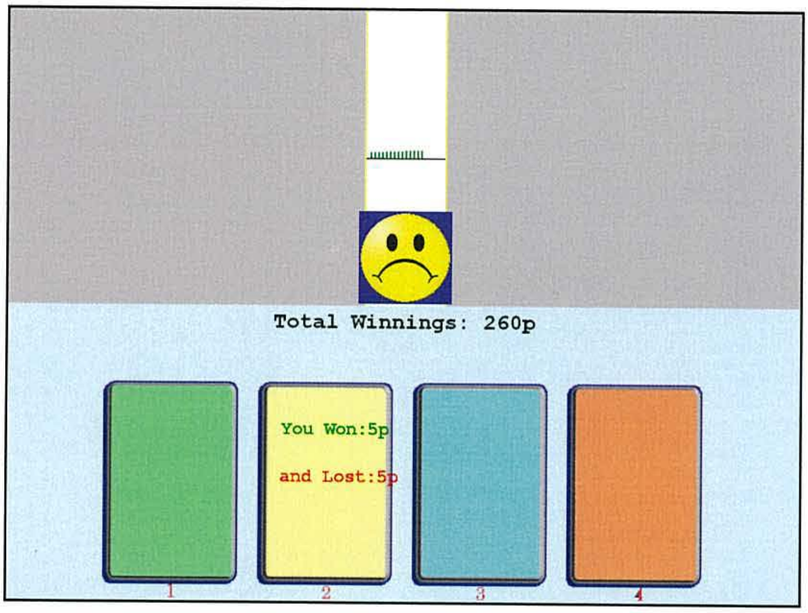


Figure 2.1c. IGT computer presentation – feedback following a loss

Figure 2.1. IGT screenshots, (a) prior to selection, (b) following a win and (c) following a loss. The feedback presentations, Figures 2.1b and 2.1c, last 4 seconds before the programme returns to the card selection phase, Figure 2.1a. Total winnings are visible at all times.

2.2 The Explicit Gambling Task (EGT): Experiment 1

The aim of this initial experiment was to pilot a novel, computerised probabilistic decision-making task where, in contrast to the IGT, all information was explicitly available to the participant, with no strategy to be learnt and little working memory involvement. Thus the primary distinguishing factor between the two experimental tasks was that the IGT focused on the role of within task reward-learning, whilst the EGT focused on performance on a task with known contingencies. A further consideration was that probability and outcome and trial type (win or loss) could be manipulated separately to fully explore the effects of arousal levels on these aspects individually. The purpose of this study was to establish normative behaviour on this task to enable further research investigating the effects of differing levels of arousal. A further aim of this study was to determine whether psychometric measures of risk-taking correlated with behavioural data on the task.

In short, the decision making task involved choosing from two probabilities with each probability represented spatially as a colour on a grid. Each probability was associated with a different outcome, with the highest possible win (or, in Lose trials, the lowest possible loss) associated with the least likely probability. This builds in inherent conflict thereby encouraging, and allowing for the exploration of, risk-taking behaviour. As we were interested in risk, the primary dependent measure used was therefore the percentage of 'Highest Probability Choice' (% HPC) (this is the choice of the most dominant colour of the grid and represents the 'safest', or most likely option). In most theories of decision making it is held that the optimum strategy involves a consideration of both the likelihood of something happening (probability) and the magnitude of the outcome. However, it is known that there are instances where either probability or outcome factor disproportionately. For example, there is evidence that people are relatively insensitive to probability when the outcome is highly emotional, such as an electric shock (Monat, Averill & Lazurus, 1972). This has been seen, for example, in psychophysiological studies of anxiety in which, during anticipation of a possible electric shock, reactions are correlated with intensity not probability. One possible explanation for this is that mental images of the possible event are so vivid as to be largely unaffected by the probability of occurrence. There are also times when people are driven by considerations of probability and are largely unaffected by magnitude of outcome. The 'certainty effect', for example, describes how when an outcome is certain and it becomes less probable, this has a greater impact than when the outcome was merely probable before the probability was reduced by the same amount. Thus, a 100% probability reduced to 90% has more impact on decision making than a 50% probability reduced by the same amount to 40% (Kahneman & Tversky, 1979; Loewenstein, Weber, Hsee, & Welch, 2001; Tversky & Kahneman, 1981). Also, regardless of outcome amount, low probabilities are often overweighted, while medium and large ones are underweighted (Kahneman & Tversky, 1979). Slovic and Lichtenstein (1968) were the first to report the concept of probability dominance in gambling experiments, where it was found that the attractiveness ratings of different gambling options were determined more strongly by the probability than by the monetary outcome. This finding has been much replicated since (e.g., Goldstein & Einhorn, 1987; Ordonez & Benson, 1997). In the EGT the participant wins or loses points or relatively small amounts of cash and, as such, it is considered that these outcomes are not highly emotional to an extent which could render the options insensitive to probability. Although % HPC is the chosen dependent measure, the outcome amount is also taken account of, however, and it is expected that this will have some effect on choice (see hypotheses below). Although the main aim of this study was to establish parameters for future investigations, there were several hypotheses:

- That for a given probability, individuals would be more likely to choose the riskier (lower probability) of the two options where the potential difference in win amount is higher (or loss amount lower) compared to where the potential win is relatively low (or loss relatively high). I.e. that there would be a significant effect of Amount, as measured by %HPC.

- That risky decisions would take longer, i.e. RTs when choosing the higher probability option would be shorter than RTs when choosing the lower probability option. These first two hypotheses were consistent with a similar probabilistic decision making task (The Cambridge Gamble Task, Rogers et al.,, 1999).

- That participants high on measures of impulsivity and sensation seeking would make more risky choices, i.e. there would be a negative correlation between the % HPC and scores on the ImpSS.

- That participants high in impulsivity and sensation seeking would make decisions quicker, as seen in a negative correlation between RT and ImpSS scores.

2.2.1 Methods

Participants

The study was approved by the Research Ethics Committee of Bangor University and written consent was obtained from the participants. 21 participants were tested, all undergraduate psychology students (11 males) recruited from the Bangor University Student

Participation Panel and receiving course credit for participation. The mean age was 20.6 (*SD* = 2.7). Participants were screened for psychiatric illness, neurological injuries and colour blindness.

Stimuli

This study piloted a novel computerised decision making task involving a choice from two probabilistic outcomes. On each trial, participants decide which colour box within a grid they think hides a 'prize'. They choose between two options (represented by either the colour red or blue) each with an assigned probability of winning or losing a specified amount of points. The probabilities were represented spatially by colours in the grid, thus the area occupied by a certain colour matched the likelihood of winning by choosing that colour. As illustrated in Figure 2.2, the likelihood of winning is proportional to the amount of space occupied by a particular colour, and the task is designed with inherent conflict, in that the highest possible win if correct (or lowest loss if incorrect) is associated with the least likely option (i.e. the colour occupying the least amount of space) and the lowest possible win if correct (or highest possible loss if incorrect) associated with the most likely option. All information regarding potential wins and losses and probabilities is explicitly available to the participant before they make their decision, i.e. there is no strategy to be learnt.

Each participant completes 3 trial types: mixed Win and Lose (W&L) trials in which they can either win or lose, Win (W) trials in which they can only win an amount or lose 0, and Lose (L) trials in which they can only lose an amount or win 0. The Lose trials were included as, according to economic theory, more risk taking is often seen in the negative domain (Kahneman & Tversky, 1979).

For each of the 4 probabilities there were 4 Amounts with every Amount having 3 mixed Win & Lose trials, 2 Win trials and 2 Lose Trials, each Probability therefore having a total of 28 trials, meaning a total of 112 trials (see Figure 2.2 for examples), in a task lasting approximately 25 minutes. Many trial types were included in this pilot experiment to ascertain the most useful parameters, with the expectation that the number of trial types could be reduced in future studies.

Presentation of the trials, i.e., box ratios, win/lose amounts, types of trial, colours used, colour correct and position of correct square was counterbalanced and pseudo-randomised. The position of the prize (i.e. whether it occurred in a box of the most dominant colour on the gird (the high probability option) or within a box of the least dominant colour (the low probability option) was calculated 'fairly' across the task according to the odds. For example, for the 12:4 Probability the prize was located 3 times out of 4 in the colour occupying 12 squares in the grid, and 1 time out of 4 in the colour occupying just 4 squares.

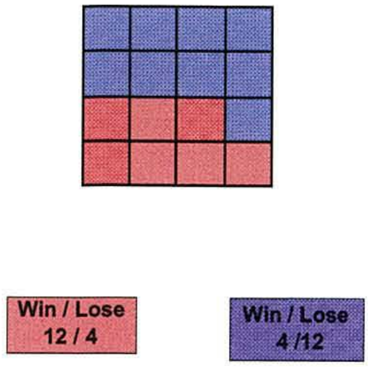


Figure 2.2a. A Win and Lose (W&L) trial: illustrated is a Probability 9:7 with 12/4 Amount trial. Participants can either win or lose the amounts specified.

In this example: Choosing red (lowest probability choice) will result in a win of 12 points if correct, a loss of 4 points if incorrect. Choosing blue (highest probability choice) will result in a win of 4 points if correct and a loss of 12 points if incorrect.

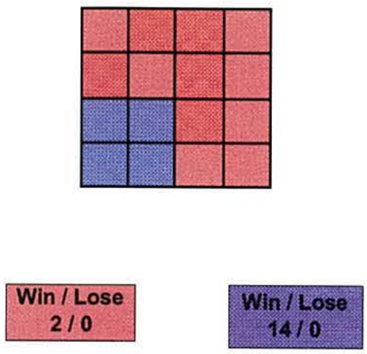


Figure 2.2b. A Win (W) trial: illustrated is a Probability 12:4 with 14/2 Amount trial.
Participants can only win the specified amount, with no possible loss.

In this example: Choosing red (highest probability choice) will result in a win of 2 points if correct and no win or loss if incorrect. Choosing blue (lowest probability choice) will result a win of 14 points if correct and no win or loss if incorrect.

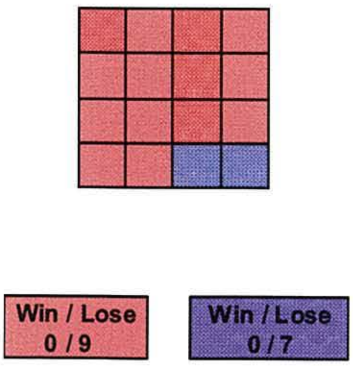


Figure 2.2c. A Lose (L) trial: illustrated is a 14:2 Probability with 9/7 Amount trial. The participant can only lose the specified amount, with no possible win.

In this example: Choosing red (highest probability choice) will result in no win or loss if correct, but a loss of 9 points if incorrect. Choosing blue (lowest probability choice) will result in no win or loss if correct, but a loss of 7 points if incorrect.

Figure 2.2. Examples of Explicit Gambling Task trial types. Note that the probabilities are represented spatially by the number of squares of each colour in the grid. Also, the highest win Amount (or the lowest lose Amount) is associated with the least dominant colour on the grid, making this the riskiest option.

At the outset, participants started the game with 100 points which was shown on a vertical winnings scale on the far left of the screen. Figure 2.3 provides a schematic of the trial events. Initially the grid of 16 appears showing the probabilities, 1.5 seconds later boxes appear under the grid showing the win/lose amounts applying to the trial. 1 second later the response keys become activated, as indicated by the text turning black in the win/ lose boxes. Participants are told they should wait for this to happen before making a response but that there is no time limit (although response times are recorded). Options are chosen by pressing the key corresponding with the colour of the box they wished to choose; the 'v' key (coloured red) for red and the 'b' key (coloured blue) for blue. Only the colour is chosen, not a specific square. Once their decision has been made the 'prize' location within the grid is revealed by the appearance of a smiley face sign and the participant is advised by text on the screen either 'You have won ...' or 'You have lost...' and the relevant amount of points. The points balance alters accordingly and the ongoing score is visible throughout the game.

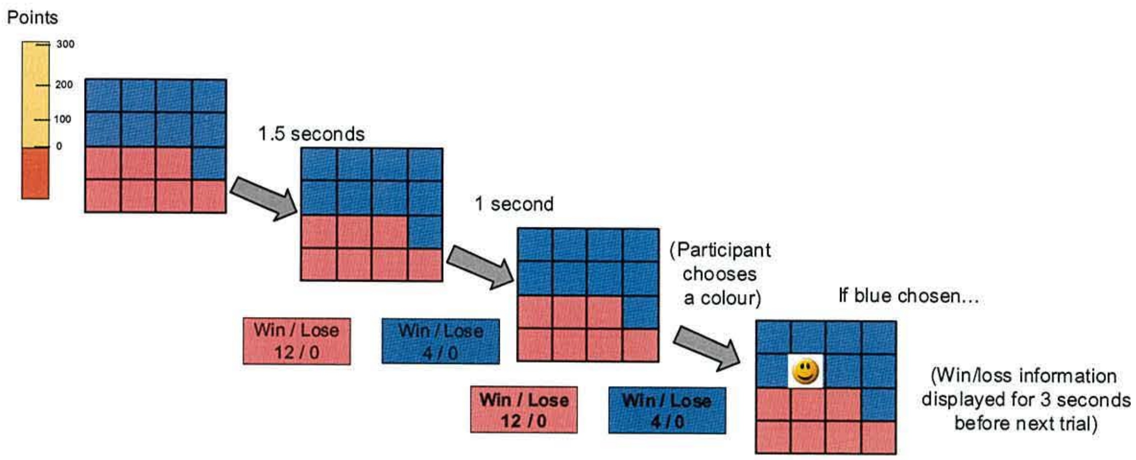


Figure 2.3. Explicit Gambling Task Trial timeline

Measures

The measure of risk-taking used was the Impulsive Sensation Seeking scale (ImpSS) from the Zuckerman Kuhlman Personality Questionnaire (Zuckerman, Kuhlman, Joireman, Teta, & Kraft, 1993), which has been shown to correlate with many aspects of real life risk taking (for a review, see Zuckerman & Kuhlman, 2000). This is a 19 point self rating scale with "Yes / No" answers.

The State component of the State Trait Anxiety Inventory (STAI) (Spielberger, 1983) was also used to establish whether participants' subjective stress levels differed pre and post testing. The State component is a 20 item self-rating, 4 point Likart scale measuring temporary conditions of anxiety as opposed to the more general and stable individual differences of Trait anxiety. The State component of the questionnaire reflects transitory emotional states characterized by subjective, consciously perceived feelings of tension, and increased autonomic nervous system activity (Spielberger, 1983).

Design

There were two different orders of schedules and subjects were randomly assigned to each. Since this was an experiment to ascertain norms there was only one experimental group. The independent variables were the Outcome type (i.e. Win & Lose, Win only, Lose only), Probability (i.e. the ratio of the 2 colours on the grid: 14:2, 12:4, 10:6, 9:7) and Amount (the amounts which can be won or lost: 14/2, 12/4, 10/6, 9/7). The dependent variables were the % Highest Probability Choices (i.e. the % of times the most dominant colour on the grid was chosen) and Response Time.

Procedure

First, participants were asked to complete the ImpSS and then the State component of the STAI. Participants were then given written instructions (Appendix B) in which they were told they would be playing a game in which they should act to maximise their points and were instructed that they should base their decision on information from both the colours on the grid and the amounts in the boxes below. Participants completed a practise run of 12 trials before the main experiment during which time they were allowed to ask any questions relating to the task.

2.2.2 Results

Key presses made before the response keys were active were recorded as 'impulsive responses'. This allowed for any participants consistently making instant responses to be excluded from the data analysis, as this indicated no account was being taking of the Amounts. Two participants were excluded as they made consistently and extremely fast responses and gave information during de-briefing indicating that they had not made use of the information in the win/loss boxes before deciding. This left 19 participants remaining (10 males).

Choice Data analysis

The dependent measure was High Probability Choices, which were considered to be instances where participants choose the most likely option (i.e. the most dominant colour on the grid).

Preliminary analyses showed the mixed Win & Lose (W&L) trials data to be noisy with little or no effect of Amount, see Figure 2.4, below. Therefore the W&L trials were excluded from the main analysis.

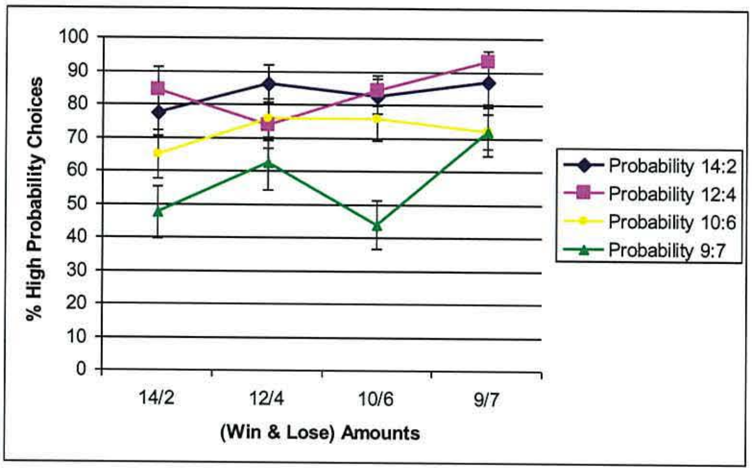


Figure 2.4 % High Probability Choices as a function of Probability and Amount on the EGT: Mixed Win and Lose Trials. (Error bars represent SEM)

A 3 factor repeated measures ANOVA was performed on the remaining Choice data: Probability (4 levels; 14:2, 12:4, 10:6, 9:7) x Outcome type (2 levels; Win, Lose) x Amount (4 levels; 14/2, 12/4, 10/6, 9/7). An overall view of results can be seen in Figure 2.5 (Win trials) and Figure 2.5 (Lose trials).

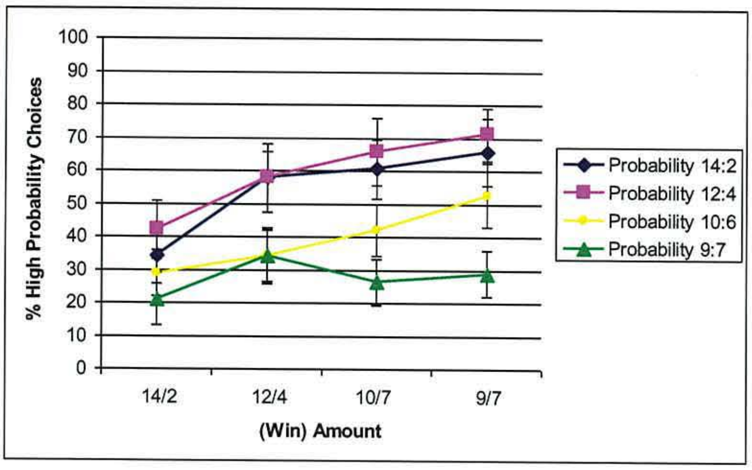


Figure 2.5. % Highest Probability Choices as a function of Probability and Amount on the EGT: Win trials. (Error bars represent SEM)

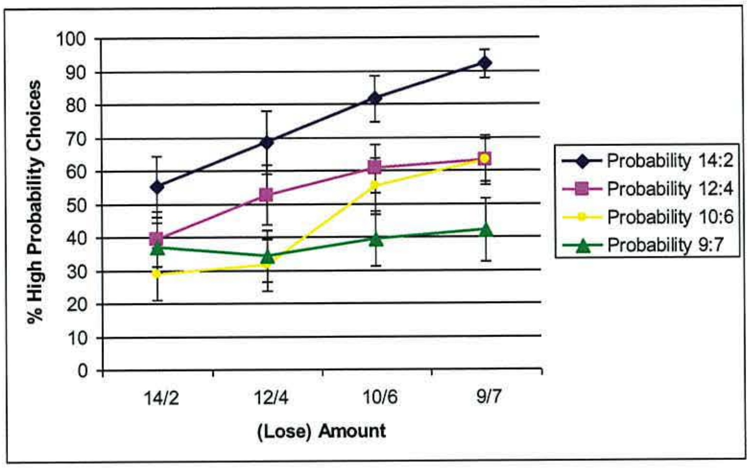


Figure 2.6. % Highest Probability Choices as a function of Probability and Amount on the EGT: Lose trials (Error bars represent SEM)

As predicted, participants were more likely to risk choosing the lower probability option where the potential difference in win amount was higher (or loss amount lower) compared to where the potential win was relatively low (or loss relatively high). I.e. there was a significant effect of Amount on % High Probability Choices. The number of Highest Probability Choices made increased steadily as the amounts which could be either won or lost became less extreme and more evenly matched (Figure 2.7), F (3, 54) = 13.55, p <.001; % Highest Probability Choices for Amount 14/2 M = 36.18; Amount 12/4 M = 46.38; Amount 10/6 M = 53.95; Amount 9/7 M = 59.87.

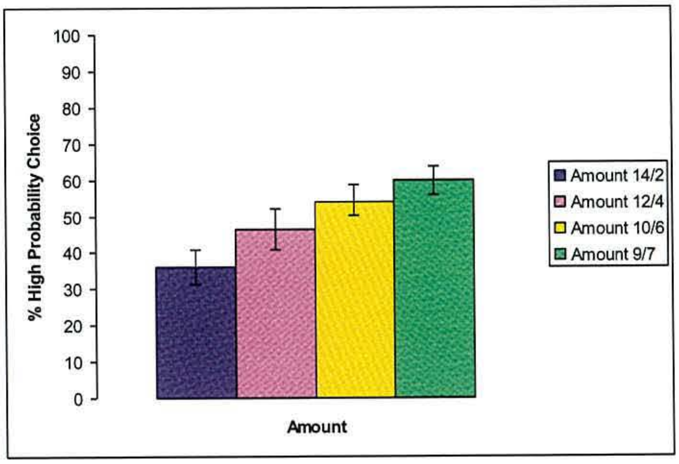


Figure 2.7. Main effect of Amount on % High Probability Choices on the EGT. (Error bars represent SEM)

As seen in Figure 2.8, it was found that more Highest Probability Choices were made where the choice of probabilities was more extreme (14:2) compared to where the choice of probabilities was more ambiguous (9:7); i.e. there was a significant main effect of Probability, F (3, 54) = 20.26, $p < .001$. % Highest Probability Choices for Probability 14:2 M = 64.47; Probability 12:4 M = 56.91; Probability 10:6 M = 42.11; Probability 9:7 M = 32.90.

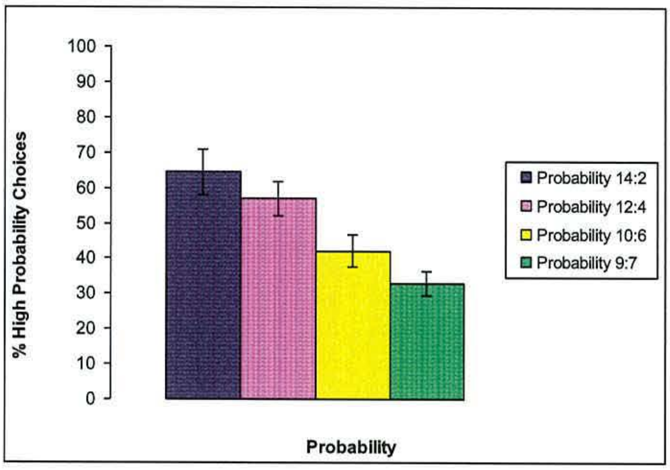


Figure 2.8. Main effect of Probability on % High Probability Choices on the EGT (Error bars represent SEM)

It was found that participants were more likely to choose the higher probability option in Lose trials than in Win trials, i.e., there was a significant main effect of Outcome type, F (1, 18) = 4.45, p = .049; % Highest Probability Choices for Win trials, M = 45.23, for Lose trials, M = 52.96.

There was also a Probability x Outcome Type interaction, F (3, 1) = 4.39, p = .008 for all Probabilities except 12:4; i.e. the % Highest Probability Choices is highest for Lose than Win trials, except in the 12:4 Probability trials (Figure 2.9).

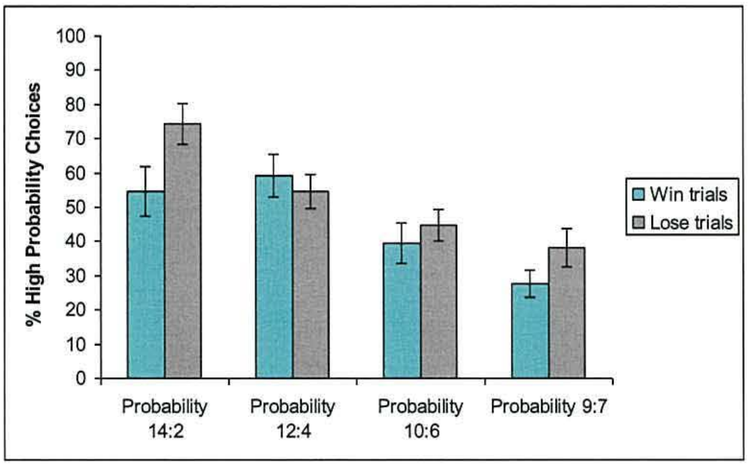


Figure 2.9. Probability x Outcome Type interaction effect on % High Probability Choices on the EGT (Error bars represent SEM).

Response time data analysis

As with the Choice data, a 3 factor repeated measures ANOVA was performed on the RT data: Probability (4 levels; 14:2, 12:4, 10:6, 9:7) x Outcome type (2 levels; Win, Lose) x Amount (4 levels; 14/2, 12/4, 10/6, 9/7). For overall results see Figures 2.10 (Win trials) and 2.11 (Lose trials).

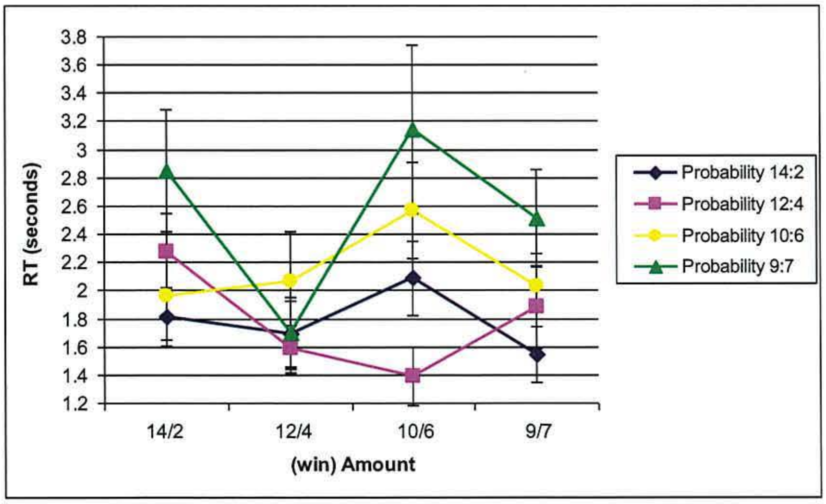


Figure 2.10. RT as a function of Probability and Amount on the EGT: Win trials (Error bars represent SEM)

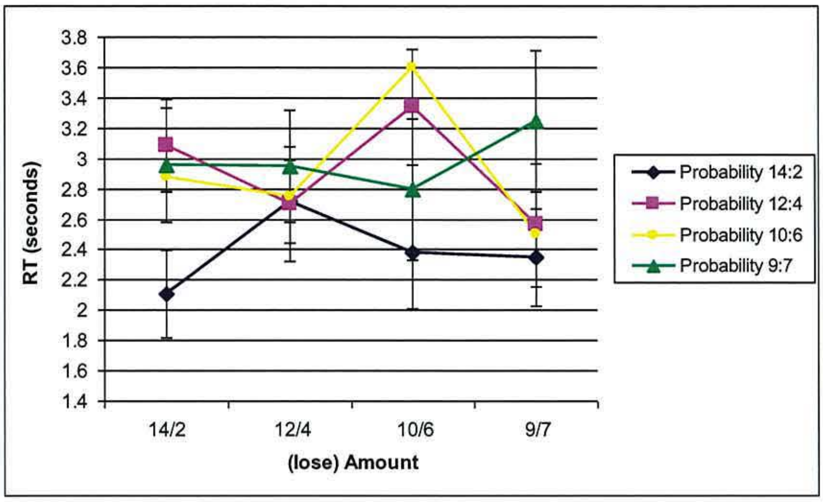


Figure 2.11. RT as function of Probability and Amount on the EGT: Lose trials (Error bars represent SEM)

As predicted there was a significant main effect of decision type on RT. RTs when choosing the higher probability of the two options were significantly shorter (M = 2.16 secs, SD = .78 secs.) than when choosing the lower probability option, (M = 2.48 secs, SD = 1.01 secs.), t (18) = -2.192, p = .021; i.e. subjects took longer making risky decisions (Figure 2.12)

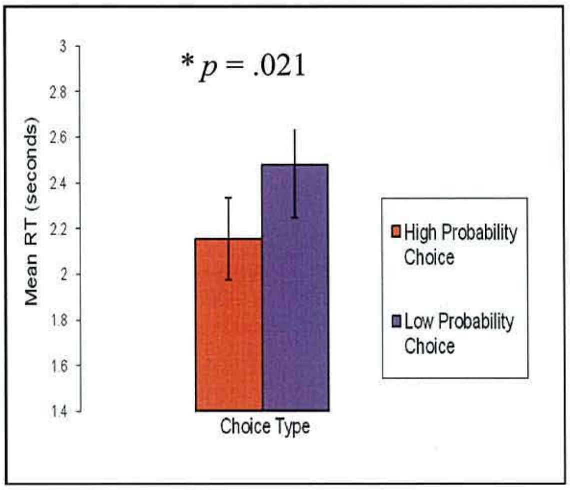


Figure 2.12. RTs for High Probability versus Low Probability choices on the EGT (Error bars represent SEM)

Also, participants deliberated longer over decisions involving possible loss, as seen in a main effect of Outcome Type F (1, 18) = 36.36, p <.001, with Lose trials M = 2.81, SD = .27; Win trials M = 2.07, SD = .22.

It can be seen that response times were shorter where the probability was more extreme, and deliberation time longer where probabilities were more evenly matched, i.e., there was a significant effect of Probability on RT, F (3, 54) = 4.61, p = .006. RT for Probabilities 14:2 M = 2.09; 12:4 M = 2.35; 10:6, M = 2.54; 9:7, M = 2.77 (Figure 2.13).

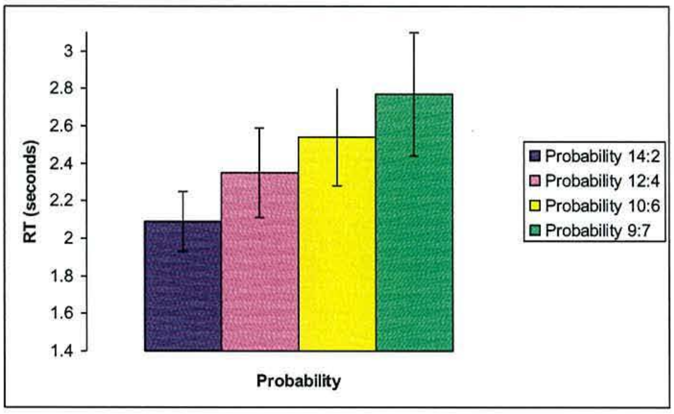


Figure 2.13. Effect of Probability on RT (data collapsed across Amount) on the EGT (Error bars represent SEM)

There was a main effect of Amount on RT, F (3, 54) = 3.26, p = .026. However, this was not a clear linear effect: for Amount 14/2 M = 2.49; Amount 12/4 M = 2.27; Amount 10/6, M = 2.66; Amount 9/7, M = 2.33 (Figure 2.14)

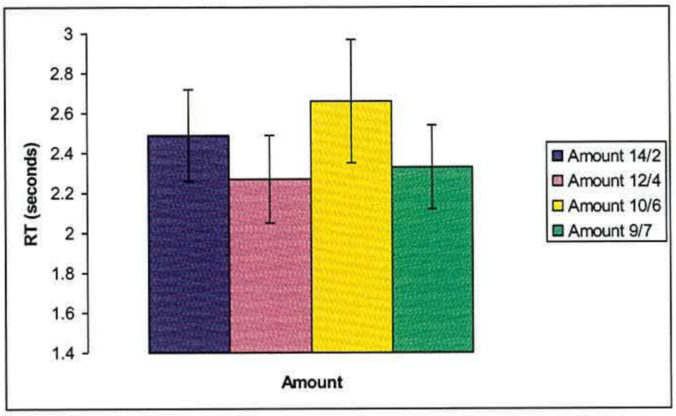


Figure 2.14. Effect of Amount on RT (data collapsed across Probability) on the EGT (Error bars represent SEM)

There was also a significant Probability x Outcome Type interaction on RT (Figure 2.15), *F* (3, 54) = 3.42, *p* = .023. Although all Probabilities show an effect of Outcome Type, with a quicker RT on Win trials than on Lose trials, it seems that Probability 12:4 is influenced to a greater degree.

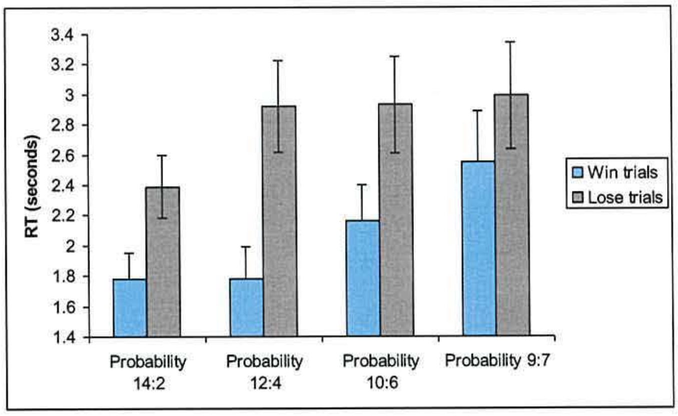


Figure 2.15. Probability x Outcome Type interaction effect on RT on the EGT (Error bars represent SEM)

In addition, there was a significant Probability x Amount x Outcome Type interaction (see Figures 2.10 and 2.11), F (9,162) = 2.26, p = .021. It appears that within the 12:4 Probability the 10/6 amount is especially influenced by Outcome Type.

Measures

ImpSS

ImpSS score $M = 10.74$, $SD = 5.25$. There was no correlation of ImpSS with % High Probability Choices. However, participants who scored higher in Impulsive Sensation Seeking took less time to make their decisions, as seen in a significant negative correlation between RT and ImpSS scores. "High Probability" choice RTs correlated with ImpSS, $r\ (17) = -.52$, $p = .011$; "Low Probability" choice RTs correlated with ImpSS, $r\ (17) = -.51$, $p = .012$.

STAI.

There was no reported difference in anxiety levels pre-testing compared to post-testing; pre-testing STAI (State component) $M = 31.84$, $SD = 7.77$; post-testing STAI (State component) $M = 32.79$, SD = 6.96.

Results summary

With regards to the choice data, the least likely (riskiest) option tended to be selected more frequently where the possible outcome seemed to justify the risk (a significant effect of Amount on % High Probability Choices, as predicted) or on trials where the lower probability option wasn't overly extreme (a significant effect of Probability on % High Probability Choices). There were more High Probability Choices made on Lose trials than on Win trials (significant effect of Outcome Type), although this effect was not seen on the 12:4 Probability (a significant Probability x Outcome Type interaction).

With respect to RT, Participants deliberated longer over decisions involving a possible loss compared to a possible win (a significant effect of Outcome Type on RT, as predicted). Some trials were affected more than other by this (as seen in a significant Probability x Amount x Outcome Type interaction). Also, when choosing the lower probability (riskier) option RTs were longer (a significant effect of Decision Type on RT). The more extreme the probability, the shorter the response time, with deliberation time longer where probabilities were more evenly matched (a significant effect of Probability on RT). Participants higher in ImpSS made their decisions quicker (a significant negative ImpSS score/ RT correlation, as predicted), although ImpSS scores did not correlate with the choice data. Analysis of STAI scores suggest that participants did not find playing the pilot game stressful (no significant difference in pre/post testing STAI scores).

2.2.3 Discussion

A novel probabilistic gambling task was piloted with the aim of ascertaining norms for comparison with later research in which arousal levels could be manipulated. The task was designed to have all information explicitly available with no required learning, and the game was also devised to allow separate manipulation of probability and amount with inbuilt conflict encouraging risk taking behaviour. Although largely exploratory some hypotheses were made and, on the whole, these were supported.

The hypothesis that, for any given probability, individuals were more likely to choose the riskier (lower probability) of the two options where the potential difference in win amount is higher (or loss amount lower) compared to where the potential win is relatively low (or loss relatively high) was supported; as seen in the significant effect of Amount on % HPC. Thus, participants would risk the lower probability (least likely) option when the possible outcome justified that choice. This is consistent with previous research (Rahman, Sahakian, Cardinal, Rogers, & Robbins, 2001). The significant effect of Probability reflected the tendency for participants to make more Highest Probability Choices on trials where the Probability was more extreme (Probability 14:2) compared to trials where the Probability was more evenly matched (Probability 9:7), where they were more likely to take a risk.

Whether the trial was one on which points could be won or lost had an effect on choice data, as seen in a significant effect of Outcome Type on % HPC. It was found that participants were more likely to choose the higher probability option on Lose trials than Win trials. Initially, this seemed contrary to economic theory (Kahneman & Tversky, 1979) which predicts more risk-seeking in the negative domain, as people are more likely to take a risk if it could mitigate a loss. However, more recent work shows this relationship to be more complex; with risk seeking with losses dependent on the relative probabilities involved. Kahneman & Tversky (1992) propose that risk-seeking is more prevalent for losses of high probability; with risk aversion reported where losses of low probability are involved. There was a significant Probability x Outcome interaction on % HPC, with more Highest Probability Choices made on Lose trials for all probabilities, except the 12:4 Probability.

The prediction that Highest Probability choice RTs would be significantly shorter than Low Probability RT, i.e. that risky decisions take longer, was also supported. This result is, again, consistent with previous similar research (Rogers et al., 1999). In addition, it was seen that participants chose faster where probabilities were more extreme rather than in the more ambiguous trials, as seen in a significant effect of Probability on RT. There was also a significant effect of Amount on RT although this was a non-linear effect which, at this stage, was hard to interpret. As participants were not restricted to responding within a certain time frame, RT data showed a lot of individual variation as seen in relatively large standard deviations, and the complex interaction effect requires replication for clear conclusions to be drawn.

The significant effect of Outcome Type on RT reflected the trend for participants to deliberate longer on trials where points could be lost, compared to trials where they could win. This seems consistent with the effect of Outcome Type on %HPC, with longer RTs and a greater likelihood of opting for the highest probability (safer) option indicative of more cautious behaviour on Lose trials. Outcome Type did not appear to influence all trial types uniformly, however, as seen in a significant Probability x Outcome Type interaction and a significant Probability x Amount x Outcome Type. As seen in Figure 2.15, it appears that Probability 12:4 is influenced to a greater extent by Outcome Type, and that within the 12:4 Probability the 10/6 Amount trials are influenced most by whether points can be either won or lost on that trial (Figures 2.10 and 2.11).

RTs on the task were found to be quicker in those participants who rated higher in Impulsive Sensation Seeking, as seen in a significant negative correlation between ImpSS scores and RT. This lends some external validation to the task. However, there was no correlation between ImpSS scores and the participants' choice behaviour (% High Probability Choices); this could be due to relatively small subject numbers.

Results from the STAI State component suggest that anxiety levels did not differ before and after playing the game – this provided a useful benchmark for comparison with later research where arousal levels would be manipulated which could have lead to greater anxiety levels.

In conclusion, participants generally made their choice-based information from both the probability, the number of points at stake (Amount) and the type of outcome (i.e. whether they would win or lose). Participants tended to opt more frequently for the least likely (riskiest) option where the possible outcome seemed to justify the risk or on trials where the lower probability option was not overly extreme. The more extreme the probability, the shorter the response time, with deliberation time longer where probabilities were more evenly matched. Participants deliberated longer over decisions involving a possible loss compared to a possible win and it was seen that participants higher in ImpSS made their decisions quicker. Analysis of STAI scores suggested that participants did not find playing this pilot gambling game stressful.

Many trial types were included in this exploratory research with the expectation that trial types could be reduced in further study with arousal manipulations. On initial investigation, results from the Mixed Win & Lose trials were noisy and there appeared to be little or no effect of Amount on Choice data. The pattern of results suggested that participants may have been choosing randomly (possibly because the trials were too confusing). They were therefore excluded from main statistical analysis. For simplicity, it was also decided to omit the 10:6 Probability trials from the task in future, as the results from the 10:6 Probability trials were very close to either the adjacent 12:4 or 9:7 Probability results and therefore superfluous.

It was unclear at this stage whether all statistical results were genuine and relevant, i.e. the significant interaction effect of Probability x Outcome Type on % HPC, the significant non linear effect of Amount on RT and the significant Probability x Amount x Outcome interaction on RT. Subsequent research would confirm whether these were authentic statistical results or merely spurious findings. Given the large individual variations inherent in a task of this nature it is conceivable that they are specious results.

This initial research confirmed that separate manipulations of probability, amount and outcome type were justified and useful. This pilot study of a novel gambling task was successful in refining the task to include the most useful parameters and in providing useful norms for comparison with subsequent testing in which arousal levels were manipulated.

2.3 The Thesis Research

This thesis explores the effect of varying levels of arousal on these two qualitatively different decision-making tasks. As discussed, the tasks employed were the IGT - a task proposed to measure emotion-based learning of contingencies, and a novel probabilistic decision making task with all information explicitly available and minimal working memory demands, the EGT. Arousal levels were systematically varied on these tasks, firstly, through manipulating the levels of financial win and loss and, secondly, through the use of varying levels of muscle-tension induced (MTI) arousal, as further discussed below. The final study employs a questionnaire to explore an example of real world decision making. The general hypothesis was that arousal level would have a significant effect on performance on these decision-making tasks, although more specific hypotheses are also presented for each study.

2.3.1 Methods of inducing arousal

Monetary reward and punishment

Money is widely considered to be a conditioned reinforcer (e.g., Skinner, 1953; Williams, 1994). Although not directly rewarding it acquires rewarding properties through association with many primary rewards and, as such, it may acquire the same motivating and arousing properties (see Berridge, 2004 for review). The arousing properties of money can be seen in the ability of small monetary wins and losses to evoke skin conductance response peaks in healthy controls on the IGT, with this response absent in amygdala patients (Bechara, Damasio, Damasio, & Lee, 1999) and the ability of monetary rewards to increase heart rate compared to positive reinforcement alone (Fowles, Fisher, & Tranel, 1982). Also, scanning studies have shown that money may elicit activity in the dopaminergic reward areas of the midbrain in the same way as primary rewards such as food or drugs (Breiter, Aharon, Kahneman, Dale, & Shizgal, 2001; Elliott, Friston, & Dolan, 2000; Elliott, Newman, Longe, & Deakin, 2003; Knutson, Adams, Fong, & Hommer, 2001; Knutson, Westdorp, Kaiser, & Hommer, 2000).

It was hypothesised, therefore, that money could be used to induce arousal in decision-making tasks in the current study. Research suggests that conditioned reinforcers may maintain their value independently, being impervious to the devaluation of the associated primary reinforcers (Parkinson, Roberts, Everitt, & Di Ciano, 2005). Therefore, devaluation of the primary reinforcers associated with money should not affect the reinforcing and arousing properties of money. As such, using money could be seen as preferable to using a primary reinforcer, such as food, as it should be less affected by internal motivational states and satiety.

Muscle tension-induced arousal

The other arousal manipulation in his research will be mild exercise, or muscle tension-induced (MTI) arousal, through use of a hand dynamometer. MTI arousal has been used previously to experimentally induce arousal in humans. Classic studies from the 1920s and 1930s showed that MTI enhanced performance in various cognitive tasks, in particular memory tasks (Bills, 1927; Courts, 1939,1942; Stauffacher, 1937), although an impairment at higher levels, i.e., a U-shaped function, was reported by Courts (1939, 1942). Wood and Hokanson (1965) later used the hand dynamometer method of MTI, as also used by Stauffacher (1937) and Courts (1939, 1942) and also reported an effect on various cognitive tasks, with elevated heart rate mediated by the level of tension. More recently, this method was used by Nielson and colleagues in the investigation of arousal-modulated memory (Nielson & Jensen, 1994; Nielson, Radtke, & Jensen, 1996).

It has long been accepted that exercise leads to an increase in noradrenaline (NA) and adrenaline levels (Banister & Griffiths, 1972, as cited in Ohman & Kelly, 1986), with serum NA concentrations directly related to exercise intensity (Hartley et al., 1972, as cited in Ohman & Kelly, 1986), whereas serum adrenaline levels only become significantly elevated after heavy physical activity (Dimsdale, Hartley, Guiney, Ruskin & Greenblatt, 1984; Hartley et al. 1972, as cited in Ohman & Kelly, 1986). It is likely therefore that the exercising with the hand dyno causes NA release, and previous research has proposed that there is also adrenaline release, since patients taking beta receptor antagonist medication (commonly known as beta blockers) did not exhibit the same hand dyno arousal-induced modulation of memory as control participants taking alternative hypertension medications (Nielson & Jensen, 1994).

The procedure used to induce MTI with the hand dyno is based on the method established by Courts (1939) and used more recently by Nielson and colleagues in investigating arousal effects on memory (Nielson & Jensen, 1994; Nielson et al., 1996). To allow for individual calibration, participants were initially asked to squeeze the hand dyno at a constant force as hard as possible for 20 seconds. Previous research has supported the view that an initial 30 seconds burst acts as a prime for later use, giving more reliable results (Nielson et al., 1996). In this study, however, the initial calibration was set at a slightly shorter 20 seconds, since in piloting 30 seconds appeared to be too difficult and to cause to much discomfort for many participants. Participants then used the hand dyno at their individually calibrated level of either 50% of maximum or 75% of maximum, for 60 seconds. Exact details vary depending on the experiment, as will be explained in the relevant chapters. Although physiological measures were not taken in the current research, previous research has demonstrated that MTI arousal via a hand dyno with this procedure leads to a significantly increased heart rate in both young and elderly participants (Nielson & Jensen, 1994; Williamson et al., 2002; Wood & Hokanson, 1965).

2.3.2 The Experiments

Experiment 1 (Chapter Two) pilots the novel probabilitistic gambling task to establish basic behavioural parameters before arousal level manipulations are applied. Research into the effects of emotional arousal on decision making is then initially focused on the IGT. Following the observation that IGT studies have varied with regards to whether reinforcement involved real cash or facsimile money (Bowman & Turnbull, 2003; Fernie & Tunney, 2006), Experiment 2 (Chapter Three) examines the effect of varying levels of monetary reinforcement on the IGT. This is followed by an investigation into the effects of increased physiological (MTI) arousal on IGT performance in Experiment 3, while Experiment 4 explores the extent of subjective awareness of a change in state following the MTI arousal induction, (Chapter Four). Results on the IGT are discussed in terms of the Somatic Marker Hypothesis predictions for the effects of task relevant (Experiment 2) and task irrelevant (Experiment 3) emotional arousal (Bechara & Damasio, 2005; Naqvi, Tranel, & Bechara, 2006). Both these manipulations of arousal level had a detrimental effect on performance on the IGT which then led to an exploration of whether similar arousal-induced effects on decision making would be seen on a task of decision making under risk without the contingency learning of the IGT. The subsequent studies (Chapter Five) therefore varied the level of monetary reinforcement (Experiment 5) and level of MTI arousal (Experiment 6) on the EGT. Finally, following the demonstration of effects of MTI arousal on the two laboratory decision making tasks, Experiment 7, (Chapter Six) sought to use this way of manipulating arousal state in an area of real-world judgement in which arousal is clearly implicated, sexual decision making. Utilising the questionnaire from the Ariely & Loewenstein (2006) study, MTI arousal was employed in an investigation into whether more general incidental arousal, rather than specifically sexual arousal, can have an effect on sexual preferences, judgements and decision making. A general discussion of the thesis findings is presented in Chapter Seven.

CHAPTER THREE

THE EFFECTS OF VARYING LEVELS OF REINFORCEMENT ON THE IGT: EXPERIMENT 2

This experiment will manipulate the overall level of reward and punishment on the Iowa Gambling Task (IGT). These manipulations will allow for an exploration of how increased reinforcement (and real versus faux reinforcement), as an example of task-relevant emotional arousal, affect IGT performance. The overall level of cash wins and losses across the schedule will be increased (in one condition by a factor of 2.5, Cash x2.5 condition; and in another by a factor of 5, Cash x5 condition) and compared with a Control condition with a standard level of cash winnings (i.e. identical to that as used in Bowman & Turnbull, 2003, and at a similar level to that used in Fernie & Tunney, 2006). The level of reinforcement will be increased across the schedule without altering either the ratios of win and loss magnitudes between the decks or the schedule of losses. An additional condition will compare whether there is a difference between real money and fake winnings on the IGT, at a level which has not been investigated previously, i.e. five times the standard cash amounts customarily employed (Bowman & Turnbull, 2003; Fernie & Tunney, 2006) (i.e., Cash x5 condition compared with Fake x5 condition). Results are discussed in terms of the effects of emotional arousal on decision making generally, and more specifically, in terms of the Somatic Marker Hypothesis and task-relevant somatic states. In order to understand the implications of IGT rewards and punishments as task-relevant emotional arousal, this chapter will first introduce the Somatic Marker Hypothesis (SMH) in more depth.

3.1 The Somatic Marker Hypothesis (SMH)

Arising from studies of neurological patients with impaired emotional processing, Damasio has recently advanced the Somatic Marker Hypothesis (SMH) of decision making (Damasio, 1994; Damasio, Tranel, & Damasio, 1991). According to this theory, in which the body interacts with the undamaged brain, knowledge and cognitive reasoning are not sufficient for making good decisions, with emotion related to the task at hand essential to advantageous decision making. The ventromedial prefrontal lesion (VMPFC) patients studied by Damasio and colleagues showed striking deficits in everyday decision making, especially in the personal and social realm. For example, these patients would make choices which were not in their best interest with respect to their work day, financial decisions, and existing and new relationships. These choices were strikingly different from the type of decision it was speculated that their pre-morbid self would have made, and despite experiencing the negative consequences, these patients appeared incapable of learning from their mistakes (Damasio, 1994; Damasio, et al., 1991; Eslinger & Damasio, 1985). Their normal performance on a variety of conventional neuropsychological tests made it difficult to explain their impairments in terms of damaged intellect, reasoning, language, memory or attention. Further investigations, however, identified that many cases had difficulty in expressing and experiencing emotion, including impaired SCR responses to emotional images (Damasio, 1994). This observation of emotional blunting (with additional evidence from the IGT) led Damasio to speculate that an inability to use (biasing emotional) signals when selecting between different options, was at the heart of the decision making impairments evident following damage to the VMPFC. As a theory of emotion, the SMH is not entirely novel, with the seminal theories of emotion advanced by James and Lange (James, 1884, 1894) also stressing the role of physiological feedback in emotional experience. However, Damasio's extension of the influence of visceral processes to explain decision making has inspired interest in researchers from diverse fields, and the IGT - the tool which provided much support for the theory - has become a well-validated and extensively used tool in both neuropsychological and healthy populations. As described in the previous chapter, on the IGT the participant chooses from decks of cards which either yield high immediate reward but high long-term punishment (overall net loss) (decks A&B) or which yield low immediate reward but even lower long-term punishment (overall net gain) (decks C&D). Over the course of 100 selections, their aim is to maximise their winnings. Healthy participants learn to avoid the 'bad' decks (A&B) and choose more from 'good' decks (C&D). With VMPFC patients, however, their performance is comparable with their real-life decision making difficulties in that they do not learn to avoid the disadvantageous decks, and this lack of learning, or 'myopia for the future' was associated with a lack of development of anticipatory SCRs while considering the next selection, which is seen in healthy controls.

According to the SMH (Bechara & Damasio, 2005; Bechara et al., 1994; Damasio, 1994; Damasio, et al., 1991; Naqvi, et al, 2006),decision making in ambiguous circumstances is biased by bodily representations (somatic markers) of the potential value of the different options. Thus, the individual is guided towards an option which has previously been good and guided away from an option previously experienced as bad. Somatic markers are the collection of visceral responses that are an essential component of emotion, i.e. changes in the internal milieu, such as endocrine release, heart rate changes, and smooth muscle contraction. When an individual plays the IGT, SCRs, a physiological correlate of emotion, are seen in response to wins and losses on the game. In addition, anticipatory SCRs (aSCRs) are also reported in the 5 seconds prior to selecting a card, and it is claimed that these aSCRs develop through the course of the game, and so allow for differentiation between 'good' and 'bad' decks. The aSCRs reported on the IGT in the moments before choosing, and before explicit knowledge has been acquired, are believed to represent a somatic marker. As the participant considers which deck to choose from, they are biased by an unconscious somatic response which is a triggering of the somatic pattern associated with the overall emotional experience associated with previously selecting from that deck. Thus, it is proposed that their choice is guided and their selection is made, initially without any conscious knowledge of why. In the 'body loop' mechanism of somatic markers an appropriate somatic state is actually re-enacted in the body, with signals then relayed back to cortical and subcortical structures. There is also, however, an 'as if' body loop, in which the brain can represent the somatic state expected to be triggered by a future event, thus allowing the person to respond more efficiently to an event without needing the activity to actually occur in the body. These signals can either occur overtly or covertly, with the individual unaware of the influence on their decisions. In a recent review, in order to distinguish beneficial effects of emotion from those instances where excessive emotion may be disadvantageous, it is stated that 'the somatic marker hypothesis concerns emotion that is *integral* to the decision making task at hand...However, the induction of somatic states which are *unrelated* to the decision at hand ...may become disruptive' (Bechara & Damasio, 2005, p. 351).

As will be discussed later some of these assumptions have been contended, in particular the extent to which learning on the IGT is implicit and, also, what aSCRs may actually represent. As will be elaborated on below, especially relevant to this research is the proposition that task-relevant emotion aids good decision making, whilst irrelevant emotional distracters are the detrimental aspects of affect which 'cloud' judgment (Bechara & Damasio, 2005; Preston, Tansfield, Buchanan, & Bechara, 2007).

3.1.1 Past research on the effects of reinforcer on the Iowa Gambling Task (IGT)

Having observed that past research using the IGT had varied in terms of whether real cash or facsimile money was used, Bowman & Turnbull (2003) investigated whether a manipulation of reinforcer type (real versus facsimile) would have any effect on IGT performance. Except for the manipulation of reinforcer, methods and analysis were reported as the same as the original (Bechara et al., 1994), with $100 in the Bechara et al. (1994) study equivalent to £100 in the facsimile condition or 10p in the real money condition. Bowman & Turnbull (2003) reported no significant effect of reinforcer type, with performance matching that of the control participants in previous experiments using the IGT. They did, however, discuss some minor and non-significant differences, noting that there was less variation in overall scores and a smaller standard deviation in the real money condition. Fernie & Tunney (2006) varied instruction and reinforcer type on the IGT and reported real money led to improved performance compared to facsimile but only with the earlier 'No Hint' type instructions (Bechara et al., 1994), not with the later 'Hint' type instructions (e.g., Bechara, Damasio, Damasio, & Lee, 1999; Bechara, Tranel, & Damasio, 2000) which most studies report using and which is used in the current research. The exact level of real money paid out on each deck is not made clear, other than that maximum possible winnings were £3. However, all conditions use slightly different populations and, with the possible exception of the 'Hint' Facsimile condition, none of the other conditions appeared to show learning to an extent which replicates previous reported results using the IGT. For example in their 'No Hint- Facsimile' condition (which is an exact replication of the original Bechara et al, 1994 experiment) performance only just reaches chance level in the last 20 selections.

It seems intuitive that winning real cash, a powerful secondary reinforcer, which can be taken away at the end of the experiment, would be more rewarding and emotionally arousing than facsimile money. Possibly one explanation for why this was not supported in previous research, was that both these studies (Bowman & Turnbull, 2003; Fernie & Tunney, 2006) compared relatively low levels of cash reinforcement (e.g. 5p wins on decks C & D; 10p wins on decks A & B on the Bowman & Turnbull, 2003 study,) with large levels of facsimile money (£50 win on decks C & D; £100 win on decks A & B on the Bowman & Turnbull, 2003). As such, it is possible that there is a difference in emotional response between real and fake money which was not adequately captured by these disproportionate amounts. Previous research (Williams: unpublished Master's thesis) reported that increased cash rewards and punishments on the IGT adversely affected performance (Figure 3.1).

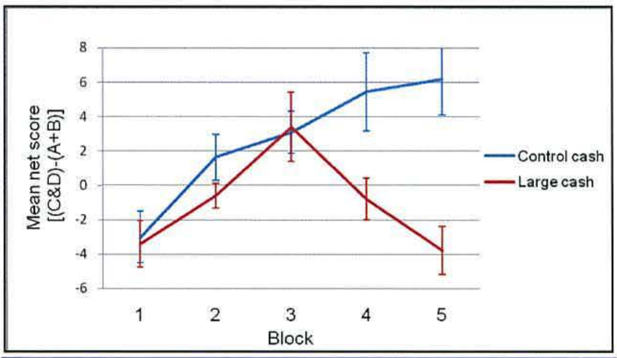


Figure 3.1. Pilot study of the effects of Control (standard) Cash reinforcement versus Large Cash (5 x increased magnitude cash reinforcment) on the IGT (Williams: unpublished Master's thesis). The line at 0 represents chance level selection, with no preference for either good or bad decks. (Error bars represent SEM)

As seen in Figure 3.1, participants in the Large Cash condition (5 x the standard cash amount used in Bowman & Turnbull, 2003; Fernie & Tunney, 2006) showed significantly impaired performance compared to Control participants. All but two of the participants in the

Large Cash condition did not learn to select more from the advantageous decks than the disadvantageous decks, and when questioned later, the two normally performing participants stated that they did not believe the cash winnings would actually be forthcoming. Thus, the difference in performance between these two individuals and the other participants may be attributable to the difference in subjective value assigned to the wins and losses on the IGT. This suggested that poor performance was mediated by greater emotional engagement with the task and an emotional reaction to the larger wins and losses which was in excess of a possible optimum level. Given that the IGT aims to simulate real world decision making, using real money would be a more realistic reinforcer; to date there doesn't appear to have been a systematic investigation of the whether the level of reinforcement can affect emotion based learning on the IGT, either in a beneficial or detrimental way.

3.1.2 Integral emotion should lead to better decision making on the IGT: Hypothesis 1

In a recent review, Bechara and colleagues (Bechara & Damasio, 2005; Naqvi, et al., 2006) distinguished the beneficial effects of emotion from those instances where excessive emotion may be disadvantageous. It was stated that the somatic hypothesis explains how emotion integral to the decision making task aids decision making, while somatic states which are unrelated to the decision at hand can disrupt good decision making. Increasing the level of real money reinforcers should allow rewards and punishments on the game (clearly an integral part of the task) to be felt more keenly (e.g. a sudden loss of £6.25 on card 9 of Deck B in the Cash x5 condition). This should encourage greater emotional engagement with the task, and it can be speculated that, in terms of the SMH, this may be reflected in stronger and / or more polarised somatic markers, leading to an increased ability to differentiate between good and bad decks on the IGT, and hence improved performance. In line with the SMH, therefore, it is predicted therefore that there will be an affect of level of real money reinforcement on the IGT, i.e. that increased magnitude reward and punishments (in the Cash x2.5 and Cash x5 conditions) will significantly improve performance, compared to Control participants receiving the standard cash amount. A further prediction is that the increased level of reinforcement (Cash x5 condition) will results in better emotional engagement and reactions, and thus improved performance on the IGT compared, to a condition with the same level of reinforcement, but with participants aware that the winnings will not be forthcoming at the end of the experiment (Fake x5 condition).

3.1.3 An excess of emotional arousal can impair decision making: Hypothesis 2

The IGT is generally seen as an example of emotion aiding decision making. However, as detailed in the thesis introduction there is much evidence that, especially at high levels, emotion can drive behaviour away from that which is considered ideal (for review, see Baumeister, DeWall, & Zhang, 2007; Loewenstein, 1996; Loewenstein & Lerner, 2003). And, there is evidence that negative affective states tend to shift decisions towards those of short- term gratification over long-term goals (Galliot & Tice, 2007; Gray, 1999). With regard to the IGT, specifically, that there is evidence that mood manipulation, or induction of strong somatic states unrelated to the task, prior to playing the IGT leads to fewer selections from the 'good' decks (Bechara & Damasio, 2005; de Vries, Holland, & Witteman, 2008; Preston, et al., 2007; Suhr & Tsanadis, 2007). It is generally accepted that there is an optimal level of arousal in cognitive tasks (Hebb, 1955; Yerkes & Dodson, 1908) – with too little arousal causing us to be inattentive to important stimuli, and too much causing unproductive levels of anxiety. This theory has been expanded upon more recently by Easterbrook (1959) and Humphreys and Revelle (1984), who both also predict an optimal arousal level dependent on task. Bechara and colleagues (Bechara & Damasio, 2005; Naqvi, et al., 2006; Preston, et al., 2007) have recently stated that it is the induction of somatic states which are irrelevant to the task at hand which are detrimental to decision making and IGT performance. However, pilot testing (Williams: unpublished Master's thesis) indicated that increased magnitude rewards and punishments on the IGT, clearly a task-*relevant* emotional manipulation, led to poorer performance. This could be interpreted in terms of an optimum level of arousal which may apply to task-relevant emotion as well as task-irrelevant emotion on the IGT, a level which was exceeded by emotional reactions to increased magnitude wins and losses. The alternative hypothesis, then, inconsistent with the SMH, is that increased magnitude rewards and punishments on the IGT (in the Cash x2.5 and Cash x5 conditions) will lead to an increased and sub-optimal level of emotional arousal and impaired performance on the IGT compared to Controls. A further prediction is that the increased level of reinforcement (Cash x5 condition) will result in increased and sub-optimal emotional engagement and arousal, and thus impaired performance on the IGT, compared to a condition with the same level of reinforcement, but with participants aware that the winnings will not be forthcoming at the end of the experiment (Fake x5 condition).

The two tailed hypothesis, therefore, is that there will be a significant effect of Condition on IGT performance, as measured by the number of card selections from the advantageous decks (C&D) minus card selections from the disadvantageous decks (A&B).

3.2 Method

3.2.1 Participants

The study was approved by the Research Ethics Committee of Bangor University and written consent was obtained from the participants. 61 undergraduate participants were recruited from the Bangor University Student Participation Panel and received course credit for participating. With the exception of the Fake x5 condition, they were also allowed to keep any winnings from the game. The Control (Standard Cash) Condition had 15 participants (11 females) (Age M = 21.93, SD = 5.73) the Cash x2.5 Condition had 15 participants (10 females) (Age M = 22.93, SD = 6.91), the Cash x5 Condition had 15 participants (10 females) (Age M = 21.6, SD = 4.42) and the Fake x5 Condition had 16 participants (11 females) (Age M = 19.38, SD = 1.20).

3.2.2 Design

This was a between-subjects study, as is necessary to avoid learning effects with the IGT. Participants were randomly allocated to one of the four conditions. The independent variable was the level of rewards and punishments. As is customary (Bechara, et al., 1994; Bechara, et al., 1999), the independent variable was the net score of card selections for each block of 20 selections, i.e. (C+D)-(A+B).

3.2.3 Stimuli

The IGT

Control (standard cash) Condition. This condition used a computerised version of the classic Iowa Gambling Task (Bechara et al, 1994), programmed with E-Prime, with $100 original facsimile money converted to 10p cash. Participants started the game with £2 credit. For a summary of the deck wins and losses on this and all other conditions, see Table 3.1; full details of deck contingencies can be seen in Appendices D-F.

Table 3.1

Summary of card deck wins and losses on the IGT, in pence. (Wins occur on every card selection; losses are less frequent. Losses on decks A and C are variable. For full schedules, see Appendix C.)

	Disadvantageous decks				Advantageous decks			
	Deck A		Deck B		Deck C		Deck D	
Condition	Win	Loss	Win	Loss	Win	Loss	Win	Loss
Control	10	15-35	10	125	5	3-8	5	25
Cash x2.5	25	37-87	25	312	12	7-20	12	62
Cash x5	50	75-175	50	650	25	15-40	25	125
Fake x5	50	75-175	50	650	25	15-40	25	125

Cash x2.5 Condition. This condition was as per the Control Condition, but with the size of all cash wins and losses multiplied by 2.5.

Cash x5 Condition. This condition was as per the Control Condition, but with the size of all the cash wins and losses multiplied by 5.

Fake x5 Condition. This condition was as per the Cash x5 Condition above, differing only in that the participants were informed clearly in both the consent form and in the game instructions that "the winnings are for the purpose of the game only and will not be paid out".

Subjective experience measures

State Trait Anxiety Inventory, State component was completed by all participants immediately before and following the Iowa Gambling Task. This contains 20 items designed to measure current levels of anxiety (Spielberger, 1983).

Visual Analogues representing 'Happy', 'Tired', 'Anxious' and 'Emotionally Aroused' were completed immediately before and after the Iowa Gambling Task (see Appendix G.)

Subjective Deck Ratings were elicited during a brief break in the game every 20 card selections. Participants were asked to rate on a scale of 1 to 9 'How good' they felt each deck (A, B, C and D) was.

3.2.4 Procedure

Participants completed the STAI and the visual analogues. Participants then read the instructions, and were reminded (with the exception of Fake x5 condition) that the winnings would be paid out in cash at the end. (For participant instructions see Appendices A and C). They performed a computerised version of the standard IGT (Bechara et. al, 1994), programmed in E-Prime, with questions asked after every block of 20, to elicit explicit knowledge regarding the deck contingencies (as detailed above). In each condition, credit of £2 was given. The participants kept the winnings in all but the Fake x5 condition, and where the game ended with a negative amount the participant was not asked to pay this amount.

3.3 Results

3.3.1 Behavioural Data

As is the convention, (Bechara, et al., 1994; Bechara, et al., 1999) the one hundred card selections from the Iowa Gambling Task were subdivided into 5 blocks: Block 1, 1-20; Block 2, 21-40; Block 3, 41-60; Block 4, 61-80; Block 5, 81-100. For each of these blocks a net score was then calculated by subtracted the number of selections from the disadvantageous decks (A and B) from the number of selections from the advantageous decks, i.e.(C + D)- (A + B). Hence, for each block, a score below zero indicates that participants were selecting disadvantageously, while a score above zero represents advantageous choices.

A mixed ANOVA was performed on the IGT data, within-subjects factor Block (5 levels: Block 1, Block 2, Block 3, Block 4, Block 5) and between subjects factor Condition (4 levels: Standard, Cash x2.5, Cash x5, Fake x5) (Figure 3.2).There was a main effect of Block F (4, 184.52) = 7.51, p <.001, Greenhouse-Geisser corrected. (Block 1 M = -2.26, SD = 5.74; Block 2 M = -.43, SD = 5.37; Block 3 M = .74, SD = 6.59; Block 4 M = 1.0 SD = 7.0; Block 5 M = 2.82, SD = 7.37). Replicating previous results, this represents a steady move from selecting disadvantageously (i.e. choosing more cards from A and B) to selecting advantageously (i.e. choosing more cards from C and D). There was a significant main effect of Condition, F (3, 57) = 3.392, p = .024, consistent with the hypothesis that the level of cash amount paid out would affect performance on the Iowa Gambling Task. There was an interesting trend towards a Block x Condition interaction effect, p = .063, suggesting that condition affected learning rates.

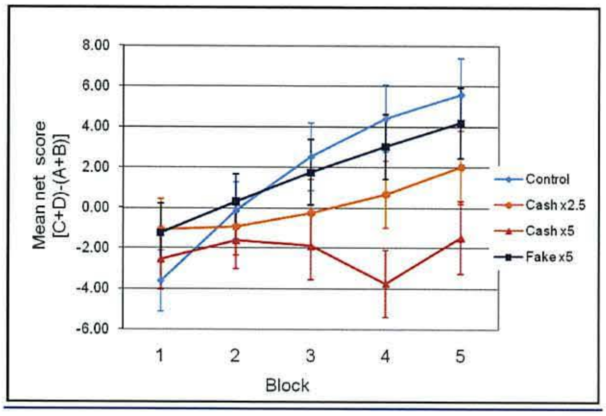


Figure 3.2 : The effect of increased magnitude monetary reinforcement on the IGT. The line at 0 represents chance level selection, with no preference for either good or bad decks (Errors bars represent SEM).

Post hoc analyses, with Fisher's LSD, showed a significant difference between the Control condition and Cash x5 condition, $p= .006$, and a significant difference between Cash x5 condition and Fake x5 Condition, $p = .01$, There was no significant difference between Control and Fake x5 Conditions.

A one way ANOVA was then performed on the Block 5 data only, with Condition as a between-subjects factor (4 levels: Control, Cash x2.5, Cash x5, Fake x5). There was a main effect of Condition F (3, 57) = 3.263, $p = .028$. Post hoc analysis, with Fisher's LSD, demonstrated a significant difference between Control and Cash x5 conditions, $p = .008$, and a significant difference between Fake x5 and Cash x5 conditions, $p = .013$. There was no significant difference between Control and Fake x5 conditions, $p = .81$, *ns*.

3.3.2 Subjective Measures

Deck Ratings

As with the card selections, a net score for deck ratings was calculated, i.e. [(C+D)-(A+B)]. Hence, for each block, a score below zero indicates that participants did not have knowledge of 'how good' decks C and D were compared to decks A and B, while a score above zero represents they do have some conscious knowledge of deck contingencies. A mixed ANOVA was performed on the Deck ratings data, within-subjects factor Block (5 levels: Block 1, Block 2, Block 3, Block 4, Block 5) and between subjects factor Condition (4 levels: Standard, Cash x2.5, Cash x 5, Fake x5).There was a significant effect of Block, F (4) = 8.48, $p < .001$ (Block 1 $M = -.20$, $SD = 4.38$; Block 2 $M = 2.39$, $SD = 4.53$; Block 3 $M = 2.90$, $SD = 3.38$; Block 4 M 3.41, $SD = 4.18$, Block 5 $M = 2.43$, $SD = 4.10$. No significant main effect of Condition and no Condition x Block interaction (Figure 3.3).

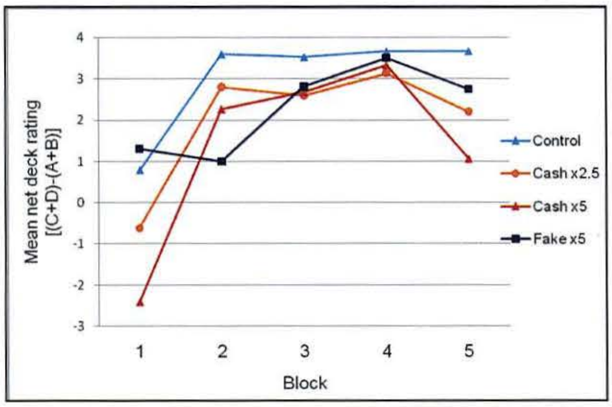


Figure 3.3: Effect of increased magnitude of monetary reinforcement on subjective deck ratings on the IGT. (Error bars omitted for clarity.)

STAI, 'State' component

A repeated measures ANOVA was carried out on the STAI scores, within-subject factor Time (2 levels: pre-testing, post-testing) and between-subjects factor Condition (4 levels: Control, Cash x2.5, Cash x5, Fake x5). There was a significant effect of Time, F (1, 57) = 17.97, p <.001 (Pre-testing M = 32.87, SD = 7.89; post-testing M = 37.62, SD = 8.47). There was no effect of Condition F (3, 57) = .803, p = .497, *ns*. There was no Time x Condition interaction, F (3, 57) = .696, p = .558, *ns*. There were thus significantly higher scores on the STAI, State component, post-testing compared to pre-testing across all conditions.

Visual Analogues

On each Visual Analogue component, a repeated-measures ANOVA was performed, within-subject factor Time (2 levels, pre-testing, post-testing), between-subject factor Condition (4 levels, Standard, Cash x2.5, Cash x 5, Fake x5).

For *'Emotionally Aroused'* and *'Tired'* there were no effects of either Time or Condition. There were also no interaction effects of Time x Condition.

For *'Happy'* there was a significant effect of Time, F (1, 56) = 20.325, p <.001. There was no effect of Condition and no Time x Condition interaction.

For *'Anxious'* there was a significant effect of Time, F (1, 56) = 9.577, p = .003. There was no effect of Condition and no Time x Condition interaction.

Thus, participants didn't report feeling any difference in tiredness or emotional arousal levels after testing compared to before. Participants did, however, report feeling significantly less happy and more anxious post-testing, across all conditions (Table 3.2).

Table 3.2

Mean pre and post testing scores on emotional visual analogues (maximum score = 10)

Visual analogue	Condition	Pre test	Post test
Tired			
	Control	4.19	4.79
		(2.59	(3.35)
	Cash x2.5	5.47	5.31
		(2.97	(2.95)
	Cash x5	5.25	5.06
		(2.92)	(2.61)
	Fake x5	5.51	6.04
		(2.63)	(2.45)
Emotionally Aroused	Control	4.67	4.32
		(3.06	(2.06)
	Cash x2.5	3.98	3.94
		(2.34	(2.48)
	Cash x5	4.38	4.76
		(2.41	(2.40)
	Fake x5	4.46	4.46
		(2.48	(2.18)

Table 3.2 (*continued*)

Visual Analogue	Condition	Pre test	Post test
Happy			
	Control	7.29	6.20
		(1.71)	(2.05)
	Cash x2.5	7.01	5.71
		(1.86)	(2.45)
	Cash x5	7.66	6.24
		(1.22)	(2.55)
	Fake x5	6.69	5.61
		(1.72)	(1.83)
Anxious	Control	1.85	3.36
		(1.88)	(2.57)
	Cash x2.5	2.89	3.27
		(2.42)	(2.54)
	Cash x5	2.91	4.12
		(1.74)	(2.38)
	Fake x5	1.56	2.58
		(1.34)	(2.18)

Bracketed figures are standard deviations

3.4 Discussion

This experiment employed the Iowa Gambling Task with a manipulation of the level of reward and punishment across the standard desk schedule. In a between-subjects study, participants played the game in one of four conditions: Control (standard wins and losses; real money), Cash x2.5 (win and loss amounts increased by a factor of 2.5 across the schedule; real money), Cash x5 (win and loss amount increased by a factor of 5 across the schedule; real money) and Fake x5 (win and loss amounts increased by a factor of 5; end of game winnings not paid out). Control group results were comparable with previous reported findings. Also replicating previous results, there was a main effect of Block across groups, indicating a steady move from initially selecting more cards from disadvantageous decks A & B, to selecting more advantageously form decks C & D, across conditions. There was a main effect of Condition, indicating that the increased levels of reward and punishment paid out on the IGT adversely affected performance. This appears inconsistent with the prediction of Bechara and colleagues (Bechara & Damasio, 2005; Preston, et al., 2007) that emotion relevant to the task should aid decision making, and supports the idea of an optimal level of even task-relevant emotion arousal. There was a marginally significant Block x Condition interaction, $p = .06$ indicating a trend for rate of learning to vary across condition. Post hoc analyses indicated that performance on the Cash x5 condition was significantly impaired compared to both Control condition performance, and compared to the Fake x5 condition. There was no significant difference between Fake x5 condition and Control condition performance. Visual analogue and STAI results suggest that the level of reinforcement had no effect on subjective affective experience or stress, although across conditions participants reported being slightly more anxious and less happy post-testing compared to pre-testing. The behavioural results, therefore report two key issues, then: one is that the *level* of reinforcement had a significant effect on IGT performance; the other is that the *type* of reinforcement had a significant effect on performance. Each aspect will be explored further below.

3.4.1 The effect of level of reinforcer on the IGT

Inconsistencies with the SMH

The first finding was that there was a detrimental effect of level of reinforcement on IGT performance, as seen in a significant effect of Condition on net scores and a near significant Block x Condition interaction. The Cash x5 condition scores were significantly lower than those of the Control condition, with the Cash x5 participants failing to approach even chance level selection from the advantageous decks (maximum mean net score -1.47 at the end of Block 5, compared to steady learning in the Control condition ending in a mean net score of 5.60, Figure 3.2). Although the Cash x2.5 condition card selection scores were not significantly different compared to the other conditions, it can be clearly seen from Figure 3.2 that the performance profile of these participants is approximately midway between the normally performing Control participants and the significantly impaired Cash x5 participants. (Cash x2.5 participants exhibited a steady learning curve, ending in a mean net score of 2.0 at the end of Block 5.). The ability of increasing magnitude of wins and losses to lead to significantly poorer performance on the IGT does not seem consistent with the somatic marker hypothesis (Bechara & Damasio, 2005; Bechara, Damasio, Tranel, & Damasio, 2005; Damasio, 1994; Damasio, et al., 1991; Naqvi, et al., 2006). Within the SMH, somatic markers are subdivided into primary and secondary inducers. Primary inducers are innate or learned stimuli that automatically and involuntarily produce a pleasurable or aversive state. The rewards and punishments on the IGT are an example of a primary inducer, in that both wins and losses elicit an automatic emotional response, as seen in reactionary SCRs. Secondary inducers are generated by personal memories or consideration of a hypothetical event, i.e. thoughts of a primary inducer. The amygdala is seen as a critical substrate in the experience of primary inducers, while the ventromedial prefrontal cortex forms a critical part of the neural system involved in triggering secondary inducers and serves as a crucial convergence zone. Once a somatic state has been induced by a primary inducer, then thoughts or memories of the triggering event can act as a secondary inducer in the future, triggering the somatic pattern associated with the primary inducer (albeit in a weaker form). The anticipatory skin conductance responses (aSCRs) reported to correlate with successful IGT performance are believed to represent a secondary inducer guiding the participant's choice based on the previous emotional experience associated with selecting from that deck. It is proposed that their choice is guided and their selection made, initially, without explicit knowledge of why. Somatic markers can be viewed as an indication of how rewarding or punishing an action is, thereby limiting the decision making space where a complicated rational, cost-benefit analysis is not feasible.

Larger, real money rewards and punishments should be felt more keenly, both as a primary inducer when initially sampling from the decks and as a secondary inducer when deliberating over selection and triggering, in a weaker format, the somatic marker pattern of the overall emotional experience previously associated with the decks. It has been stated that the SMH explains the beneficial effect of task-relevant emotion, with disruptive emotional activation arising from incidental affect, and unrelated to the task at hand (Bechara & Damasio, 2005; Naqvi, et al., 2006; Preston, et al., 2007). According to the SMH, then, one could speculate that, with a larger level of rewards and punishments (the Cash x2.5 and Cash x5 conditions), the performance profile should possibly reflect a greater attraction to the instantly gratifying decks A& B initially, followed by a more pronounced avoidance, i.e. more rapid learning, as punishments are received and deck contingencies learnt. However, rather than more rapid learning and improved performance, the current research found to the contrary. The finding that Fake x5 condition performance was no difference from that of Controls but significant better than when real money was paid out in the Cash x5 condition further testifies to the idea that it is the level of emotional engagement and arousal which is at the heart of the impaired performance in the current study.

Increased magnitude wins and losses as excess detrimental emotional arousal on the IGT

Although the IGT is generally cited as an example of the ways in which emotion has a crucial role in advantageous decision making, there are many opposing examples of emotion having a detrimental effect on decisions, especially with respect to a tendency to make us act in favour of short-term gratification over long term benefits (Galliot & Tice, 2007; Loewenstein & Lerner, 2003). With regard to the IGT specifically, and possibly emotion-based learning more generally, it may be that there is an optimal level of arousal applicable to the generation, integration or attention to somatic markers. Inverted u-shaped effects of arousal on performance are commonly explained in terms of Easterbrook's (1959) concept of relevant versus irrelevant cues. It is proposed that increased arousal leads to the processing of fewer cues, as the most relevant ones are focused on at the expense of the less relevant. As the level of arousal increases, however, cues which are relevant to the task start to be left unattended. In an alternative explanation, Humphreys and Revelle (1984) proposed that arousal increases attention and persistence but is detrimental to the efficiency of information processing.

It has been suggested that different neural brain systems are involved at different stages of the IGT (Bechara & Damasio, 2005; Van den Bos, Houx, & Spruijt, 2006). This may provide a more specific explanation of why increased rewards and punishments and, presumably, increased emotional reactions, can adversely affect IGT performance. It is proposed that in the early stages, the dopaminergic reward system is most active, necessary for assessing the best long-term action by integrating the different wins and losses as the decks are sampled. As the game proceeds, serotonin-mediated self-control becomes more pertinent in resisting the initially high payout but low long-term gain decks (A&B). Both serotonin and dopamine have also been shown to be involved in reversal learning (Clark, Cools, & Robbins, 2004), of which the IGT can be considered a more complicated example. Two recent studies using a temporal discounting design (McClure, Laibson, Loewenstein, & Cohen, 2004) and a Markov decision task (Tanaka, et al., 2004) have supported the idea of two different systems being involved in regulating choice behaviour across different timescales. McClure et al. (2004) found that parts of the limbic system associated with midbrain dopamine are active in response to choices of short-term gratification, whereas long-term pay-offs were mediated by the lateral prefrontal cortex and associated structures, which are able to evaluate abstract rewards, including trading off immediate gratification for reward in the future. Human and animal behaviour is partly driven by internal motivational states, related to the desire to seek reinforcement. There appears to be an inhibitory control mechanism in the prefrontal cortex which can control this kind of behaviour known as pre-potent responding (Dias, Robbins, & Roberts, 1997). This may provide the means by which innate or conditioned emotional responses and reflexes aimed at short-term reward can be suppressed, so that behaviour can be guided more by slower and more reflective goal-directed cognitive processes. It is believed that dopamine release (and thus presumably the dopamine-mediated arousal proposed to be involved in covert biasing, Bechara & Damasio, 2005; Naqvi, et al., 2006) may disrupt the inhibitory influence of the prefrontal cortex, allowing more habitual responses mediated by sub-cortical structures to dominate. While allowing for rapid learning and pre potent responding in the presence of especially rewarding stimuli, this would also act to reduce the consideration of longer term consequences, i.e. would shift the balance between deliberation and action, and can be maladaptive in human society (Arnsten & Goldman-Rakic, 1998).

3.4.2 The effect of reinforcement type on the IGT

The second finding was that there was a significant effect of reinforcement *type*, i.e. real cash versus fake reinforcement, with Cash x5 participants performing at a significantly lower level than those in the Fake x5 condition. Cash x5 participants never exceeded a mean net score of 0 (representing chance level selection, or an indifference between decks), whereas it can be seen that Fake x5 participants exhibited a steadily improving performance profile, not significantly different from the Control group. Importantly, the only difference was that participants in the Fake x5 condition were informed that 'winnings are for the purpose of the game only and will not be paid out'. The fact that Fake x5 participants performed at Control participant level rules out poor performance on the Cash x2.5 and Cash x5 conditions as being attributable to the larger win and loss sums affecting any possible explicit mathematical calculations and working memory load. This further supports the interpretation that it is the emotional arousal associated with the increased magnitude wins and losses which affected IGT performance.

This suggests that the use of real money in gambling experiments, as opposed to facsimile money or points may make a substantial difference to results. Although research so far has found no significant effect of reinforcer type on the IGT (Bowman & Turnbull, 2003; Fernie & Tunney, 2006), these experiments have generally involved relatively small amounts of cash, whereas the current research demonstrates that there may be a level at which reinforcer type does make a difference. Bowman & Turnbull (2003) reported no effect of reinforcer type on IGT performance, although they did note that there was a less variation in overall scores and a smaller standard deviation in the Real Money condition (12) compared to the Facsimile group (20.5). It was observed that this could be important when IGT is in use as a clinical neuropsychological tool, presumably since less variance in scores would allow for easier differentiation between groups. It does seem intuitive that where emotional responses are an integral part of an experiment, real money would evoke a great emotional response and encourage greater participant engagement than either points, or the paying out of facsimile money of which the participant is obviously aware is without value outside the parameters of the game.

3.4.3 Subjective deck ratings: Is impaired performance due to lack of implicit learning or explicit risk-taking?

Since the IGT is purported to involve non conscious emotional biasing (Bechara, et al., 1994; Damasio, 1994) this raises the question of whether the impaired performance demonstrated with increased magnitude wins and losses is due either to a detrimental effect on implicit, unconscious, visceral processes (somatic markers), or to an increased tendency to take risks or focus on short-term gain despite having acquired explicit knowledge regarding the deck contingencies, or a combination of both phenomena.

There was no significant effect of Condition on Deck Ratings and no Condition x Block interaction. However, although there was no statistical difference between IGT deck ratings according to the magnitude of wins and losses, it is interesting to note that the trend for deck ratings across the course of playing the IGT is largely in line with the behavioural results (Figure 3.3). That is, that most knowledge is reported in Control and Fake x5 conditions, then progressively less so in the Cash x2.5, and least in the Cash x5 conditions. This trend in subjective deck ratings between groups appears most evident just after Block 1 (where any implicit, intuitive processes would, presumably, be dominant compared to explicit learning processes) with any (non significant) difference between groups, arguably, evening out across the course of the IGT.

In order to investigate at what point any explicit awareness of IGT contingencies develops Bechara and colleagues carried out a study on 10 healthy controls and 6 VMPFC patients and questioned them periodically through the IGT. (Bechara, Damasio, Tranel, & Damasio, 1997). On the basis of this, the authors claimed the game could be split into 4 phases – the 'pre-punishment' phase (little of no experience of losses, approximately up to the 10th card), the 'pre-hunch' phase (cards were still sampled from all decks and no knowledge of what was happening was reported, approximately card 10-50). A 'hunch' phase followed in which healthy subjects developed a gut feeling and could guess at which decks were good or bad (approximately card 50 - 80). Here they began to choose more advantageously before they could report why some decks were better than others. Finally, a 'conceptual' phase then reached where healthy subjects were able to report fairly accurate explicit knowledge about the deck contingencies, (i.e. that the best strategy was to choose from decks C and D as these decks paid less in winnings but also incurred less in losses) (from approximately card 80 onwards). Bechara et al. (1997) also reported that development of the aSCRs, proposed to discriminate between the good and bad decks, preceded both the 'conceptual' and 'hunch' periods. As expected from previous studies (Bechara, et al., 1994), the VMPFC group failed to choose advantageously and this was linked this to a failure to develop the discriminating aSCRs. In addition, VMPFC patients failed to develop 'hunches', although 50% reached the conceptual phase despite performing badly.

Consistent with later research, however (Bowman, Evans, & Turnbull, 2005; Maia & McClelland, 2004), this study also found that explicit knowledge emerges earlier than Bechara et al. (1997) originally claimed. Knowledge of the 'goodness' or 'badness' of decks is above chance levels as early as at the end of Block 1, after the first 20 card selections for the Control and Fake x5 conditions. (*M* net deck ratings 0.8 and 1.31, respectively, where 0 represents chance level selection and an indifference between decks). In the Cash x2.5 and Cash x5 group there was a trend for participants to still be rating Decks A and B slightly higher, i.e. less explicit knowledge regarding Decks C and D representing the best long-term strategy (*M* net deck ratings were -0.6 for Cash x2.5, and -2.5 for Cash x5). These results therefore provide further support for the relatively early emergence of conscious awareness regarding the optimal IGT strategy.

Both the Bechara et al. (1997) and later studies (Bowman, et al., 2005; Maia & McClelland, 2004) found that some healthy controls continue to choose from the disadvantage decks despite being able to report the correct strategy. This has been seen as analogous to how VMPFC patients function with relation to personal and social decision making (Naqvi, et al., 2006). VMPFC patients may be able to report the correct strategy for decision making in their personal and social lives and yet be severely impaired in executing such decisions in real life (Saver & Damasio, 1991). This has been interpreted as an indication that 'in the IGT, and in real life, conscious knowledge of the correct strategy may not be enough to guide advantageous decisions making' (Naqvi, et al., 2006, p. 341). In what has been considered by some to be a retreat from the original SMH (Dunn, et al., 2006), it has now been stated that somatic markers may operate on a non conscious level, independently from conscious knowledge – essential for advantageous decision making, but not necessarily preceding conscious knowledge (Naqvi, et al., 2006). In the current experiment, the impaired healthy participants from the increased magnitude cash amount groups (Cash x2.5 and Cash x5) could report explicit knowledge comparable to those who performed normally (Control and Fake x5 conditions) which is consistent with the claim that conscious knowledge alone is not sufficient to guide emotion based learning.

The concept of implicit learning and the appropriate methods for tapping implicit versus explicit knowledge have not been without controversy, however (Shanks, 2005). Also, a further epistemological issue is that the existence of explicit knowledge does not rule out an influence of more implicit processes, or vice versa (Shanks, 2005). In order to ascertain the relative impairment of implicit versus explicit processes when IGT performance is disrupted, it may be necessary to use more sophisticated dissociation methods which have been devised to separate out procedural versus declarative knowledge (e.g., Anderson, Fincham, & Douglass, 1997; Jacoby, 1991; Stocco & Fum, 2008).

3.4.4 Summary and conclusion

The current finding, that integral, relevant emotional arousal may be detrimental to IGT performance in the same way as irrelevant emotional arousal (Bechara & Damasio, 2005; de Vries, et al., 2008; Preston, et al., 2007) adds to other criticism of the SMH of decision making. Previous criticism has generally been aimed at the assumption of the necessity of somatic markers, the extent of implicit versus explicit knowledge on the IGT and, also, with regard to alternative phenomena which the aSCRs may represent (for review, see Dunn, et al., 2006). Where relevant to arousal effects on the IGT, as studied in this thesis, SMH criticisms will be considered in the general discussion.

This experiment, therefore, found that increased magnitude cash wins and losses led to impaired IGT performance. It was found that, contrary to the predictions of the Iowa lab (Bechara & Damasio, 2005; Naqvi, et al., 2006), this example of highly task-relevant emotional arousal had a detrimental effect on IGT performance. Rather, this finding is consistent with the idea of an optimal level of arousal in emotion based learning, even where that emotion is integral to the task. The results were also inconsistent with previous IGT research which claimed that real money versus facsimile money does not affect participant behaviour (Bowman & Turnbull, 2003; Fernie & Tunney, 2006). Subjective deck ratings taken during the course of the game were not significantly different although there was a possible trend for more explicit awareness of deck contingencies in the better performing groups without increased magnitude real cash wins and losses (Control and Fake x5). Further research may be necessary to fully understand this phenomenon. Supporting the idea that impaired performance is attributable to the increased emotional arousal induced by larger monetary wins and losses, a condition employing five times the standard cash amount (Fake x5) performance was comparable with Control cash levels, but only when it was clear the money would not be forthcoming. Interestingly, this detrimental effect of increased arousal on IGT behaviour was evident in the absence of any difference in reported subjective emotional state.

CHAPTER FOUR

THE EFFECTS OF MUSCLE-TENSION-INDUCED AROUSAL ON THE IOWA GAMBLING TASK: EXPERIMENTS 3 & 4

Chapter Three examined the effect of task-relevant emotional arousal in regards to IGT performance and found that even emotional arousal which is integral to the decision making task at hand could disrupt performance. This chapter now focuses on an example of task-irrelevant emotional arousal, namely muscle-tension-induced (MTI) arousal to investigate whether this form of neutral (i.e. non-valenced) background arousal can also disrupt decision making behaviour.

4.1 The Somatic Marker Hypothesis and Arousal

As described in Chapter Three, the SMH proposes that emotional arousal integral to a task will aid decision making under ambiguous conditions, while emotional arousal which is not integral to a task may be disruptive. Specifically, the somatic markers, which are proposed to bias decision making by rapidly signalling the prospective consequences of an action, involve a wide range of physiological changes. These modifications include both changes in the internal viscera such as endocrine release, smooth muscle contractions and heart rate changes, and also, more externally obvious changes in the musculoskeletal system, such as facial expressions, posture or 'fight or flight' behaviours. According to the SMH, these visceral responses lead to changes in the brain, including the release of neurotransmitters, such as dopamine, serotonin, acetylcholine and noradrenaline from brainstem nuclei, and a change in the communication of visceral signals to somatosensory brain regions (Bechara & Damasio, 2005). There is accumulating evidence that visceral states can affect neurotransmitter release from these nuclei (for review, see Berntson, Sarter, & Cacioppo, 2003) and it is known that these neurotransmitter systems have a widespread influence over prefrontal cortex function, including attentional, executive and motivational processes (Berridge & Robinson, 1998; Robbins, 1998; Robbins, Clark, Clarke, & Roberts, 2006).

4.1.1 Background somatic states

Bechara & Damasio (2005) have stated that decision making can be disrupted by the presence of unrelated emotion, citing as indirect evidence observations of neuropsychiatric bipolar patients who exhibit indecisiveness during depression and impulsiveness during manic phases (First, Spitzer, Gibbons & Williams, 1997, cited in Bechara & Damasio, 2005). The reported effects of mood on decision making generally (for review, see Loewenstein & Lerner, 2003) and risk taking, more specifically, (for review, see Andrade & Cohen, 2007) are complex and not always consistent. With regard to the IGT, there is evidence that negative affective states can impair performance, i.e., lead to less selections from the advantageous decks (C&D) and more selections from the decks with short term gain but long term net loss (A&B) (Bechara & Damasio, 2005; Preston et al., 2007; Suhr & Tsanadis, 2007). More generally, it is also known that negative emotions have been associated with a bias towards short term goals over long term benefits (Galliot & Tice, 2007; Gray, 1999).

Bechara and colleagues state that background somatic states (emotions and moods) affect the somatic marker mechanism and thereby influence subsequent decisions and risk taking (Bechara & Damasio, 2005). In an account of investor behaviour and market crashes it is stated that reactions to events (primary inducers) and thoughts about one's next move (secondary inducers) induce somatic states which affect subsequent financial decision making. Crucially, it is proposed that the influence of pre-existing somatic states on decision making depends on both the strength of the background state and, also, to what extent the background state is congruent with the somatic states triggered by secondary inducers (thoughts associated with consideration of an option). Thus, when the existing somatic state is neutral or weak, the signal (somatic state triggered by pondering an option) to noise (background state) ratio is high and the somatic markers triggered by the decision are able to provide feedback to the brain and influence decision making in an advantageous way. Under these background conditions, people are purported to be more sensitive to long term consequences. When the background somatic state is strong, then the effect this has on somatic markers triggered by a decision depends on whether this strong background state is congruent or incongruent with the triggered somatic markers. Where a strong pre-existing somatic state is incongruent with triggered somatic markers, then this low signal to noise ratio means that the feedback signals from the secondary inducers are weak or ineffective. However, where the strong background somatic state is congruent with triggered somatic markers then those triggered somatic states are amplified. The concept of congruent versus incongruent background somatic states is discussed specifically as means of predicting investor behaviour in relation to the emotions generated by current market circumstances and as a way of explaining market crashes, although presumably this was intended to be extrapolated to other situations.

4.1.2 Variability in control populations

In addition to poor performance of neurological and psychiatric patient populations on the IGT (for review, see Dunn et al., 2006), it has become increasingly apparent that a notable minority of healthy control participants, also, do not learn the optimum strategy (Adinoff, et al., 2002; Bechara & Damasio, 2002; Crone, Somsen, Van Beek, & Van Der Molen, 2004). It may be that these individuals merely enjoy risk-taking on the task, as suggested by Bechara and Damasio (2002), or it may be due to another factor which could differ across healthy individuals. Whereas studies to explore the role of personality characteristics in the variability in decision making within healthy control populations have often been inconsistent (Werner, Jung, Duschek, & Schandry, 2009), background arousal level, or somatic state, is one variable which could conceivable vary widely amongst participants at the time of testing. As such, an investigation of this factor may further help explain the phenomenon of poorly performing control subjects.

4.1.3 Hypothesis

Whereas previous research of affective manipulations on the IGT has involved mood induction (e.g., Bechara & Damasio, 2005; de Vries, Holland, & Witteman, 2008; Preston, et al., 2007; Suhr & Tsanadis, 2007), this experiment aims to manipulate non-valenced general arousal to examine its effects on the IGT. The arousal manipulation in his experiment is mild exercise, or MTI arousal, via use of a hand dynamometer (hand dyno). As detailed in Chapter Two, MTI arousal has been previously used to experimentally induce arousal in humans and to have an effect on cognitive tasks (Bills, 1927; Courts, 1939, 1942; Nielson & Jensen, 1994; Nielson et al., 1996; Quartz, 2009; Stauffacher, 1937; Wood & Hokanson, 1965). If a subtle change in general arousal levels can affect IGT performance then this may partly explain the large amount of individual variation in the task and the frequent finding that a significant minority of healthy participants perform at neurological patient level (Adinoff, et al., 2002; Bechara & Damasio, 2002; Crone, et al., 2004). This experiment will also test the claims by Bechara and Damasio (2005) regarding background somatic states and task-irrelevant emotional arousal. The MTI arousal could be considered task-irrelevant since it is induced by a source external to the game (the hand dyno). However, Bechara and Damasio (2005) have also stated that the existence of a strong background arousal state may act to amplify the visceral signals crucial to learning on the IGT.

In a two-tailed hypothesis, is therefore predicted that participants experiencing MTI arousal (Medium and High Arousal Groups) will significantly differ in their IGT performance as measured by net card selections (i.e., the sum of C and D selections minus the sum of A and B selections) compared to those without MTI arousal (Low Arous condition).

4.2 Method

4.2.1 Participants

The study was approved by the Research Ethics Committee of Bangor University and written consent was obtained from the participants.46 undergraduate participants were recruited from Bangor University Student Participation Panel and received course credit for participating. They were also allowed to keep any winnings from the game. The Low Arousal condition had 15 participants (6 females) (Age $M = 21.33$, $SD = 4.70$), the Medium Arousal Condition had 15 participants (13 females) (Age $M = 20.20$, $SD = 3.65$) and the High Arousal Condition had 16 participants (9 females) (Age $M = 20.13$, $SD = 4.08$). Participants were screened for neurological or psychiatric illness.

4.2.2 Design

A between-subjects design was employed to avoid learning effects. Participants were randomly allocated to one of 3 conditions: Low Arousal condition (no hand dyno use), Medium Arousal (hand dyno used at 50% maximum) and High Arousal (hand dyno used at

75% maximum). The independent variable was the level of MTI arousal, the dependent variable was the net score for card selections on the IGT and for IGT subjective deck ratings, and scores on the STAI, State component and emotion visual analogues.

4.2.3 Apparatus

A 0-100 kg Takei Kiki Kogyo hand dynamometer was used.

4.2.4 Stimuli

The IGT

This study used a computerised version of the classic Iowa Gambling Task (Bechara et al., 1994), programmed with E-Prime, with $100 original facsimile money converted to 10p cash. Participants started the game with £2. The participants kept the winnings in and where the game ended with a negative amount the participant was not asked to pay this amount.

Low Arousal Condition. This condition acted as a control for comparison with the 2 MTI arousal conditions below, with Low Arousal participants merely holding the hand dyno without exertion in the two 60 second arousal manipulation breaks. The arousal manipulation breaks were situated immediately prior to starting the IGT and, also, at the end of Block 2 (i.e. after the first 40 card selections).

Medium Arousal Condition. This condition is as per the Low Arousal, except that following individual calibration, participants were asked to use the hand dyno at 50% of their individual maximum in the two 60 second arousal manipulation breaks.

High Arousal Condition. This condition is as per the Low Arousal condition, except that following individual calibration, participants were asked to use the hand dyno at 75% of their individual maximum in the two 60 second arousal manipulation breaks.

4.2.5 Measures

In order to assess subjective experience the following measures were employed:

State Trait Anxiety Inventory

The State Trait Anxiety Inventory, State component was completed by all participants immediately before and following the Iowa Gambling Task. This contains 20 items designed to measure current levels of anxiety (Spielberger, 1983) .

Visual Analogues

Visual Analogues representing *'Happy', 'Tired', 'Anxious'* and *'Emotionally Aroused'* were completed immediately before and after the Iowa Gambling Task. These visual analogues required participants to bisect a horizontal line indicating their level of, for example, emotional arousal, with 'very' being represented by a mark to the far right of the line and 'not at all' being represented at the far left of the line.

Subjective Deck Ratings

Subjective Deck Ratings were elicited during a brief break in the game every 20 card selections. The computerised task paused and the participants were asked to use the keyboard to rate on a scale of 1 to 9 'How good' they felt each deck (A, B, C and D) was.

4.2.6 Procedure

Participants performed a computerised version of the standard IGT (Bechara et. al, 1994), with questions asked after every block of 20, to elicit explicit knowledge regarding the deck contingencies (as detailed above). An additional break was built into the task at the end of Block 2, (i.e., after the first 40 card selections) to enable use of the hand dyno (or mere non-exertive holding of the hand dyno in the Low Arousal condition). (For participant instructions, see Appendix H.)

Firstly, participants allocated to the Medium and High Arousal conditions were asked to squeeze the hand dyno in their dominant hand at their maximum force for a constant 20 seconds in order to allow for individual calibration. Participants then completed the STAI and the visual analogues and read the IGT instructions. This allowed a break of approximately 2-3 minutes to avoid excessive muscle fatigue. Depending on the condition allocated to, the 50% (Medium Arousal) or 75% (High Arousal) levels were then calculated for each participant based on the initial 20 second calibration. The first arousal manipulation was then administered, with the participant using the hand dyno in a constant pumping action at their designated level for 60 seconds. Participants then started playing the IGT until, when prompted by the programme at the end of Block 2, they called the experimenter in from the adjoining room to oversee a second 60 second session of hand dyno use. The remainder of the IGT was then completed. For comparison, during these two sessions of MTI arousal, participants in the Low Arousal condition merely held the hand dyno, resting it on the desk without exerting any pressure.

4.3 Results

4.3.1 Behavioural Data

As is the convention, and as in Bechara et al (1994) the one hundred card selections from the Iowa Gambling Task were subdivided into 5 blocks: Block 1, 1-20; Block 2, 21-40; Block 3, 41-60; Block 4, 61- 80, Block 5, 81-100. For each of these blocks a net score was then calculated by subtracted the number of selections from the disadvantageous decks (A and B) from the number of selections from the advantageous decks (C and D), i.e.[(C + D) - (A + B)]. Hence, for each block, a score below zero indicates that participants were selecting disadvantageously, while a score above zero represents advantageous choices. A mixed ANOVA was performed on the IGT data, within-subjects factor Block (5 levels: Block 1, Block 2, Block 3, Block 4, Block 5) and between subjects factor Condition (3 levels: Low Arousal, Medium Arousal, High Arousal).

As seen in Figure 4.1, there was a significant main effect of Block F (4, 172) = 9.231, p <.001. (Block 1 M = -4.0, SD = 6.02; Block 2 M = -0.13, SD =5.34; Block 3 M = 1.19, SD = 4.50; Block 4 M = .75, SD = 6.88; Block 5 M =2.13, SD = 6.34). Replicating previous results, this represents a steady move from selecting disadvantageously (i.e. choosing more cards from A and B) to selecting advantageously (i.e. choosing more cards from C and D). There was a significant main effect of Condition, F (2, 43) = 5.063, p =.011, consistent with the hypothesis that the level of muscle tension induced arousal would affect performance on the Iowa Gambling Task. There was a near significant Block x Condition interaction effect, indicating that MTI arousal affected learning rates, F (8, 172) = 1.901, p = .063.

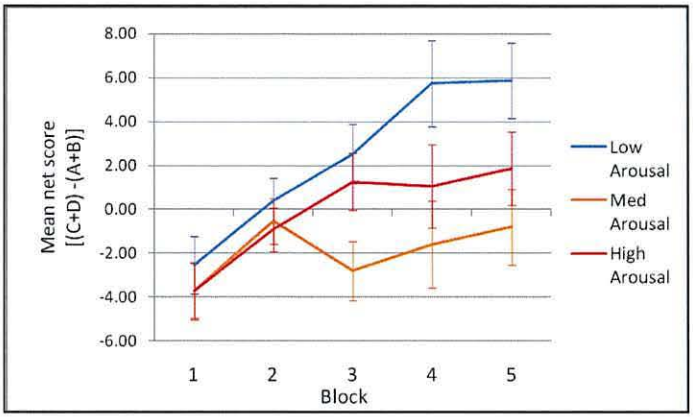


Figure 4.1. The effects of MTI arousal on IGT performance. The line at 0 represents chance level selection, with no preference for either good or bad decks. Errors bars represent SEM.

Post hoc comparisons showed a significant difference between the Low Arousal condition and the Medium Arousal condition, p = .003, with Fisher's LSD. Other comparisons were non significant. A post hoc one Way ANOVA was then performed on the Block 5 data only, with Condition as a between-subjects factor (3 levels: Low Arousal, Medium Arousal, High Arousal). There was a significant effect of Condition F (2, 45) = 3.741, p = .032 (Low Arousal Condition M = 5.87, SD = 7.35; Medium Arousal Condition M = -0.80, SD = 6.36; High Arousal Condition M = 2.13, SD = 6.34).

Because there was no significant difference between the Medium and High Arousal conditions, this data was collapsed into one 'High Arousal' group and the initial ANOVA re-run. In a mixed ANOVA, within-subjects factor Block (5 levels: Block 1, Block 2, Block 3, Block 4, Block 5) and between subjects factor Condition (2 levels: Low Arousal, High Arousal). There was a significant effect of Block, F (4, 176) = 10.75, p <.001, a significant effect of Condition, F (1, 44) = 7.72, p = .008, and a significant Condition x Block interaction, F (4, 176) = 2.66, p = .03 (Figure 4.2).

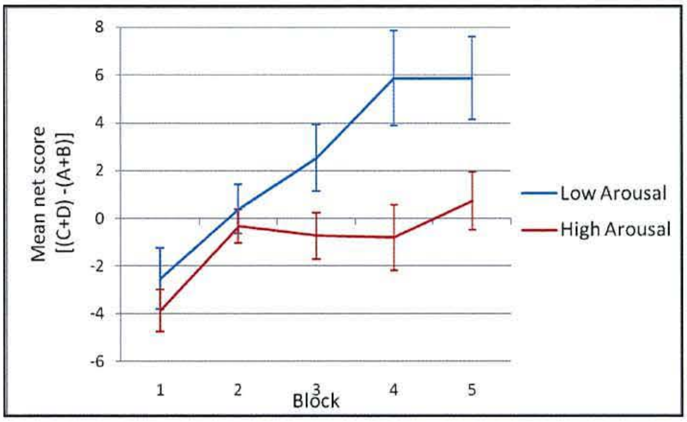


Figure 4.2. The effects of MTI arousal (collapsed to 2 levels) on IGT performance. The line at 0 represents chance level selection, with no preference for either good or bad decks. Errors bars represent SEM.

4.3.2 Subjective measures

Deck ratings

As with the card selections, a net score for deck ratings was calculated, i.e. [(C=D)-(A+B)]. Hence, for each block, a score below zero indicates that participants did not have knowledge of 'how good' decks C and D were compared to decks A and B, while a score above zero represents the existence of knowledge in this area. A mixed ANOVA was performed on the Deck ratings data, within-subjects factor Block (5 levels: Block 1, Block 2, Block 3, Block 4, Block 5) and between subjects factor Condition (3 levels: Low Arousal, Medium Arousal, High Arousal). As seen in Figure 4.3, there was a significant effect of Block, F (4, 172) = 6.208, $p < .001$ (Block 1 *M*). No significant main effect of Condition and no Condition x Block interaction.

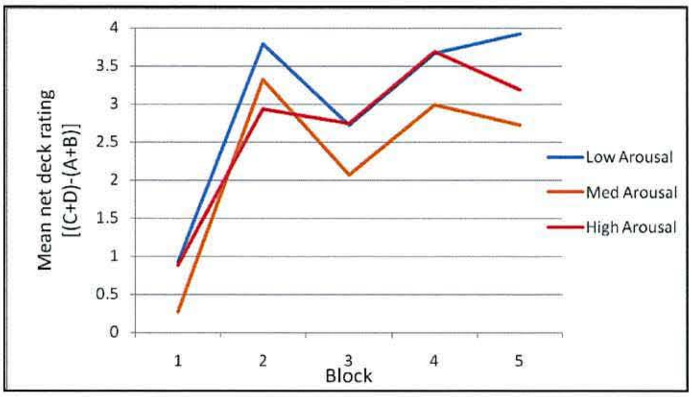


Figure 4.3. Effect of MTI arousal on IGT Deck ratings). 0 represents an indifference between decks. (Error bars omitted for clarity.)

STAI

A repeated measures ANOVA was carried out on the STAI (State component) scores, within-subject factor Time (2 levels: pre-testing, post-testing) and between-subjects factor Condition (3 levels: Low Arousal, Medium Arousal, High Arousal). There was a significant effect of Time, F (1, 43) = 5.399, p = .025 (Pre testing M = 32.62, SD = 8.03; post-testing M = 35.13, SD = 9.17). There was no effect of Condition and there was no Time x Condition interaction. There were thus significantly higher scores on the STAI, State component, post-testing compared to pre-testing across all conditions.

Visual Analogues

A repeated-measures ANOVA was performed on each Visual Analogue component, within-subject factor Time (2 levels, pre-testing, post-testing), and between-subject factor Condition (3 levels: Low Arousal, Medium Arousal, High Arousal).

For '*Happy*' there was a significant effect of Time, F (1, 43) = 6.043, p <.018 (pre-testing M = 7.23, SD=1.68; post testing M=6.62, SD= 2.25). There was no effect of Condition and no Time x Condition interaction.

For *'Emotionally Aroused'* there was a significant effect of Time, $F(1, 56) = 9.577$, $p = .003$. (pre-testing $M = 3.06$, $SD = 2.20$; post-testing $M = 4.07$, $SD = 2.48$). There was no effect of Condition and no Time x Condition interaction.

For *'Anxious'* and *'Tired'* there were no effects of either Time or Condition. There were also no interaction effects of Time x Condition. Thus, participants didn't report feeling any difference in tiredness or anxiety levels after testing compared to before. Participants did, however, report feeling significantly less happy and more emotionally aroused post-testing, across all conditions.

Table 4.1

Mean pre and post testing scores on emotional visual analogues (maximum score = 10)

Visual analogue	Condition	Pre test	Post test
Tired			
	Low Arousal	5.18	5.38
		(2.91)	(2.91)
	Medium Arousal	3.73	4.39
		(2.76)	(2.98)
	High Arousal	4.86	4.27
		(3.24)	(2.92)
Emotionally Aroused	Low Arousal	2.61	4.21
		(2.03)	(2.32)
	Medium Control	3.71	4.83
		(2.62)	(2.62)
	High Arousal	2.86	3.23
		(1.91)	(2.39)

Visual Analogue	Condition	Pre test	Post test
Happy			
	Low Arousal	7.31	6.57
		(1.37)	(2.61)
	Medium Arousal	7.09	6.16
		(1.77)	(2.44)
	High Arousal	7.30	7.09
		(1.94)	(1.68)
Anxious	Low Arousal	1.97	2.40
		(1.95)	(2.07)
	Medium Arousal	2.27	3.03
		(2.49)	(3.30)
	High Arousal	1.76	1.81
		(2.46)	(1.92)

Bracketed figures are standard deviations

4.4 Discussion

In an investigation of task-irrelevant arousal on IGT performance, this experiment found a significant effect of MTI arousal on net card selections. In a between-subjects study, participants played the game in one of three conditions: Low Arousal (hand dyno held without exertion in a 60 *s* pause prior to playing and after the 40th card selection), Medium Arousal (hand dyno used in the two pauses at 50% of individual maximum), High Arousal (hand dyno used in the two pauses at 75% of individual maximum). Low Arousal group results were comparable with previous reported findings and also with Experiment Two Control results. Also replicating previous results, there was a main effect of Block across groups, indicating a steady move from initially selecting more cards from disadvantageous decks A & B, to selecting more advantageously from decks C & D, across conditions. Consistent with the hypothesis that MTI arousal would have an effect on decision making behaviour on the IGT, there was a main effect of Condition. There was also a marginally significant Block x Condition interaction, $p = .063$ indicating a trend for rate of learning to vary across condition. Post hoc analyses indicated that performance on the Medium Arousal condition was significantly impaired compared to the Low Arousal condition, although the difference between the High Arousal condition and both the Low Arousal and Medium Arousal condition was non significant. The implications of this are discussed in fuller detail below. With regard to subjective state, although visual analogue and STAI results suggest that participants felt slightly more emotionally aroused, slightly more stressed and slightly less happy post-testing compared to pre-testing, this was a cross-condition effect, not mediated by MTI arousal. Explicit knowledge as measured by Subjective Deck Ratings did not differ significantly across experimental groups.

Thus, the results are consistent with the claim that task-irrelevant arousal disrupts emotion based decision making and IGT performance (Bechara, et al., 2005; Naqvi et al., 2006). Previous impairments on the IGT due to emotion have generally involved negatively-valenced affect such as the induction of stress (Preston, et al., 2007) or negative emotional imagery (Bechara & Damasio, 2005). In discussing the SMH, observations of neuropsychiatric patients with bipolar disorders were also cited as indirect evidence for the detrimental effect of excessive emotion during decision making (First, Spitzer, Gibbons & Williams, 1997, cited in Bechara & Damasio, 2005). These patients show disturbances which include indecisiveness during depression and impulsiveness during manic phases. It is believed, however, that the current study provides one the first example of a neutral background arousal state affecting behaviour on the IGT.

According to Bechara & Damasio (2005), the pre-existence of unrelated emotion can be detrimental to decision making under ambiguity. They state that reactions to events (primary inducers) and thoughts about one's next move (secondary inducers) induce somatic states and these pre-existing states then influence subsequent decisions in the somatic marker circuitry. Current affective states feedback can alter the rate of neuronal firing in the amygdala (the critical substrate for feeling a primary inducer) and the ventromedial prefrontal cortex (the critical substrate for triggering secondary inducers). It is claimed that how a background arousal state will affect subsequent somatic markers depends both on the strength of background state and, also, the extent of congruency between background state and the somatic states triggered by secondary inducers. Thus a neutral or weak somatic state leads to a high signal to noise ratio and advantageous decision making which better takes account of long term considerations. When the background somatic state is strong and incongruent with triggered somatic markers background state then signals from secondary inducers are weak or less effective, meaning a low signal to noise ratio, but it is claimed that a strong congruent state will amplify triggered somatic markers. The experimentally induced arousal in the current study was presumably neutral since participants' subjective measures did not differ across conditions. According to the way background somatic states are proposed to operate, then, the 3 minutes exercise during testing would constitute a stronger but neutral background arousal state which should lend itself to advantageous decision making. This prediction of the somatic marker hypothesis was not borne out by the results, however, with increased MTI arousal leading to disadvantageous decision making on the IGT.

4.4.1 Theoretical accounts of MTI arousal interference on the IGT

MTI arousal effects as a change in the balance of neurotransmitters

This study found that MTI arousal was detrimental to IGT performance. As detailed in Chapter Two, it is known that exercise leads to increased noradrenaline and adrenaline release (Banister & Griffiths, 1972, as cited in Ohman & Kelly, 1986). It is likely, therefore, that the exercising with the hand dyno causes noradrenaline and adrenaline release, and such MTI arousal has also been shown to increase heart rate (Nielson & Jensen, 1994; Williamson, et al., 2002; Wood & Hokanson, 1965). The SMH proposes that physiological changes are important in advantageous decision making under ambiguity. Specifically, visceral signals are said to 'mark' decision options by rapidly signalling the prospective consequences of an action from past experience. These physiological changes include such phenomena as endocrine release, smooth muscle contractions and heart rate changes, changes in the musculoskeletal system, and or 'fight or flight' responses (Bechara & Damasio, 2005; Naqvi, et al., 2006b). The precise source of these biasing somatic markers continues to be debated. Bechara and Damasio have stated that ascending neurotransmitters systems are most likely involved (Bechara & Damasio, 2005) and Robbins et al. (2006) have proposed that these signals could arise from the ascending monoaminergic systems, associated with arousal, mood and reward processing. The SMH proposes that visceral states exert an influence on ascending neurotransmitter systems via release of dopamine, serotonin, acetylcholine and noradrenaline from brainstem nuclei, which in turn influence decision making by both promoting specific goals in working memory and by biasing behaviour towards these goals (Naqvi et al., 2006). There is a increasing evidence that visceral states can exert an influence on neurotransmitter release from these nuclei (for review, see Berntson, et al., 2003) and these neurotransmitter systems, in turn, have a widespread influence on attentional, executive and motivational processes governed by the prefrontal cortex (Berridge & Robinson, 1998; Robbins, 1998; Robbins, et al., 2006).

It is possible that MTI arousal could cause noradrenaline release which could in turn interact with other neurotransmitters affecting behaviour on the IGT. Although the ascending neurotransmitter arousal systems were initially presumed to function independently, there is now accumulating evidence that these neurotransmitters operate as interacting systems (e.g., Briand, Gritton, Howe, Young, & Sarter, 2007; Carlsson, 2001; Carlsson, et al., 2001; Robbins, et al., 2006). More precise details regarding anatomical and functional interactions of the ascending arousal systems are still relatively sparse, however. Some of the phenomena discussed with regards to the effect of increased magnitude cash wins and losses on the IGT (Chapter Three) may also be applicable to the current effects of MTI arousal on IGT performance. It may be that there is an optimal level of arousal regarding the generation, integration or attention to somatic markers on the IGT, and possibly emotion-based learning more generally. Changes in physiological arousal, via NA release may alter the balance of DA to 5-HT, which are proposed to be dominant in different parts of the game (Bechara & Damasio, 2005; Van den Bos et al., 2006). Also, it could be speculated that a change in arousal and alertness levels may have an effect on inhibitory control and increase the likelihood of pre-potent responding (Dias et al., 1997). Thus choice behavior may have been guided more by rapid, innate reward-driven responses at the cost of slower, more deliberative cognitive processes.

MTI arousal effects as interference of interoceptive processes

Cardiovascular changes are one example of the signals on which the somatic marker mechanism is proposed to rely (Bechara & Damasio, 2005; Naqvi, et al., 2006). For somatic markers to be useful in guiding selections on the IGT, they need to convey information about both the valence (i.e., whether a win or a loss is expected) and the magnitude (i.e., how much money will be won or lost) of the selection under consideration. Research from the Iowa lab has shown that the VMPFC triggers anticipatory visceral responses, as indexed by SCRs, to the advantageous decks as well as the disadvantageous decks, albeit to a lesser degree (Bechara et al., 1994; Bechara et al., 1997; Damasio, 1994). Further experiments have shown that when the reward-punishment contingencies are reversed so that disadvantageous decks pay out lower reward, rather than higher punishment, SCRs are then larger in response to the advantageous decks rather the disadvantageous decks (Bechara, Dolan, & Hindes, 2002; Tomb, Hauser, Deldin, & Caramazza, 2002). It has been suggested that this is an indication that the SCR represents not how 'good' or 'bad' an option is, but the magnitude of both anticipated positive and negative outcomes, while the actual valence of the outcome is undifferentiated (Naqvi, et al., 2006). This is consistent with research on psychophysiological responses to emotional stimuli (Lang, Greenwald, Bradley, & Hamm, 1993) which showed that SCRs index the level of arousal elicited by the emotional stimuli, but not the valence. With regards to how the positive versus negative anticipated emotional outcomes are signalled, there is evidence that this may occur through cardiovascular changes, such as changes in heart rate (Bradley & Lang, 2000; Rainville, Bechara, Naqvi, & Damasio, 2006). Although other theories of emotion would stress the necessity of cognitive appraisal in interpreting bodily changes (Schachter & Singer, 1963), Rainville et al. (2006) propose that these signals combine with those reflected in SCRs to provide more comprehensive information about both perceived valence and magnitude.

It is has been demonstrated that the ability to attend to cardiac signals is important in emotional processing (Barrett, Quigley, Bliss-Moreau, & Aronson, 2004; Herbert, Pollatos, & Schandry, 2007; Pollatos, Schandry, Auer, & Kaufmann, 2007). Also, a close association has been demonstrated between heartbeat awareness and specific brain structure activity, with a heartbeat perception accuracy correlated with increased activation in the right anterior insula (Critchley, Wiens, Rotshtein, Ohman, & Dolan, 2004). Activity in this area was also correlated with individual ability to experience emotion, suggesting that subjective experience of emotion arises at least in part from brain activity relating to bodily sensations. Consistent with the Critchley et al. (2004) study, Pollatos et al. (2007) reported that the right insula was mutually activated by interoceptive awareness and arousal, in participants who performed a heartbeat perception task during increased cardiovascular load. These studies support the claims of the SMH that the right insular cortex is important in decision making, through the mapping of body states into feelings and bringing such interoceptive signals to conscious awareness (Bechara & Naqvi, 2004; Damasio, 1994). Heartbeat detection tasks draw attention to bodily sensations but lack an emotional focus. Being aware of a visceral sensation is not necessarily the same as feeling an emotion, and Schachter and Singer (1962) would stress the necessity of an emotional stimulus to allow for cognitive interpretation and for the bodily signal to be interpreted and emotion experienced. The findings of Critchley et al. (2004) have therefore been interpreted as meaning that interoceptive awareness and emotional experience initially share a common mechanism, up to the point of the anterior insular cortex (Naqvi, et al., 2006). Recently, it has also been reported that individuals who were superior at perceiving their own heartbeat performed better on the IGT, compared to those who were poor at cardiac perception (Werner, et al., 2009). Also relevant to this study are the findings of Williamson et al. (2002), that increased cardiovascular effort through hand dyno exercise was associated with increased activity in the insular and anterior cingulate.

These studies, linking interoceptive awareness to learning on the IGT, and increased cardiovascular arousal, interoceptive awareness and subjective feelings to activity in the right insular, may provide an explanation for how increased physiological arousal in the current study could interfere with IGT performance. I.e., brain representation of increased (MTI) physiological arousal and the interoception of visceral signals, proposed to bias choices and allow learning on the IGT, may share a common neural pathway.

4.4.2 The disproportionate effect of Medium versus High Arousal: A misattribution of arousal?

This study reported an effect of MTI arousal on the selection of cards from the advantageous versus the disadvantageous decks on the IGT. However, it can be seen that there was a paradoxical effect of the level of arousal, with the Medium Arousal condition (50% of individual maximum) having a more detrimental effect than the High Arousal condition (75% of individual maximum) (Figure 4.1). The Medium Arousal condition was significantly different from the Low Arousal condition; the High Arousal condition was not significantly different from the other groups but the trend for mean net selections fell approximately mid way between the Low Arousal and Medium Arousal conditions from Block 2 onwards. Misattribution of arousal theory may help explain this phenomenon. Schachter and Singer (1962) stressed that subjective emotional experience depends simultaneously on both physiological emotional response and cognitive interpretation of the triggering stimulus. Thus, in ambiguous circumstances where an explanation for the physiological arousal is not obvious, attribution will depend on what cognitions are immediately available. Originally, the theory stated that the emotional arousal would not be wrongly attributed where the source was obvious and appropriate, however such instances have since been reported (Dutton & Aron, 1974; Meston & Frohlich, 2003; White, Fishbein, & Rutstein, 1981). This misattribution may result from excitation transfer, where physiological arousal from one event transfers to a subsequent event (Cantor, Zillmann, & Bryant, 1975; Zillmann, 1971). Emotional reactions are thus enhanced as arousal from different sources, relevant or irrelevant, whether current or preceding, is combined. Crucial to this theory is the fact that, whereas physiological arousal hormones may be relatively slow to dissipate in changing circumstances, cognitions can change rapidly. It is therefore possible that, whereas the participants in the High Arousal condition are very obviously aware of the effort exerted and arousal induced by their hand dyno use, for those in the Medium Arousal condition the exercise is experienced as relatively easy. Thus, Medium Arousal participants may be less likely to 'discount' the arousal induced by the hand dyno exercise, the cause of this increased arousal being less obvious and more easily (and falsely) attributable to wins and losses on the game. In this way, arousal from the hand dyno exercise may interfere with the visceral signals genuinely induced by the IGT. In comparison, for the High Arousal participants the exertion required is more strenuous, clearly so from the perspective of the experimenter, and the subsequent arousal effects experienced during the IGT may be more clearly attributable to the physical exercise.

The alternative explanation for the pattern of results is that the trend for High Arousal participants to perform better than Medium Arousal participants was merely a spurious finding. To accommodate this possibility, further analysis was carried out with data collapsed across these two levels of MTI arousal. There remained a significant effect of Arousal, consistent with brief physiological arousal having a detrimental effect on IGT performance.

In order to explore the extent to which conscious awareness of arousal effects may differ between Medium and High Arousal conditions, Experiment 4 was carried out, (see below). It was found that there was no significant difference in subjective measures of transient arousal (Short Form AD ACL, Thayer, 1986) between participants carrying out a hand dyno exercise at the Medium Arousal and High Arousal levels (Medium Arousal *M* = 20.72, *SD* = 4.82; High Arousal *M* = 20.55, *SD* = 5.01). Additionally, when asked 'Do you feel any more alert/ aroused after using the hand dyno', the 4 point scale response options being, (1) "definitely do not feel", (2) "cannot decide", (3) "feel slightly", and (4) "definitely feel", there was no significant differences between Medium Arousal and High Arousal groups (Medium Arousal *M* = 2.73, *SD* = 0.83; High Arousal *M* = 2.74, *SD* = 1.12). The mean scores indicate that participants were approaching the 'feel slightly' option, this option scoring 3. It is interesting, then, that despite the fact that the hand dyno use associated with the High Arousal level was visibly more difficult for participants compared to the Medium Arousal level, no differences were reported between the two conditions, either with regard to subjective feelings of transient energetic arousal as measured by the AD ACL (Thayer, 1986), or in response to the explicit question addressing arousal state after hand dyno exercise. There is, therefore, a mismatch between awareness and actual arousal which could be consistent with a misattribution of arousal explanation for the disproportionate effect of Medium Arousal compared to High Arousal.

EXPERIMENT 4: MTI AROUSAL SUBJECTIVE RATINGS

Introduction

In order to assess whether participants in the Medium Arousal condition and the High Arousal condition perceived any difference in the effects of the MTI arousal a further experiment was carried out. A different sample of participants carried out the hand dyno exercise and rated their subjective feelings of post testing arousal.

Method

Participants. N = 22 (males = 8), undergraduate students receiving course credit for participation. Age $M = 20.91$, $SD = 3.61$.

Design. A 2-condition, within-subjects design. The Medium Arousal was a 60 second burst of hand dyno exercise at 50% individual maximum; the High Arousal Condition was a 60 second burst of hand dyno exercise at 75% individual maximum, each condition followed by subjective measures as below. Order of MTI Arousal condition was counterbalanced and participants randomly assigned to which condition they experienced first.

Apparatus. A 0-100 kg Takei Kiki Kogyo hand dynamometer was used.

Measures. The Activation-Deactivation Adjective Check List (AD ACL) (Thayer, 1986), Short Form, was administered immediately post-testing in both conditions. The Short Form AD ACL is a list of 20 adjectives to which participants self- report; the four response options being "definitely feel", "feel slightly", "cannot decide", "definitely do not feel" .The scale was devised, and has been extensively validated, for rapid and unobtrusive assessment of transitory arousal. An additional, specific question, 'Do you feel any more alert/ aroused after use of the hand dyno?' was added, with the same 4 point scale.

Procedure. At the start of the testing, participants underwent individual calibration, as in Experiment 3. Following this 20 second burst of hand dyno exercise, 10 minutes was allowed for dissipation of any arousal effects. Participants then completed one of the arousal conditions, followed by a 40 minutes break and then by the second arousal condition. Following each condition, participants immediately completed the AD ACL and answered the additional arousal question as detailed above.

EXPERIMENT 4 continued

Results

As is customary, just the 'Energetic and 'Tense' components of the AD ACL were scored. Paired samples t tests were performed on the post testing AD ACL scores and on the post-testing Arousal question scores. There was no significant difference between Medium and High Arousal groups on AD ACL scores, t (21) = .197, p = .85, *ns* (Medium Arousal M = 20.72, SD = 4.82; High Arousal M = 20.55, SD = 5.01), or on the additional arousal question scores, t (21) = .0, p = 1.0, *ns,* (Medium Arousal M = 2.73, SD = 0.83; High Arousal M = 2.74, SD = 1.12).

Discussion

Despite carrying out a level of MTI Arousal requiring more exertion, High Arousal participants did not report feeling any more physiologically aroused or alert, i.e. there was a mismatch evident between actual physiological arousal and reported subjective feeling of arousal.

4.4.3 Deck ratings

In order to assess explicit knowledge participants' subjective deck ratings were taken from participants after every 20 card selections. There was no significant difference in the deck ratings according to condition, despite significant differences in behavioural results. However, there was a possible trend for higher scores, representing more knowledge, in line with the behavioural results. Interestingly, this trend was also seen in examining the effects of increased magnitude wins and losses on the IGT, Experiment 2. Although the intention was to assess explicit knowledge by asking participants to rate decks according to how 'good' or 'bad' they thought they were, further consideration has led to the belief that additional research would be necessary in order to draw any conclusion from this subjective data. This rating system may only reflect what Bechara et al. (1997) considered a progression to the 'hunch' period, i.e. a conscious awareness of a gut feeling of which decks may be better than others, without full conceptual knowledge of how the contingencies work. Within psychology there is much criticism of both the concept of implicit knowledge and of the practise of assessing explicit versus implicit knowledge with direct questions (Shanks, 2005). Shanks (2005) also points out that the involvement of explicit knowledge does not rule out an influence of more implicit processes, or vice versa. Indeed the fact that healthy controls may perform badly despite explicit knowledge, and that VMPFC patients perform badly despite attaining conceptual knowledge as been cited as evidence that explicit knowledge alone may not be sufficient to guide behaviour (Bechara, et al., 1997). In order to ascertain to what extent implicit versus explicit processes were affected by MTI arousal, it may be necessary to use more sophisticated dissociation methods (e.g., Anderson, Fincham, & Douglass, 1997; Jacoby, 1991; Stocco & Fum, 2008), as will be discussed further in the general discussion.

4.4.4 Variability in controls

The findings that MTI arousal affected IGT performance may aid an explanation of variability in control participant behaviour. Bechara and Damasio (2002) reported that 7 out of 22 the healthy controls did not perform according to the optimum strategy, i.e. never shifted from selecting more from the advantageous decks than the disadvantageous ones. Within this group they found that there was much variance in SCR profile, with some showing normal SCRs, while others showed a pattern similar to VMPFC patients. The authors characterised those who performed badly despite normal SCR profiles as high risk-takers, choosing to override the information conveyed by somatic markers in favour of conscious deliberation. Other studies have also found that a sub group of healthy controls do not learn the optimum strategy (Adinoff, et al., 2002; Bechara & Damasio, 2002; Crone, et al., 2004). Bechara and Damasio (2002) reported that within their sub-normally performing control group there was a vide variation in anticipatory SCR, with some showing normally developing SCR profiles, while others had a profile comparable with VMPFC patients. It was speculated that those poorly-performing controls with normal SCR profiles were high risk-takers who choose to ignore and override information conveyed by somatic markers in favour of more conscious deliberation. It may be that these individuals merely enjoy risk-taking on the task, as suggested by Bechara and Damasio (2002), or it may be due to another factor which may differ across healthy individuals. Following the finding that enhanced cardiac perception was associated with more advantageous behaviour on the IGT, Werner et al. (2009) proposed that the individual propensity to attend to somatic feedback may mediate individual differences on the task. The current study has shown that a mere 3 minutes of exercise can affect learning on the IGT, and therefore it may be that a change in background arousal level may interfere with this ability to attend to visceral signals, such as heart rate changes. This has implications for the testing of controls populations generally, and suggests that care should be taken to ensure participants are in a similar state of arousal prior to testing. Reducing variability in control populations would help ensure clearer differentiation between controls and comparison groups with genuine decision making deficits.

4.4.5 Conclusion

Whereas disruptive influences of emotion on the IGT have generally involved negative affect, this experiment manipulated physiological arousal level via MTI arousal and found that even subtle effects of non-valenced arousal can have a detrimental effect on IGT performance. This is consistent with claims that task irrelevant arousal can interfere with decision making, but does not support the more specific idea that a strong but neutral background somatic state can enhance somatic markers and thus lead to more advantageous decision making (Bechara & Damasio, 2005). Previous research concerning IGT performance, subjective awareness, increased arousal and associated brain structures (Critchley, et al., 2004; Pollatos, et al., 2007; Werner, et al., 2009; Williamson, et al., 2002) have led to the speculation that increased physiological arousal in the current study may interfere with interoceptive awareness via a common neural pathway involving the right insular. This is consistent with SMH claims that afferent feedback of visceral responses is an important factor in decision making and that the insular is an essential neural substrate in mapping interoceptive states (Damasio, 1994; Naqvi, et al., 2006). This raises the question of to what extent subtle changes in arousal can affect everyday emotion-based decision making in ambiguous circumstances. These findings could also help account for the individual variation regularly reported in healthy controls and has implications for future testing conditions.

CHAPTER FIVE

THE EFFECTS OF INCREASED EMOTIONAL AROUSAL ON AN EXPLICIT GAMBLING TASK: EXPERIMENTS 5 AND 6

5.1 Introduction

In this chapter the focus moves from decision making involving 'gut feelings', and the learning of reward contingencies, to a study of risk-taking performance. As described in Chapter Two, the Explicit Gambling Task (EGT) is a task designed to examine decision making under risk where, unlike the IGT, all contingencies are available for the subject on a trial by trial basis. In Experiments 2 and 3 it is impossible to ascertain whether arousal-induced impaired performance was due to a failure in the implicit learning of contingencies, a greater tendency towards risk-taking, or a combination of both of these factors. Thus, the same two arousal manipulations, magnitude of cash reward and punishment, and MTI arousal, are now applied in an investigation of whether these factors can affect behaviour on a probabilistic risk-taking task without contingency learning. Although the existence of similarly-induced arousal effects on this task would not rule out the impairment of more implicit processes in Experiments 2 and 3, it would suggest that an increased tendency towards risk-taking was a factor to be considered in interpreting the effects seen on the IGT.

5.5.1 Judgment and decision making (JDM) theory accounts of risk-taking, and recognition of 'affect heuristics

A long traditional of research in decision making arising from an economic (von Neumann & Morgenstern, 1944) or philosophical (Jeffrey, 1983) perspective presumed that decisions involving uncertainty arose from purely rational, cognitive processes, logical inference and cost-benefit calculations. Prospect Theory (Kahneman & Tversky, 1979) provided a more psychologically realistic model of how individuals actually behave. In particular, Prospect Theory accounted for deviations from Expected Utility models, such as increased risk-seeking in the negative domain compared to where gains are involved, and the finding that people respond emotionally to incremental gains not overall levels of wealth. Also, it was also found that the value of an option may be determined by comparison with a subjective, sometimes arbitrary, reference point which can lead to framing effects. Framing effects describe how different values can be assigned to the same outcome depending on which features are cognitively prominent. Many more modern theories, based on Expected Utility theory (von Neumann & Morgenstern, 1944) still assume that options are decided upon depending on a calculation of outcome and objective probability, with the option with the best cost-benefit ratio being the one chosen. Although sometimes accepting that cognitive evaluations may give rise to emotions, the role of affect in decision making was often not considered within economic utility frameworks.

Over recent years, however, there has been increasing recognition that emotional processes should be involved in any comprehensive account of decision making under risk (e.g., Finucane, Alhakami, Slovic, & Johnson, 2000; Loewenstein et al., 2001). Given the limited capacity of attention and working memory, a deliberate cost-benefit analysis of all possible options in a complex decision making situation seems inefficient and unfeasible. As models of decision making progressed a common theme within JDM theory, therefore, was to view emotional contributions as involving rapid, approximating heuristics in contrast to the slower, exacting calculations previously focused on (Bohm & Brun, 2008; Finucane et al., 2000; Greene, Nystrom, Engell, Darley, & Cohen, 2004; Kahneman, 2003; Kahneman, Slovic, & Tversky, 1982; Loewenstein et al., 2001; Weber & Johnson, 2009). In addition, conflicts in decision making and pathological decision making were often seen as resulting from these rapid emotional responses, or 'affect heuristics' (Finucane et al., 2000; Greene et al., 2004; Loewenstein et al., 2001).

5.1.2 Contradictory evidence from mood manipulation research.

There is considerable evidence that emotional state can exert a powerful influence on decision making under risk. When investigating the effects of mood and expected outcomes, there is much evidence that positive mood leads to optimism and negative mood to pessimism when assessing probabilities (Constans & Mathews, 1993; Johnson & Tversky, 1983; Mayer, Gaschke, Braverman, & Evans, 1992; Pietromonaco & Rook, 1987; Wright & Bower, 1992). However, even though the research on risk *perception* is fairly consistent, there is conflicting research with regard to actual risk-*taking*.

Isen has reported that positive mood may increase risk-taking, but only when the probability of loss is low or when the nature of the loss is considered trivial, with risk averse behaviour when the risk of loss is relatively high (Isen, 1997; Isen & Means, 1983; Isen & Patrick, 1983; Nygren, Isen, Taylor, & Dulin, 1996). People in positive or neutral mood have been found to be more likely to take risks on a life dilemma task (Yuen & Lee, 2003) and more tolerant of financial risk (Grable & Roszkowski, 2008). And yet, in a real life setting, investors were found to be more tolerant of risk when in a negative mood (Kliger & Levy, 2003). Arkes et al. found that positive mood led to participants being willing to pay a larger amount for a hypothetical lottery ticket (Arkes, Herren, & Isen, 1988), but then a very similar study, found that induced stress (i.e. a negative mood) led to the same effect (Mano, 1992). Negative mood has been associated with greater risk-taking on a strategic decision making task (Mittal & Ross, 1998), and in consumer studies (Bruyneel, Dewitte, Franses, &

Dekimpe, 2009; Lin, Yen, & Chuang, 2006). Also with regard to negative mood, Ragahunathan and Pham (1999) reported opposing effects of different forms of negative affect, with sadness associated with risk seeking behaviour while anxious individuals were risk averse. Compulsive gambling has been shown to increase in times of negative mood (Peck, 1986) and an increase in impulsive and risk-seeking behaviour has been shown when individuals are in negative moods, but only those bad mood accompanied by high arousal (Leith & Baumeister, 1996).

So it seems that both positive and negative mood can similarly induce risk taking, but the direction which this could take is highly inconsistent. Theories which strive to account for some of these effects have often involved the concept of mood regulation or mood maintenance (e.g., Andrade & Cohen, 2007; Forgas, 1995; Isen & Labroo, 2003), however it could be that arousal level is a confounding and neglected factor in past studies of mood on risk-taking. Thus, the next two experiments in this chapter examine the effects of emotional arousal, rather than of a specific mood, on decision making under risk. Two methods of inducing arousal which have been previously shown in this thesis to have effects on the IGT, namely increased magnitude cash reinforcement and MTI arousal, will now be applied to the EGT.

5.2 Experiment 5: The Effects of Increased Magnitude Wins and Losses on the Explicit Gambling Task

Experiment 2 demonstrated that increased magnitude cash wins and losses on the Iowa Gambling Task led to less cards being selected from the advantageous decks. Learning on the IGT is purported to involve unconscious biasing (Bechara, Damasio, Tranel, & Damasio, 1997). However, as also reported and discussed in Chapters Three and Four, participants appear to have more knowledge of which decks were good or bad than the Iowa group previously claimed. One possibility for impaired performance whilst in possession of explicit knowledge about the task is that participants were consciously choosing to take risks. This arousal manipulation is therefore extended to the Explicit Gambling Task (EGT) to investigate whether increased cash rewards and punishments can also affect risk-taking on a gambling task where there is no element of learning. Using the previously piloted decision making task (Experiment 1, Chapter Two) it is predicted that increased arousal, achieved via manipulating the level of financial wins and losses, will have an effect on decision making, as measured by % High Probability Choices and Response Time.

5.2.1 Method

Participants

The study was approved by the Research Ethics Committee of Bangor University and written consent was obtained from the participants. 19 undergraduate students (10 males) were recruited from Bangor University Student Participation Panel and received course credit for taking part. Mean age was 20.0 (SD = 2.08). Participants were screened for neurological and psychiatric illness and for dyslexia and colour blindness.

Design

This was a 3 condition, repeated measures design. Participants were tested on three separate occasions, each time within 1 and 7 days of the previous session, at the same time of day. Each session had a different order of task schedules; with task schedule and condition order counterbalanced. The independent variable was the level of reinforcement; the dependent variables were the % Highest Probability Choices (% HPC) and Response Time.

Stimuli

The computerised gambling task described in Chapter Two was employed (with the post-piloting adaptations, as discussed). The task lasted approximately 25 minutes. The level of reinforcement was varied as follows:

Low Arousal condition: Points only, as in Experiment 1.

Medium Arousal condition: Cash wins and losses, with points from Experiment 1 converted into pence, (e.g., 2p would become 2 points).

High Arousal Condition: Participants were advised that, on full completion of testing approximately 2-3 weeks later, the highest scoring participant would win a large cash prize of £35. This condition was accompanied by visual cues (pictures of money on walls, money picture background to task, and an open cashbox of notes on desk visible upon entering the room). For practical reasons participants played the game for points (as in the Low Arousal condition) and did not received trial by trial cash wins and losses as in the Medium Condition.

In the Medium condition a '£' sign appears in the grid to denote the 'hidden prize', and after choosing a colour the text on the screen advises "you have won (lost) ... p". The winnings bar shows the sum of money won. These are replaced in the Low Arousal (points) condition and High Arousal (points, with possibility of large cash prize) by an 'X' in the grid and text of "you have won (lost) ... points". The Low and High Arousal condition winnings bar shows the sum of points won.

Measures

The State Trait Anxiety Inventory (STAI), State component

This questionnaire was completed by all participants in each session immediately before and following the task. The STAI, State component contains 20 items designed to measure current levels of anxiety (Spielberger, 1983).

Visual Analogues

Visual Analogues representing 'Happy', 'Tired', 'Anxious' and 'Emotionally Aroused' were completed immediately before and after the EGT. These visual analogues required participants to bisect a horizontal line indicating their level of, for example, emotional arousal, with 'very' being represented by a mark to the far right of the line and 'not at all' being represented at the far left of the line.

Procedure

As detailed above, participants were asked to complete the State component of the STAI and the visual analogues before completing the task, and again immediately afterwards. Participants were then given written instructions which were identical to those for the pilot, Experiment 1, except with regard to the winnings (See Appendices I-K). They were told they would be playing a game in which they should act to maximise their points/ cash winnings and were instructed that they should base their decision on information from both the colours on the grid and the amounts in the boxes below. Participants completed a practise run of 12 trials before the first session during which time they were allowed to ask any questions relating to the task.

5.2.2 Results

Choice Data

Initially, a 6 Factor Mixed ANOVA was performed on the data with within subject factors: Arousal (3 levels; Low, Medium, High) x Outcome Type (2 levels; Win, Lose) x Probability (3 levels; 14:2, 12:4, 9:7) x Amount (3 levels, 14/2, 12/4, 9/7) and between subject factors: Gender (2 levels) x Order of condition (5 levels). There were no effects of Gender or Order of condition, so analysis on was re-run without these factors, i.e. as a 4 factor within-subjects ANOVA.

Replication of pilot parameters

On the choice data the pattern of results from the pilot Experiment 1 (Chapter Two) were replicated, as seen in Figures 5.1 - 5.2. There was a main effect of Probability, F (1.16, 20.91) = 79.94 with Greenhouse Geisser correction, $p < .001$, so that more Highest Probability Choices were made where the choice of probabilities was more extreme (14:2) compared to where the choice of probabilities was more ambiguous (9:7), (14:2 Probability M = 77.78; 12:4 Probability M = 68.66; 9:7 Probability M = 37.14). There was a main effect of Amount, F (1.35, 24.25) = 41.63 with Greenhouse Geisser correction, p <.001; the %HPC increased steadily as the amounts which could be either won or lost became less extreme and more evenly matched (14/2 Amount M = 48.59; 12/4 Amount M = 59.31, 9/7 Amount M = 75.68). There was a main effect of Outcome Type F (1, 18) = 5.13, p = .036 with Greenhouse Geisser correction, (Win trials M = 58.74, Lose trials M = 63.64); participants were more likely to choose the higher probability option in Lose trials than in Win trials.

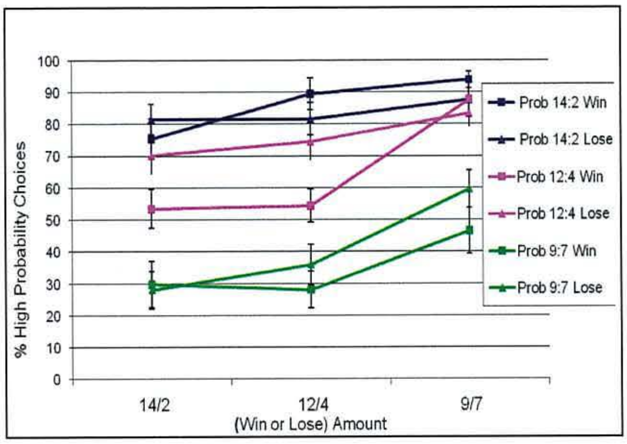


Figure 5.1. Low Arousal (points) condition: % High Probability Choices as a function of Probability and Amount on the EGT (Error bars represent SEM).

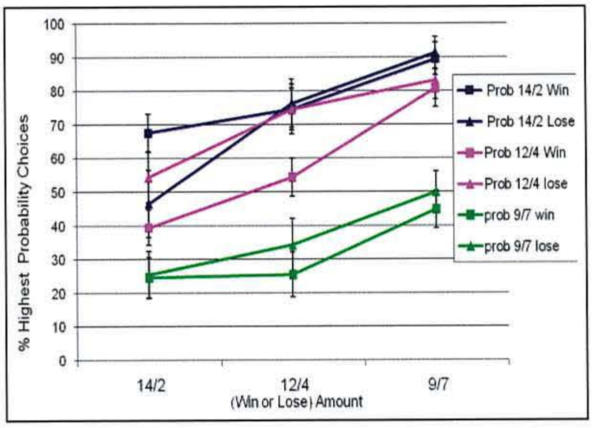


Figure 5.2. Medium Arousal (small cash) condition: % High Probability Choices as a function of Probability and Amount on the EGT (Error bars represent SEM).

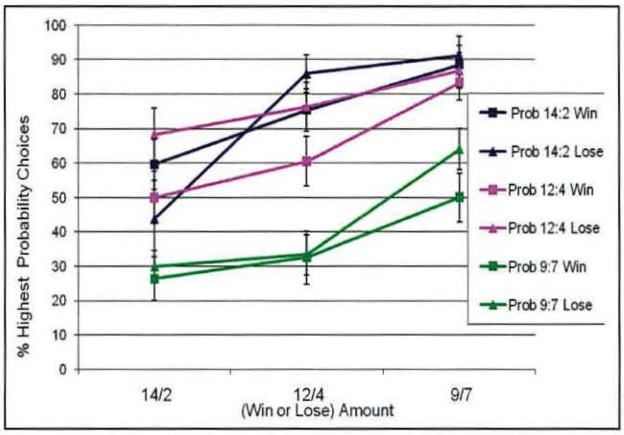


Figure 5.3. High Arousal (large cash) condition: % High Probability Choices as a function of Probability and Amount on the EGT. (Error bars represent SEM)

There was a significant Probability x Outcome Type Interaction, F (2 36) = 8.19, p = .001; (Figure 5.4). The trend was for a higher % HPC in the Lose trials compared to the Win trials in the 12:4 and 9:7 Probabilities in particular; the data suggests that, collapsed across Arousal condition, any difference according to Outcome Type in the most extreme probability, the 14:2 Probability would be in the opposite direction.

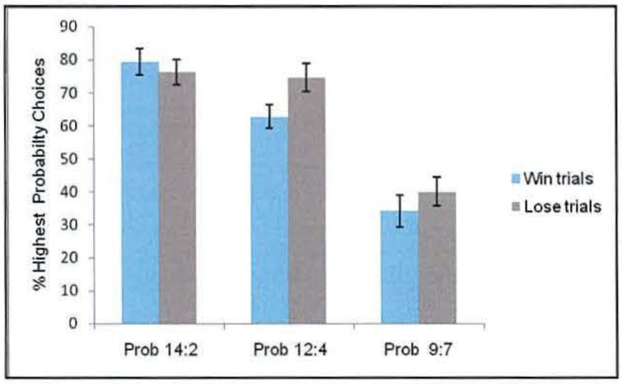


Figure 5.4. Probability x Outcome Type interaction on % HPC on the EGT(Error bars represent SEM).

In addition to the replicated results from the pilot study (Experiment 1, Chapter Two), there was a significant Probability x Amount interaction, F (3.16, 56.81) = 6.27, p = .001 with Greenhouse Geisser correction (Figure 5.5). For all Probabilities, participants were more likely to make a Highest Probability Choice when the probabilities were more extreme (14:2) and when the win/lose Amounts were more evenly matched, however Amount appeared to have a less of a mediating effect on the 9:7 Probability, where there was least risk involved.

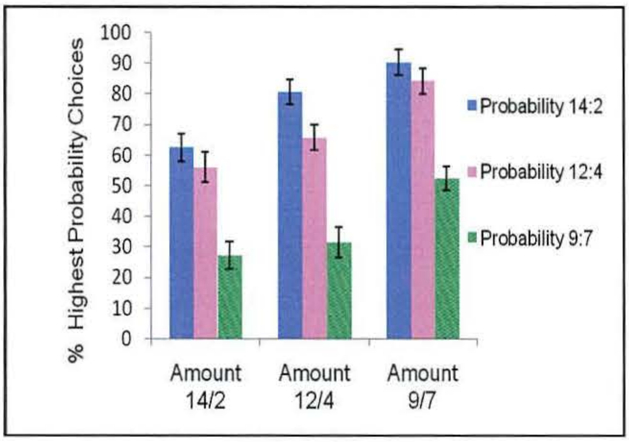


Figure 5.5 . The Probability x Amount interaction effect on % HPC on the EGT (Error bars represent SEM).

There was a significant Outcome Type x Amount interaction, F (2, 36) = 3.63, p = .037; there appeared to be a trend towards a greater effect of Outcome Type on the 12/4 Amount compared to the other amounts (Figure 5.6).

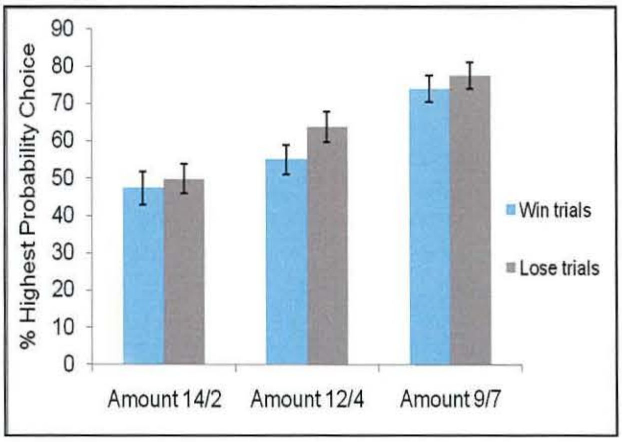


Figure 5.6. The effects of the Outcome x Amount interaction on % HPC on the EGT (Error bars represent SEM)

There was also a significant Outcome Type x Probability x Amount interaction, F (2.77, 49.83) = 6.26 with Greenhouse Geisser correction, p = .001. This interaction is explored with further analyses below.

Effects of Arousal

There was no main effect of Arousal. However, there was an Arousal x Outcome Type x Probability x Amount interaction, F (8, 144) = 2.09, p = .040. There was also a significant Arousal x Amount interaction, F (4, 72) = 3.04, p = .022, a near significant interaction of Arousal x Probability F (4, 72) = 2.92, p = .053 with Greenhouse Geisser correction and a near significant interaction of Arousal x Probability x Amount F (4.72, 85.01) = 2.30 p = .056, with Greenhouse Geisser correction. In order to explore these interactions each Probability was analysed in a separate 3 factor repeated measures ANOVA: Outcome Type trial type (2 levels: Win, Lose), Arousal (3 levels: Low Arousal, Medium Arousal, High Arousal), Amount (3 levels: 14/2, 12/4, 9/7). When analysed in this way there were no effects of Arousal in the 12:4 or 9:7 Probabilities but effects of Arousal were seen in the 14:2 Probability (Figures 5.7 and 5.8).

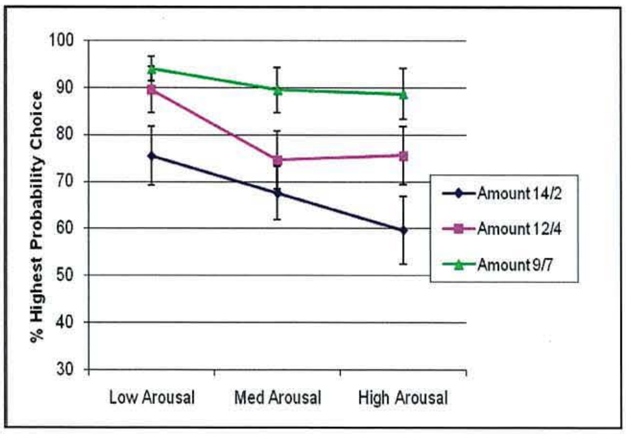


Figure 5.7. The effects of Arousal on the 14:2 Probability, Win trials, i.e. the interaction effect of Arousal x Outcome Type x Probability x Amount on the EGT (Error bars represent SEM.)

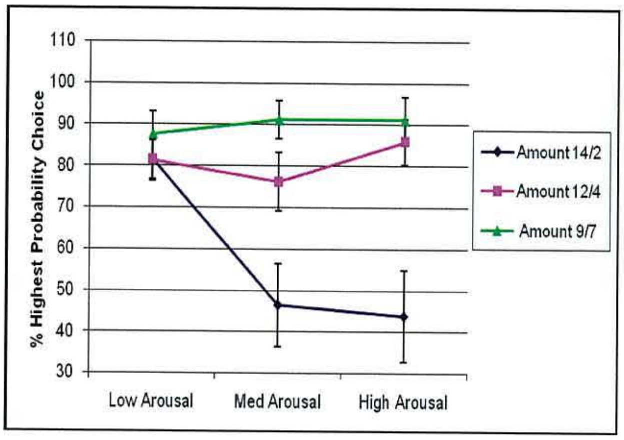


Figure 5.8. The effects of Arousal on the 14:2 Probability, Lose trials, i.e. the interaction effect of Arousal x Outcome Type x Probability x Amount (Error bars represent SEM).

In an ANOVA solely on the 14:2 Probability choice data there a significant main effect of Arousal: F (2, 36) = 3.431, p =.043 (M Low Arousal = 84.94, M Medium Arousal = 74.27, M High Arousal = 74.12) (Figures 5.7 and 5.8). As seen in the main analysis on all of the choice data, there was a main effect of Amount, F (1.44, 25.90) = 36.81, p <.001, with Greenhouse Geisser correction (M Amount 14/2 = 62.43, M Amount 12/4 = 80.56, M Amount 9/7 = 90.35). There was no main effect of Outcome Type, unlike the main analysis, but there was Arousal x Outcome Type x Amount interaction, F (1.99, 35.75) = 3.59, p =.038, with Greenhouse Geisser correction, and there was also an Outcome Type x Amount interaction, F (2, 36) = 5.03, p = .012 and an Arousal x Amount interaction, F (2.41, 43.41) = 4.94, p = .009, with Greenhouse Geisser correction.

In order to establish exactly where the arousal effects lie, two final repeated measures ANOVAs were performed on the 14:2 probability, 14/2 Amount data. An ANOVA was performed on the Win trials of this data, one factor, Arousal (3 levels: Low Arousal, Medium Arousal, High Arousal) there was a significant effect of Arousal F (2, 36) = 3.48, p = .042.

Pairwise comparisons with LSD showed a significant difference between Low Arousal and High Arousal, p = .038. There was no significant difference between Low and Medium Arousal or between Medium Arousal and High Arousal conditions. Similar analysis was also carried out on the Lose trials of the 14:2 Probability, 14/2 Amount; i.e. a repeated measures ANOVA, one factor, Arousal (3 levels: Low Arousal, Medium Arousal, High Arousal). There was also a significant effect of Arousal on the Lose trials, F (1.42, 25.61) = 4.61, p = .030 with Greenhouse Geisser correction. Pairwise comparisons with LSD on these Lose trials showed a significant difference between Low Arousal and Medium Arousal conditions, p = .003, and between Low Arousal and High Arousal conditions, p = .009. There was no significant difference between Medium Arousal and High Arousal conditions. As seen in Figures 5.7 and 5.8, then, these analyses demonstrate that the effects of Arousal are concentrated on the 14:2 Probability, 14/2 Amount trials on both Win and Lose trials,

Choice data results summary

A 4 factor repeated measures ANOVA, within-subject factors: Arousal (3 levels; Low, Medium, High) x Outcome Type (2 levels; Win, Lose) x Probability (3 levels; 14:2, 12:4, 9:7) x Amount (3 levels, 14/2, 12/4, 9/7) was performed on the choice data. Pilot parameters (Experiment 1, Chapter 2) were replicated, and it was found that Arousal led to significantly lower % HPC. With regards to the manipulation of the magnitude of cash rewards and punishments, arousal effects were evident initially in significant Arousal interactions, which were then further explored by conducting separate 3 factor ANOVAs on the three Probabilities. Following these analyses significant effects of this arousal manipulation were seen only in the most extreme Probability (14:2) (a significant main effect of Arousal in the 14:2 Probability). Specifically, on the 14: 2 Probability, effects of arousal were seen when the difference in Amount to be won or lost is at the most extreme (14/2) (a significant Arousal x Amount interaction), with the effects of Arousal further affected by whether it is a Win or Lose trial as seen in an Arousal x Outcome Type x Amount interaction). Results from final analyses on the 14:2 Probability 14/2 Amount data were consistent with the effects of arousal being focused on these trials specifically, on trials of both Outcome Types (although levels of significance were higher in the Lose trials). Thus, effects of Arousal resulted in participants choosing less Highest Probability choices in both the Win and Lose trials of the 14: 2 Probability, 14/2 Amount trials in the Medium and High Arousal conditions. (A reminder of how these trials appear in the task is shown in Figure 5.9.)

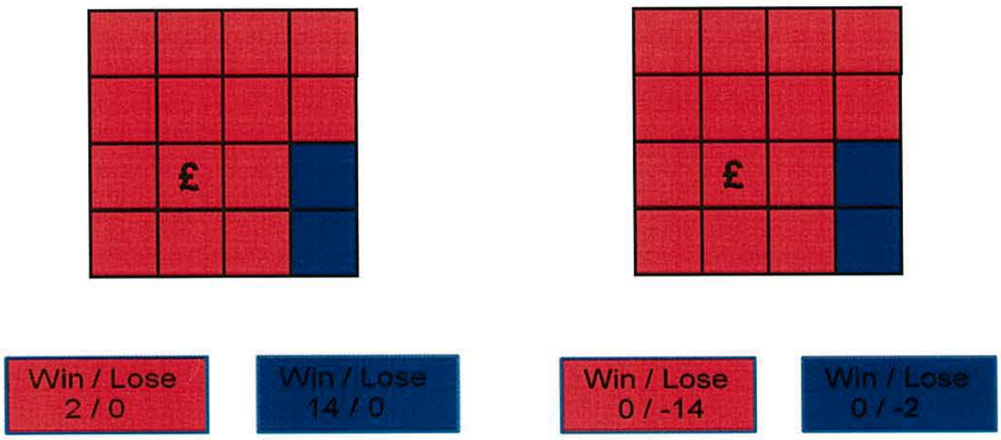


Figure 5.9. Illustration of the arousal effect on the EGT: In the Medium and High arousal conditions participants are more likely to choose Blue (Lowest Probability) in Win trials (on left) and Lose trials (on right) compared to the Low Arousal condition.

RT data

As with the Choice data, an initial 6 Factor Mixed ANOVA was performed on the data with within subject factors: Arousal (3 levels; Low, Medium, High) x Outcome Type (2 levels; Win, Lose) x Probability (3 levels; 14:2, 12:4, 9:7) x Amount (3 levels, 14/2, 12/4, 9/7) and between subject factors: Gender (2 levels) x Order of condition (5 levels). There were no effects of Gender or Order of condition, so analysis on was re-run without these factors, i.e. as a 4 factor within-subjects ANOVA.

Replication of pilot parameters

Pilot results from Experiment 1 (Chapter Two) were largely replicated. An overview of the data can be seen in Figures 5.10 – 5.12.

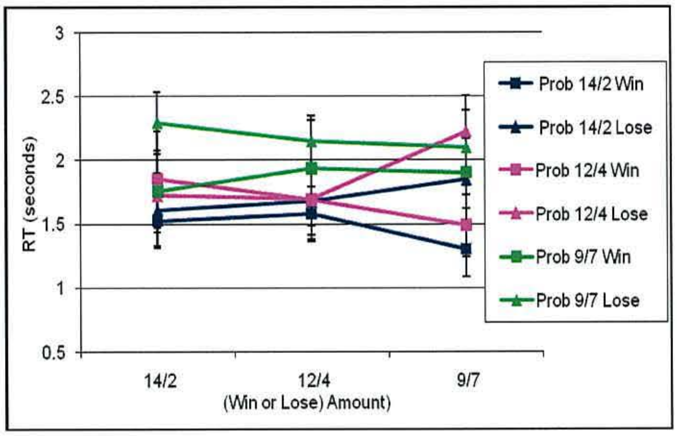


Figure 5.10. Low Arousal: RTs as a function of Probability and Amount on the EGT (Error bars represent SEM).

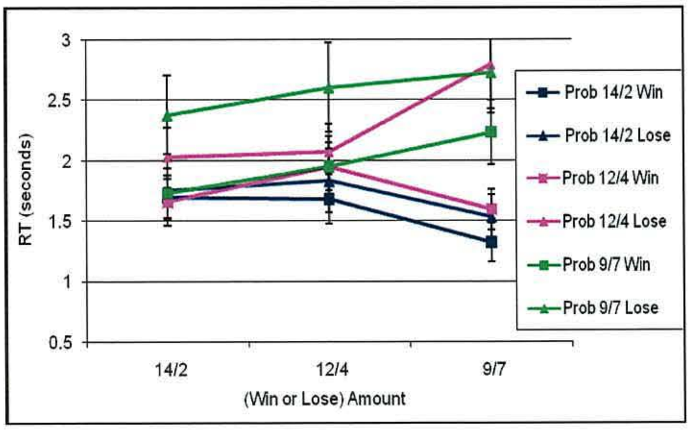


Figure 5.11. Medium Arousal: RTs as a function of Probability and Amount on the EGT (Error bars represent SEM).

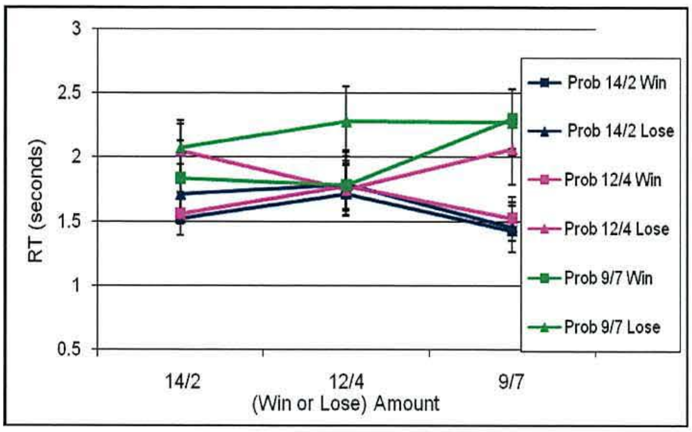


Figure *5.12*. High Arousal: RTs as a function of Probability and Amount on the EGT (Error bars represent SEM).

The Low Arousal condition replicated results from the pilot study (Experiment 1, Chapter Two) and so, as expected, participants chose quicker where they stood to win money compared to those trials in which they could lose. Also, decisions were quicker where the Probability and the Amounts were more extreme compared to where they were more evenly matched, i.e. more ambiguous. There was a significant main effect of Probability, F (2, 36) = 20.73, p <.001 with Greenhouse Geisser correction (For Probability 14:2, M = 1.61s; for Probability 12:4, M = 1.86s; for Probability 9:7, M = 2.13s.) There was a main effect of Outcome Type, F (1, 18) = 58.71, p <.001; (Win trials M = 1.72s; Lose trials M = 2.02s)

There was an Outcome Type x Probability x Amount interaction, F (4, 72) = 6.33, p < .001 (Figure 5.13). Whether the trial was a Lose trial or a Win trial appeared to have had most effect on the 12:4 Probability, 9/7 Amount.

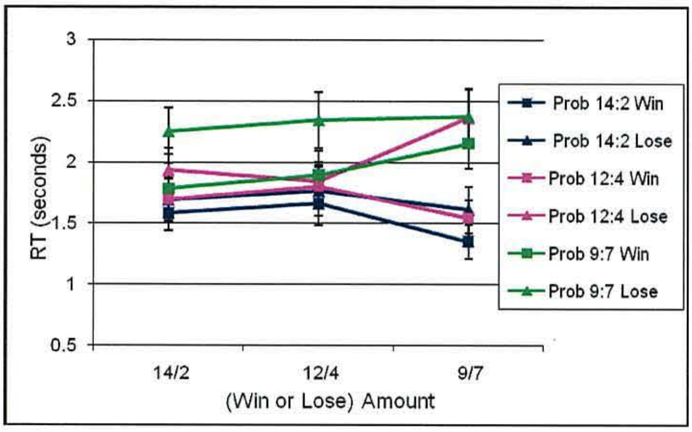


Figure 5.13. The Outcome x Probability x Amount interaction on RTs on the EGT, across Arousal conditions (Error bars represent SEM).

In addition to those results replicated from the Pilot study, in this experiment, there was also a Probability x Amount interaction, F (2.90, 52.17) = 3.04, p = .038, with Greenhouse Geisser correction (Figure 5.14).

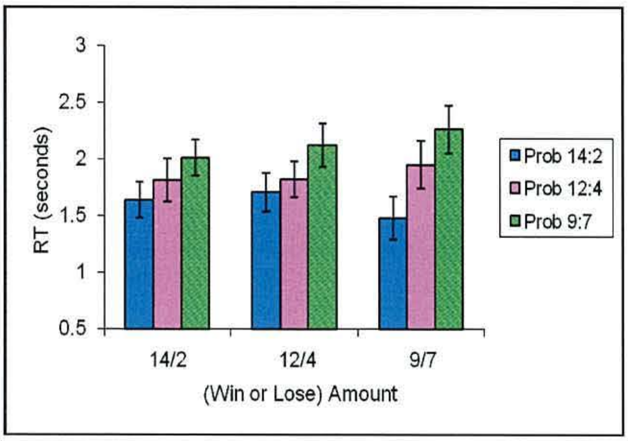


Figure 5.14. Probability x Amount interaction on RTs on the EGT, across Outcome Type and Arousal conditions. (Error bars represent SEM).

Effects of Arousal

There were no effects of Arousal on RT (Low Arousal *M* = 1.78s, *SD* = 1.04s; Medium Arousal *M* = 2.01s, *SD* = 0.88s; High Arousal *M* = 1.85s, *SD* = .60s).

Subjective Measures

STAI, 'State' component

A repeated measures ANOVA was carried out on the STAI scores, within-subject factor Time (2 levels: pre-testing, post- testing) and Arousal (3 levels: Low Arousal, Medium Arousal, High Arousal). There were no significant effects of Time or of Arousal, nor was there any Time x Arousal interaction (Pre testing Low Arousal *M* = 32.0, *SD* = 8.54; Medium Arousal *M* = 33.21, *SD* = 9.95, High Arousal = *M* = 36.16, *SD* = 11.04. Post testing Low Arousal *M* = 31.79, *SD* = 8.9; Medium Arousal *M* = 33.0, *SD* = 7.98; High Arousal *M* = 33.79, *SD* = 8.38.)

Visual Analogues

On each Visual Analogue component in turn, a repeated-measures ANOVA was performed, within-subject factors Time (2 levels, pre-testing, post-testing), and Arousal (3 levels, Low Arousal, Medium Arousal, High Arousal). Visual analogue means are provided in Table 5.1.

For *'Emotionally aroused', for 'Tired' and for 'Happy':* There were no significant effects of Time or of Arousal, and no significant Time x Arousal interactions on subjective reports of emotional arousal, tiredness or happiness

For '*Anxious*': There was a significant effect of Arousal F (2, 36) = 7.15, p =.002, no effect of Time and no Time x Arousal interaction. However the lack of an Arousal x Time interaction and the lack of any significant effect or trend towards an effect of Arousal on STAI scores suggests that this may be a spurious result.

Table 5.1
Mean pre and post testing scores on emotional visual analogues (maximum score = 10), Experiment 5.

Visual analogue	Condition	Pre test	Post test
Tired			
	Low Arousal	4.64	4.92
		(2.90)	(3.16)
	Medium Arousal	5.33	4.97
		(3.02)	(3.09)
	High Arousal	5.77	5.86
		(2.45)	(2.50)
Emotionally Aroused			
	Low Arousal	3.90	3.77
		(2.28)	(2.10)
	Medium Arousal	4.86	4.45
		(2.69)	(2.26)
	High Arousal	4.10	4.44
		(2.54)	(2.58)

Table 5.1 (continued)

Visual Analogue	Condition	Pre test	Post test
Happy			
	Low Arousal	6.55	6.46
		(1.98)	(1.67)
	Medium Arousal	6.43	6.50
		(2.18)	(2.22)
	High Arousal	6.30	6.11
		(1.61)	(1.88)
Anxious	Low Arousal	1.81	1.84
		(2.03)	(1.98)
	Medium Arousal	2.89	2.87
		(2.41)	(1.87)
	High Arousal	3.24	3.63
		(2.43)	(2.73)

Bracketed figures are standard deviations

5.2.3 Experiment 5 Discussion

It was proposed that the effect of reinforcement level on the Iowa Gambling Task (Experiment 2) was mediated by increased arousal. Following this, it was hypothesised that arousal level could be manipulated by altering the magnitude of the cash wins and losses on the EGT, and that arousal level would thus affect Choice (% HPC) and RT data. The EGT pilot results (Experiment 1, Chapter 2) were largely replicated in this experiment with regard to both Choice and RT data. Arousal level did not have any effect on RT. With regards to Choice data, arousal effects were evident initially in significant Arousal interactions, which were further explored by conducting analyses on the three Probabilities separately. These analyses highlighted that the effects of the arousal manipulation were seen in the Medium and High Arousal conditions in the most extreme Probability (14:2) (a significant main effect of Arousal) and when the difference in Amount to be won or lost is at the most extreme (14/2) (a significant Arousal x Amount interaction). The effects of Arousal in the Probability 14:2, Amount 14/2 trials were further mediated by Outcome Type, with participants choosing less Highest Probability Choices in the Lose trials (as seen in an Arousal x Outcome Type x Amount interaction) than in the Win trials. These results may therefore reflect an increased tendency for participants in the arousal conditions to become more risk-seeking, opting for the least likely but largest potential reward (or lowest potential loss) on the occasions where the choices were more extreme.

For practical reasons it was decided the High Arousal condition would consist of the chance to win a large cash amount at the end the testing period rather than pay a large amount of cash to every participant. (This was not considered to be an issue with testing on the IGT, Experiment 2, since pilot testing had suggested that participants would perform poorly on the potentially highly paying Cash x5 condition). In addition, visual cues were used during testing on the High Arousal condition on the EGT– with pictures of money on the walls, and on the computer task background and cash visible on the desk when participants entered the room. It may be however, that this was not as successful in inducing as high level of emotional arousal as if, for example, the cash wins and losses from the Medium Arousal condition had been increased and, similarly, paid out immediately following testing. This method may have introduced a possible confound of delay discounting. Delay discounting refers to the finding that rewards are valued less if they are temporally further off, compared to a reward which is immediate (e.g., Frederick, Loewenstein, & O'Donoghue, 2002; McClure, Ericson, Laibson, Loewenstein, & Cohen, 2007; Rangel, Camerer, & Montague, 2008), i.e. the fact that the large cash win was not immediately forthcoming may have led a devaluation on the part of the participant.

The induced changes in % HPC were not accompanied by a change in the time taken to make the decision; this could imply that the effects on Choice behaviour were not driven by an increase in impulsivity but instead reflected a shifting in the balance of decision weighting for different options. This may reflect a biasing towards riskier decisions – in this case 'riskier' being defined as the option with lowest probability of occurrence. Interestingly, as with the findings on the IGT, the effects of increased level of reinforcement reported on the EGT occurred without any arousal-induced differences in reported subjective levels of stress, emotional arousal, tiredness or happiness. Although there was a significance effect of Arousal on the 'anxious' visual analogue, there was no Time x Arousal interaction and no corresponding trend across condition seen in the STAI scores. This relatively small rise in 'anxious' visual analogue scores pre-testing in the High Arousal group was therefore presumed to be spurious. (It should be noted that participants were not aware of which condition they would be subsequently performing at the time of completing the subjective measures.)

In Experiment 2 (Chapter Three) increased magnitude cash reinforcement was shown to have a detrimental effect on the IGT, an emotion-based learning task. In Experiment 2, performance was impaired in the Cash x5 condition (standard cash wins and losses x 5) whereas performance in the Fake x 5 condition (standard cash wins and losses x 5, but with participants aware that winnings are not paid out) was comparable with controls. This suggested that the effect of increased cash rewards and punishments on the IGT was mediated by emotional arousal. Increased magnitude reinforcement has now also been shown to have an effect on the EGT, where all contingencies are clearly available on a trial by trial basis with no learning requirement. These two studies suggest that the level and type of reinforcement employed could have implications for testing using both decision making tasks involving emotion based learning and gambling tasks without a learning element. Using the level of monetary reinforcement as a way of increasing arousal could be a confounding factor, however, in that it also affects the outcome of the decisions and may have an effect on explicit motivation on this task. For this reason, and following the results of MTI arousal on the IGT documented in Experiment 2, the following experiment will investigate whether MTI arousal has an effect on behaviour on the EGT.

5.3 Experiment 6: The Effects of Muscle-Tension-Induced Arousal on the Explicit Gambling Task

Experiment 2 demonstrated that MTI arousal had an effect on Iowa Gambling Task performance with increased levels of physiological arousal associated with less cards being selected from the advantageous decks. Although learning on the IGT has been proposed to involve unconscious biasing (Bechara et al., 1997), it has often been reported that participants develop knowledge of which decks were good or bad earlier on than the Iowa group previously claimed (as also reported and discussed in Chapter Three and Four). One possibility for impaired performance despite possession of explicit knowledge about the task is that, rather than a failure to learn, participants were exhibiting risk-taking behaviour. This arousal manipulation is therefore extended to the Explicit Gambling Task (EGT) to investigate whether MTI arousal can also affect risk-taking on a gambling task where there is no strategy to be learnt. Using the previously piloted decision making task (Experiment 1, Chapter Two) it is predicted that increased arousal, achieved via manipulating the level of MTI arousal, will have an effect on risk-taking, as measured by % High Probability Choices and Response Time.

5.3.1 Method

Participants

The study was approved by the Research Ethics Committee of Bangor University and written consent was obtained from the participants. 16 undergraduate students (7 males) were recruited from Bangor University Student Participation Panel and received course credit for taking part. (One participant did not complete the High Arousal condition). Mean age was 19.9 (SD = 2.10). Participants were screened for neurological and psychiatric illness and for dyslexia and colour blindness.

Design

This was a 3 condition, repeated measures design. Participants were tested on three separate occasions, each time within 1 and 7 days of the previous session, at the same time of day. The level of arousal was varied in the same way as the investigation into MTI arousal on IGT performance (Experiment 3, Chapter Four). Participants thus performed the task in 3 conditions: Low Arousal condition, merely holding the hand dynamometer without exertion of force, a Medium Arousal condition, with subjects exerting themselves at 50% maximum individual force, and a High Arousal condition, with subjects exerting themselves at 75% maximum individual force. Each session had a different order of task schedules; with task schedule and condition order counterbalanced. The independent variable was the level of MTI arousal; the dependent variables were the % Highest Probability Choices and Response Time.

Apparatus

A 0-100 kg Takei Kiki Kogyo hand dynamometer was used.

Stimuli

The computerised gambling task described in Chapter Two was employed (with the post-piloting adaptations, as discussed). The task in this experiment, however, had two equally spaced breaks built into the task to allow for a second and third 60 second hand dyno session (or, in the Low Arousal condition, for holding of the hand dyno without exertion of force). The task lasted approximately 25 minutes. Subjects used the hand dynamometer, at the level appropriate to the condition, for 60 seconds three times in total: immediately before the task, after the first third and after the second third. Each third of the task took approximately 8 minutes.

Measures

In order to assess subjective experience the following measures were employed:

State Trait Anxiety Inventory

The State Trait Anxiety Inventory, State component was completed by all participants immediately before and following the EGT. This contains 20 items designed to measure current levels of anxiety (Spielberger, 1983) .

Visual Analogues representing 'Happy', 'Tired', 'Anxious' and 'Emotionally Aroused'

These measures were also completed immediately before and after the EGT. These visual analogues required participants to bisect a horizontal line indicating their level of, for example, emotional arousal, with 'very' being represented by a mark to the far right of the line and 'not at all' being represented at the far left of the line.

Procedure

In the first session, for individual calibration, subjects initially squeeze the hand dynamometer for approximately 20 seconds as hard as possible to enable the 50% and 75% parameters to be set. The STAI, State component, and the visual analogues were then administered and the task instructions read (See Appendix L). This allowed a break of approximately 2-3 minutes to avoid excessive muscle fatigue As with previous testing with the EGT, participants were told they would be playing a game in which they should act to maximise their cash winnings and were instructed that they should base their decision on information from both the colours on the grid and the amounts in the boxes below. Participants completed a practise run of 12 trials before the first session during which time they were allowed to ask any questions relating to the task.

Participants then commenced the EGT, calling in the experimenter from the adjoining room to oversee the second and third hand dyno sessions, when prompted by the programme. The remainder of the EGT was then completed, immediately followed by the post testing STAI and visual analogues. For comparison, during the three sessions of MTI arousal, participants in the Low Arousal condition merely held the hand dyno, resting it on the desk without exerting any pressure. Money was won in each condition (approximately £3- £4 each session) and was paid at the end of each session.

5.3.2 Results

Choice Data

As previously on the EGT, a 6 Factor Mixed ANOVA was performed initially on the data with within-subject factors: Arousal (3 levels; Low, Medium, High) x Outcome Type (2 levels; Win, Lose) x Probability (3 levels; 14:2, 12:4, 9:7) x Amount (3 levels, 14/2, 12/4, 9/7) and between subject factors: Gender (2 levels) x Order of condition (5 levels). There were no effects of Gender or Order of condition, so analysis on was re-run without these factors, i.e. as a 4 factor within-subjects ANOVA.

Replication of pilot parameters

On the choice data the pattern of results from the pilot Experiment 1 (Chapter Two) and Experiment 5 were largely replicated, as seen in Figures 5.17-5.19. There was a main effect of Probability on % HPC, F (2, 28) = 119.65, $p < .001$ (Probability 14:2 M = 74.14; Probability 12:4 M = 61.91; Probability 9:7 M = 33.95), with more Highest Probability Choices made where the choice of probabilities was more extreme (14:2) compared to where the choice of probabilities was more ambiguous (9:7). There was a main effect of Amount on % HPC, F (1.09, 15.22) = 25.30, $p < .001$, with Greenhouse-Geisser correction (14/2 Amount M = 47.28; 12/4 Amount M = 54.88; 9/7 Amount M = 67.84), % HPC increased steadily as the amounts which could be either won or lost became less extreme and more evenly matched. There was also a main effect of Outcome Type, F (1, 14) = 8.41, p = .012 (Win M = 52.14; Lose M = 61.19), participants were more likely to choose the higher probability option in Lose trials than in Win trials.

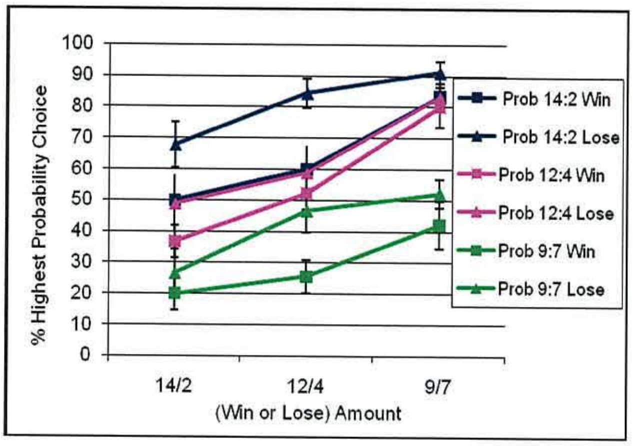


Figure 5.17. Low Arousal condition: % High Probability Choices as a function of Probability and Amount on the EGT (Error bars represent SEM).

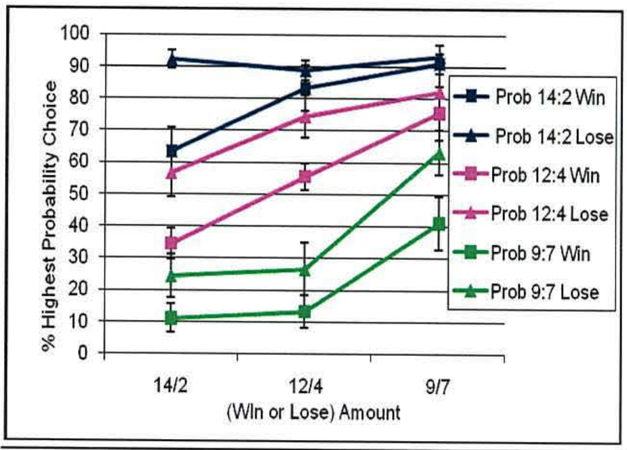


Figure 5.18. Medium Arousal condition: % High Probability Choices as a function of Probability and Amount on the EGT (Error bars represent SEM).

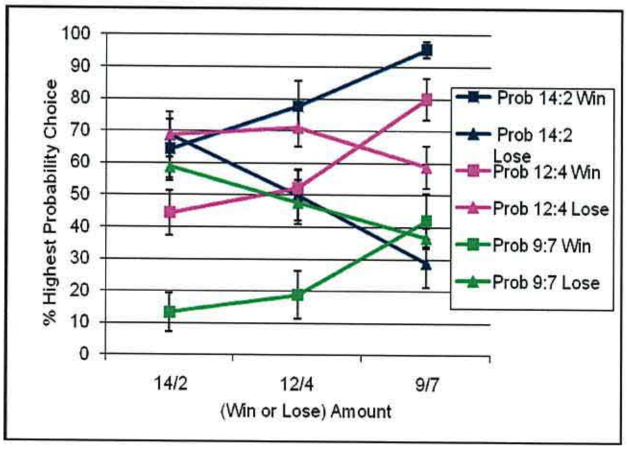


Figure 5.19. High Arousal condition: % High Probability Choices as a function of Probability and Amount on the EGT. (Error bars represent SEM)

There was a significant Outcome Type x Probability interaction seen, F (2, 28) = 5.65, p = .009 (Figure 5.20). The trend was for a higher % HPC in the Lose trials compared to the Win trials appears to be evident in the 12:4 and 9:7 Probabilities in particular.

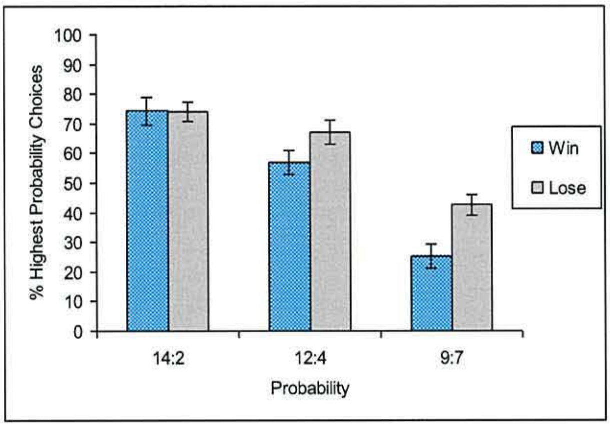


Figure 5.20. Probability x Outcome Type interaction on % HPC on the EGT (Error bars represent SEM).

In addition to the pilot parameters seen in Experiment 1 (but as also seen in Experiment 5) there was a significant Probability x Amount interaction F (2.28, 31.89) = 4.79, p = .012 with Greenhouse-Geisser correction (Figure 5.21). This reflects the pattern that, for a given Probability, participants were more likely to make a Highest Probability Choice when the probabilities were more extreme (14:2) and when the win/lose Amounts were more evenly matched, however Amount appeared to have a less of a mediating effect on the 9:7 Probability, where there was least risk involved (as also seen in Experiment 5).

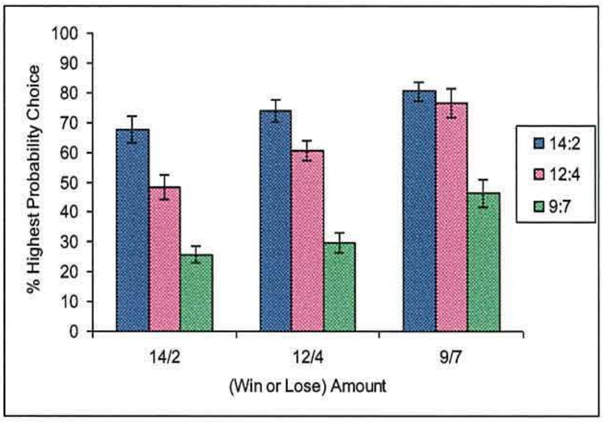


Figure 5.21. The Probability x Amount interaction effect on % HPC on EGT (Error bars represent SEM).

Arousal effects

In addition to the significant effects which replicate previous findings in Experiment 1 and Experiment 5, effects of MTI Arousal were seen. From the 4 factor ANOVA analysis, the most important findings are considered to be the significant Arousal x Outcome x Probability interaction (Figure 5.25) and the significant Arousal x Outcome Type x Amount interaction (Figure 5.26), as detailed later. However, the simpler effects of Arousal will be described first.

There was a significant Arousal x Probability interaction F (4, 56) = 9.58, p < .001 (Figure 5.22). The effects of Arousal appear more evident at the 14:2 Probability

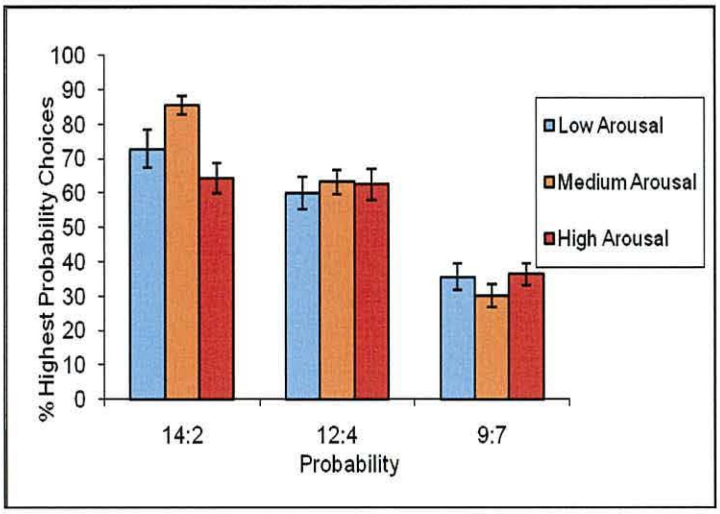


Figure 5.22. The Arousal x Probability interaction effect on % Highest Probability Choice (Error bars represent SEM)

There was a significant Arousal x Amount interaction *F* (4, 56) = 15.43, *p* < .001. The effects of Arousal appear more evident in the 14/2 and 9/7 Amounts (Figure 5.23).

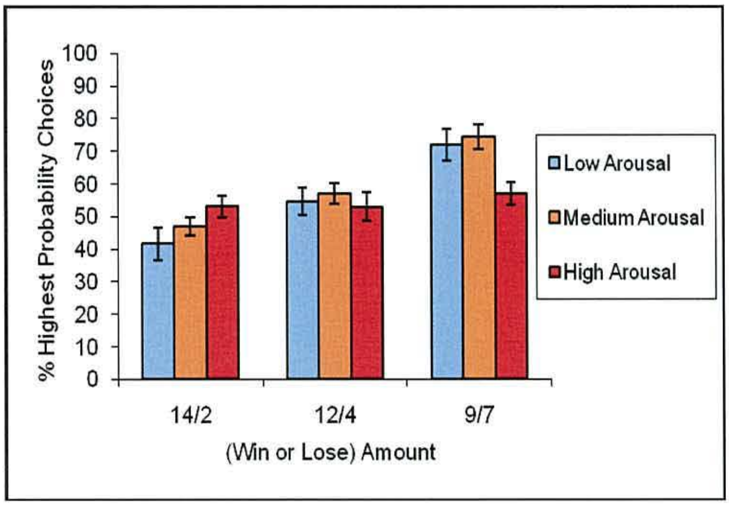


Figure 5.23. The Arousal x Amount interaction effect on % Highest Probability Choices. (Error bars represent SEM).

There was a significant Arousal x Probability x Amount interaction *F* (3.98, 55.65) = 2.92, *p* = .029 with Greenhouse- Geisser correction (Figures 5.24 - 5.26). In the High Arousal condition there appears to be no effect of Amount, as seen in level lines on Figure 5.26. This effect seems especially apparent in the 14:2 Probability. (However, as will be seen below, in Figure 5.27, this effect is further mediated by Outcome Type.)

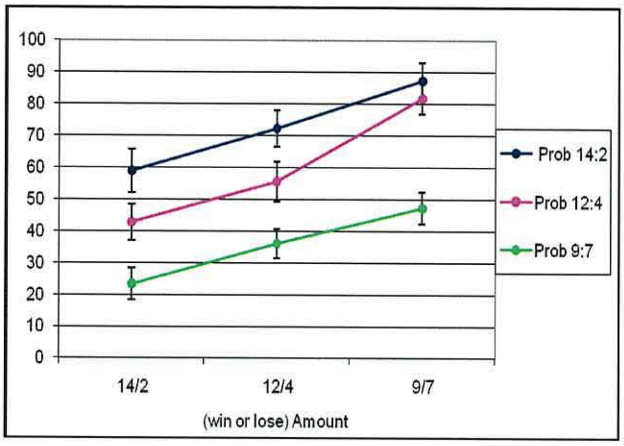


Figure 5.24. The Arousal x Probability x Amout interaction effect on % Highest Probability Choice on the EGT, Low Arousal condition (Error bars represent SEM).

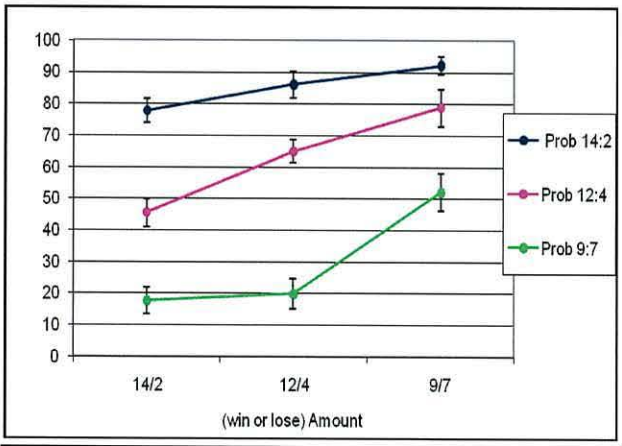


Figure 5.25. The Arousal x Probability x Amout interaction effect on % Highest Probability Choice on the EGT, Medium Arousal condition (Error bars represent SEM).

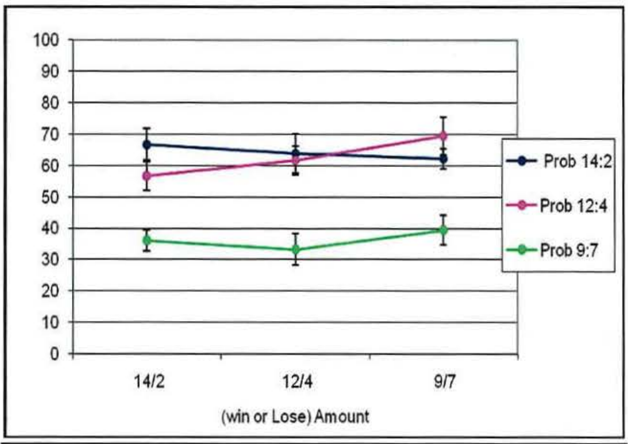


Figure 5.26. The Arousal x Probability x Amout interaction effect on % Highest Probability Choice on the EGT, High Arousal condition (Error bars represent SEM).

There was a significant Arousal x Outcome Type interaction F (2, 28) = 9.21, p = .001 (Figure 5.27). So, whereas participants select the highest probability option more often in Lose trials compared to Win trials (as seen in the previously detailed main effect of Outcome Type), in the High Arousal condition this effect is not evident, i.e. more risk-taking is seen in the High Arousal Lose trials.

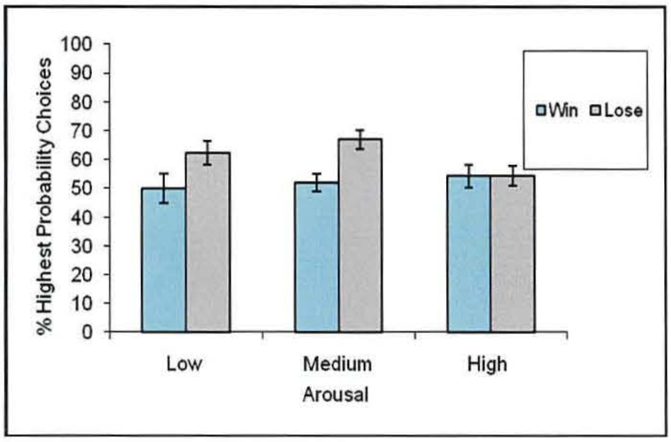


Figure 5.27. The Arousal x Outcome Type interaction effect on % Highest Probability Choices on the EGT (Error bars represent SEM).

In interpreting the 4 factor ANOVA analysis, the following two results are considered to be the key findings: The Arousal x Outcome Type x Probability interaction (Figure 5.28) and the Arousal x Outcome x Amount interaction (Figure 5.29).

The significant Arousal x Outcome Type x Probability interaction, F (4, 56) = 10.96, $p < .001$ (Figure 5.28) illustrates that the effect of Arousal appears to be in the High Arousal condition, in the Lose trials of the 14:2 Probability.

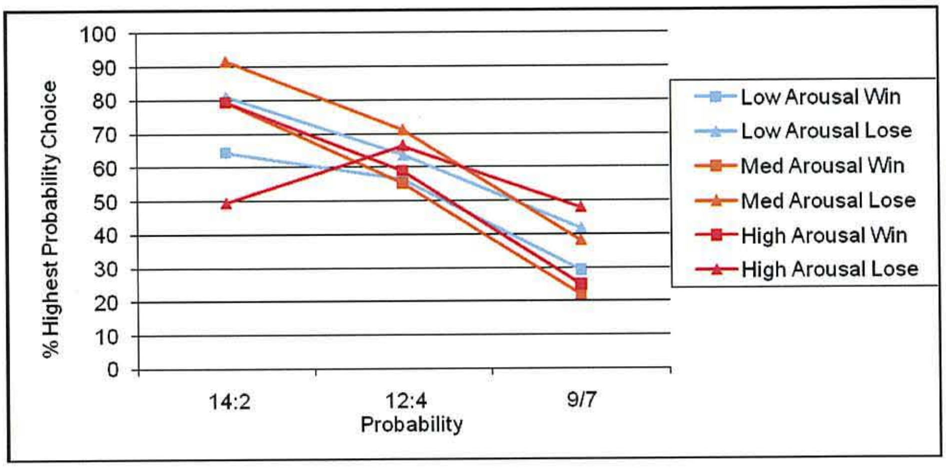


Figure 5.28. The Arousal x Outcome Type x Probability interaction effect on % HPC on the EGT (Error bars omitted for clarity).

Post hoc analysis on the Arousal x Outcome Type x Probability interaction effect. From the parameters established in the piloting of the EGT (Experiment 1, Chapter Two) and from the control (Low Arousal conditions) of both the current experiment and the previous EGT experiment (5), It would be expected that participants would make significantly more High Probability Choices at the extreme 14:2 Probability compared to the more evenly matched 9:7 Probability. This pattern is seen both in previous studies and in the current study's Low and Medium Arousal condition results. Post hoc Bonferroni corrected t tests on the High Arousal Lose trial data, however, showed no significant difference between % High Probability Choices at 14:2 Probability and 9:7 Probability on these trials, t (14) = .222, p =

Probability Choices at 14:2 Probability and 9:7 Probability on these trials, t (14) = .222, p = .827, *ns*. (% High Probability Choices 14:2 Probability M = 49.26, SD = 21.30; 9/7 Probability M = 47.78, SD = 14.67). This demonstrates a higher level of risk taking with regards to probability in the High Arousal Lose trials, as seen in Figure 5.28 above.

A repeated-measures ANOVA (1 factor: Arousal, 3 levels) carried out specifically on the 14:2 Probability Lose trials showed that Arousal had significant effect on these trials, F (2, 28) = 39.83, $p < .001$ (Low Arousal M = 81.11, SD = 17.16; Medium Arousal M = 91.48, SD = 7.23; and High Arousal M =49.26, SD = 21.30. Also, post hoc Bonferroni corrected t tests showed that on the 14:2 Lose trials % High Probability Choices on the High Arousal condition was significantly lower than the Medium Arousal condition, t (14) = -8.61, $p < .001$ and significantly lower than the Low Arousal condition, t (14) = -6.01, $p < .001$. There was no significant difference at this point between the Low and Medium Arousal conditions, t (15) = -2.128, p = .118, *ns*. Effects of Arousal, therefore, are specific to 14:2 Probability Lose trials, with significantly more risk taking in the High Arousal condition in these trials.

There was also an Arousal x Outcome Type x Amount interaction F (4, 56) = 11.01, $p < .001$ (Figure 5.29). It would be expected that participants would make significantly more High Probability Choices at the 9/7 Amount compared to the 14/2 Amount. This pattern is seen both in previous studies and in the current study's Low and Medium Arousal condition results. The opposite pattern is apparent for the High Arousal Lose trials, however.

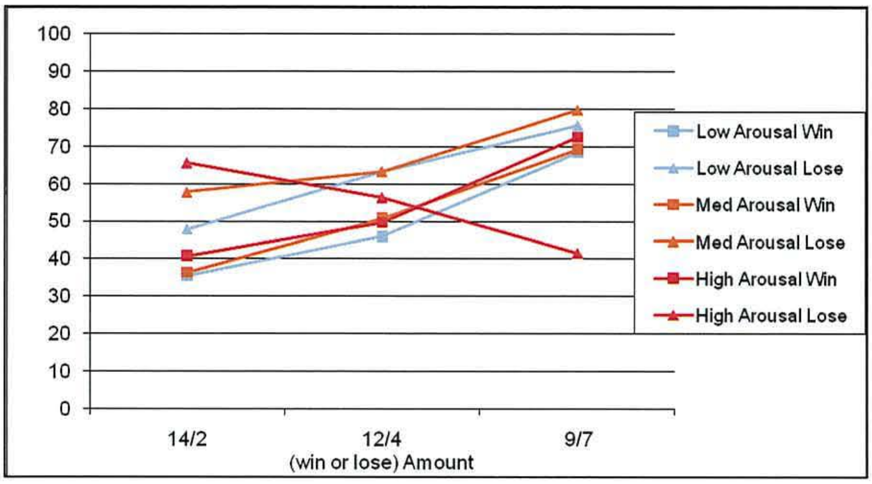


Figure 5.29. The Arousal x Outcome Type x Amount interaction on % Highest Probability Choices on the EGT (Error bars omitted for clarity)

Post hoc analysis on the Arousal x Outcome x Amount interaction effect. Post hoc Bonferroni corrected t tests showed that on High Arousal Lose trials there were significantly less High Probability Choices at the 9/7 Amount compared to the 14/2 Amount, t (14) = 5.14, p <.001 (M 9/7 Amount = 41.48, SD = 18.76; 14/7 Amount M = 65.56, SD = 10.11). This is the opposite trend to that seen in the Low and Medium Arousal conditions. Also, an ANOVA on the Amount 9/7 Lose trial data (1 factor: Arousal, 3 levels) showed there was a significant effect of Arousal, F (2, 28) = 47.59, p < .001. Post hoc Bonferroni corrected t tests then showed significantly less High Probability Choices on the 9/7 Amount Lose trials in the High Arousal condition compared to the Medium Arousal condition, t (14) = 7.64, p <.001 and compared to the Low Arousal condition t (14) = 7.63, p <.001. There was no significant difference between Low and Medium Arousal conditions, t (15) = -1.13, p = .683, *ns*. (% HPC Low Arousal M = 75.56, SD =15.69; Medium Arousal M = 79.63, SD = 13.55; High Arousal M = 41.48, SD = 18.76). In this interaction, the effects of Arousal are again seen in the High Arousal Lose trials, with riskier behaviour with regards to probability where amounts are more evenly matched on the 9/7 amounts, compared to Low and Medium Arousal conditions.

Choice data results summary

A 4 factor repeated measures ANOVA, within-subject factors: Arousal (3 levels; Low, Medium, High) x Outcome Type (2 levels; Win, Lose) x Probability (3 levels; 14:2, 12:4, 9:7) x Amount (3 levels, 14/2, 12/4, 9/7) was performed on the choice data. Pilot parameters were replicated and, with regard to the effect of MTI arousal on choice data, it was found that Arousal led to significantly lower % HPC. This arousal effect was specific to the Lose trials of the 14:2 Probability in the High Arousal condition (as seen in the Arousal x Outcome Type x Probability interaction, Figure 5.28) and to the Lose trials of the 9/7 Amount trials in the High Arousal condition (as seen in the Arousal x Outcome Type x Amount interaction, Figure 5.29).

RT data

As with the Choice data, an initial 6 Factor Mixed ANOVA was performed on the data with within subject factors: Arousal (3 levels; Low, Medium, High) x Outcome Type (2 levels; Win, Lose) x Probability (3 levels; 14:2, 12:4, 9:7) x Amount (3 levels, 14/2, 12/4, 9/7) and between subject factors: Gender (2 levels) x Order of condition (5 levels). There were no effects of Gender or Order of condition, so analysis on was re-run without these factors, i.e. as a 4 factor within-subjects ANOVA. An overview of the data can be seen in Figures 5.27 – 5.29.

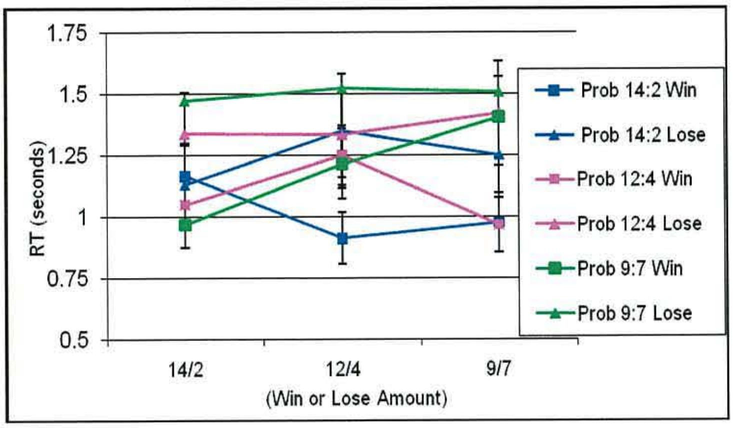


Figure 5.27. Low Arousal condition: RT as a function of Probability, Outcome Type and Amount on the EGT (Error bars represent SEM)

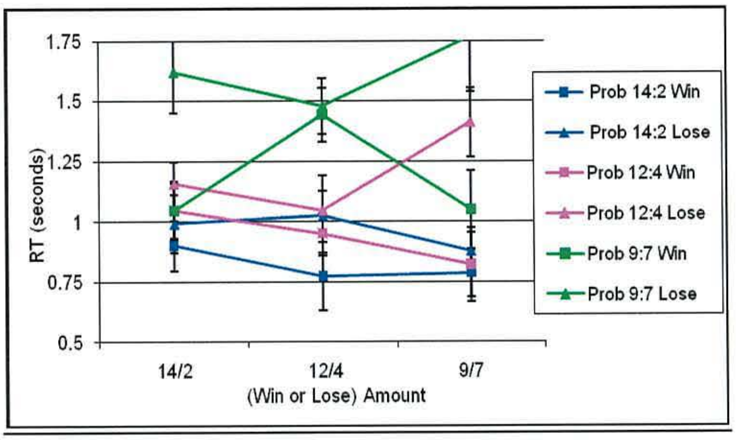


Figure 5.28. Medium Arousal condition: RT as a function of Probability, Outcome Type and Amount on the EGT (Error bars represent SEM).

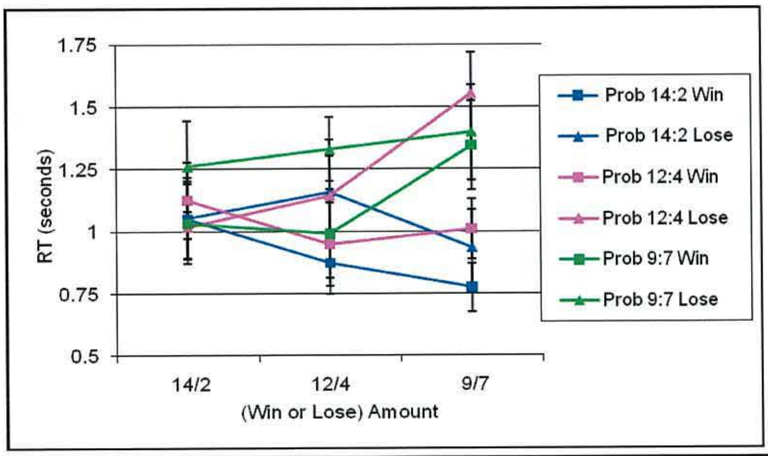


Figure 5.29. High Arousal condition: RT as a function of Probability, Outcome Type and Amount on the EGT (Error bars represent SEM).

Replication of pilot parameters

The Low Arousal condition replicated results from previous studies (Experiment 1, and Low Arousal condition of Experiment 5). As expected, then, participants chose quicker where they stood to win money compared to those trials in which they could lose as seen in a main effect of Outcome Type, F (1, 13) = 18.14, p = .001 (Win M = 1.03s, Lose M = 1.28s). Also, decisions were quicker where the Probability and the Amounts were more extreme compared to where they were more evenly matched, i.e. more ambiguous as seen in a main effect of Probability, F (1.40, 18.15) = 11 89, p = .001 (M 14:2 = .10s, M 12:4 = 1.15s, M 9:7 = 1.31s). There was also a main effect of Amount F (2, 26) = 4.02, p = .30 (M 14/2 = 1.12s, M 12/4 = 1.14s, M 9/7 = 1.21s). Response Time increases as the Amounts become more evenly matched.

There was also a Probability x Amount interaction F (4, 52) = 5.35, p = .001. For the 14:2 Probability RTs decrease as the Amounts become more evenly matched, i.e. quicker RT to 9/7 (M = .934) than to 12/4 (M = 1.015) and quicker RT to 12/4 than to 14/2 (M = 1.048). For the 9:7 Probability the opposite is true, with RT increasing as the Amount becomes more evenly matched. I.e. both Probability and Amounts are evenly matched therefore the choice is more ambiguous in both aspects. (For 9:7 Probability M 14/2 Amount = 1.196, M 12/4 Amount = 1.264, M 9/7 Amount = 1.479). There appears to be little difference between Amount RTs for 12:4 Probability.

There was an Outcome Type x Probability x Amount interaction F (4, 52) = 10.01, $p < .001$. The 9/7 Amount in both the 14:2 Probability and the 12:4 Probability appears most affected by whether the trial was a Lose or Win trial.

Arousal effects

In addition to this expected pattern of results there was an Arousal x Probability interaction, F (4, 52) = 2.64, p = .044, (Figure 5.30).

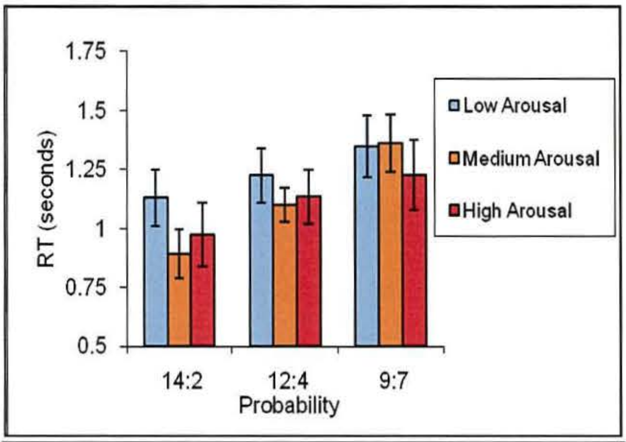


Figure 5.30. Arousal x Probability interaction effect on RT on the EGT (Error bars represent SEM)

Post hocs analysis was carried out on this Arousal x Probability interaction effect to ascertain exactly where the effect lay. Each probability was analysed separately in a one factor (Arousal, 3 levels: Low Arousal, Medium Arousal, High Arousal) repeated measures ANOVA. All results were non significant, however from Figure 5.30 it appears that with higher arousal levels there may be a trend towards quicker responding particularly in the 14:2 Probability, followed by the 12:4 Probability, and then the 9:7 Probability, respectively.

RT results summary

A 4 factor repeated measures ANOVA was performed on the data with within subject factors: Arousal (3 levels; Low, Medium, High) x Outcome Type (2 levels; Win, Lose) x Probability (3 levels; 14:2, 12:4, 9:7) x Amount (3 levels, 14/2, 12/4, 9/7). The Low Arousal condition replicated previous parameters (Experiment 1 and Experiment 5 Low Arousal conditions). Effects of arousal were seen in an Arousal x Probability interaction, with a trend towards a greater effect of arousal (as seen in quicker responding) in the 14:2 and 12:4 Probabilities, rather than the more equally matched 9:7 Probability.

Subjective Measures

STAI, 'State' component

A repeated measures ANOVA was carried out on the STAI scores, within-subject factor Time (2 levels: pre-testing, post- testing) and Arousal (3 levels: Low Arousal, Medium Arousal, High Arousal). There was no effect of Time, p = .329, *ns*, there was no significant effects of Arousal, p = .272, *ns*, and there was no Time x Arousal interaction, p = .585, *ns*. (Pre-testing, Low Arousal M = 30.75, SD = 7.10; Medium Arousal M = 30.5, SD = 8.23; High Arousal M = 28.5, SD = 10.10. Post-testing, Low Arousal M = 30.63, SD = 6.78, Medium Arousal M = 32.12, SD = 7.22, High Arousal M = 30.06, SD = 8.22)

Visual Analogues

On each Visual Analogue component in turn, a repeated-measures ANOVA was performed, within-subject factors Time (2 levels, pre-testing, post-testing), and Arousal (3 levels, Low Arousal, Medium Arousal, High Arousal). Visual analogue means are provided in Table 5.2.

For *'Emotionally Aroused'*. There was a significant effect of Time, F (1, 15) =11.05, p = .005. There was no significant effect of Arousal and no Time x Arousal interaction.

For *'Tired'*. There was a significant effect of Time, F (1, 15), = 7.25, p = .017. There was no significant effect of Arousal and no significant Time x Arousal interaction.

For *'Happy'*. There was a significant effect of Time, F (1, 15) = 10.70, p = .005. There was no significant effect of Arousal and no Time x Arousal interaction.

For *'Anxious'.* There was a significant effect of Time, F (1, 15) = 5.48, p = .034. There was no significant effect of Arousal and no Time x Arousal interaction.

Thus, participants reported feeling significantly more tired, anxious, emotionally aroused and happy after testing compared to before but this was not mediated by the level of arousal.

Table 5.2
Mean pre and post testing scores on emotional visual analogues (maximum score = 10), Experiment 6.

Visual analogue	Condition	Pre test	Post test
Tired			
	Low Arousal	4.11	4.69
		(3.04)	(2.71)
	Medium Arousal	4.66	4.84
		(3.32)	(2.94)
	High Arousal	3.03	3.81
		(1.90)	(1.92)
Emotionally Aroused	Low Arousal	3.63	3.73
		(2.25)	(1.87)
	Medium Arousal	3.38	4.21
		(2.03)	(2.13)
	High Arousal	4.08	5.16
		(2.70)	(2.33)

Table 5.2 (continued)

Visual Analogue	Condition	Pre test	Post test
Happy			
	Low Arousal	7.68	6.85
		(.93)	(1.13)
	Medium Arousal	7.37	6.86
		(1.95)	(1.89)
	High Arousal	7.57	6.95
		(2.03)	(2.03)
Anxious	Low Arousal	2.14	2.80
		(1.97)	(2.04)
	Medium Arousal	2.36	3.31
		(2.40)	(2.18)
	High Arousal	1.48	2.16
		(2.34)	(2.29)

Bracketed figures are standard deviations

5.3.3 Experiment 6 Discussion

This study sought to investigate the effects of non-valenced MTI arousal on the EGT. There were highly significant effects of Arousal on Choice data as measured in % Highest Probability Choices. This effect occurred in the High Arousal condition in the Lose trials of the most extreme probability, the 14:2 Probability. Although the Medium Arousal condition did not have an effect on Choice data, analysis of RTs suggested that increased MTI arousal led to a trend towards more rapid responses in both the Medium and High Arousal condition This adds to the findings of Experiment 3 in which MTI arousal was found to have an effect on an emotion-based learning task, the Iowa Gambling Task. A mere 3 minutes of exercise altered decision making behaviour and led to more risk taking with regard to probability, despite no significant difference in reported subjective state. As with Experiment 5, the increased risk taking with increased arousal was specific to the Lose trials. This is consistent with findings that individuals are often more risk seeking with losses than with gains (Kahneman, 2003; Tversky & Kahneman, 1981), and suggests that arousal arising from consideration of the loss may be a factor in this phenomenon.

It has been speculated that MTI arousal could cause noradrenaline release which could affect behaviour via other neurotransmitter interactions. It is therefore possible that increased arousal and behavioural could have an effect on inhibitory control and increase the likelihood of pre-potent responding (Dias et al. 1997). Thus choice behavior may have been guided by rapid, innate reward-driven responses rather than slower, more deliberative cognitive processes. From the perspective of hot versus cold processing (Metcalfe & Mischel, 1999) it may have led to a more rapid 'hot' emotional processing or, from the judgment and decision making perspective more intuitive versus deliberate processing. The finding that a subtle change in physiological arousal level induced by 3 minutes exercise with a hand dyno has implications both for decision making in everyday life and for the conditions under which participants are tested in gambling experiments.

5.4 Experiments 5 and 6 General Discussion

5.4.1 Summary of Experiment 5 and 6 Results

Experiment 5 and 6 demonstrated that changes in arousal level may impact upon decision making behaviour and increase risk taking. In Experiment 5 it is proposed that increased levels of reinforcement increased arousal, whilst Experiment 6 employed MTI arousal to alter the state of physiological arousal without a change in participant mood. As a result of the arousal manipulations, both studies demonstrated a significantly higher level of risk taking with regards to probability, with this effect concentrated on the most extreme probability, Probability 14:2 in both studies. In the control, or Low Arousal conditions (as in Experiment 1,) greater risk taking was seen in the Win trials, compared to the Lose trials. The modulating arousal effect is apparent in both Win and Lose trials in Experiment 5 (although with higher levels of significance for the Lose trials) and is specific to the Lose trials in Experiment 6 (i.e. a reversal of the original main effect of Outcome Type). This is consistent with economic theory which predicts more risk seeking will be evident when losses are involved compared to gains (Kahneman, 2003; Kahneman & Tversky, 1979). More rapid responding was seen as a result of MTI arousal in Experiment 6, although not as a result of increased magnitude reinforcement in Experiment 5. This quicker response time in Experiment 6 could be the result of a greater increase in general behavioural activation related to the MTI arousal. The replication of the pilot parameters in the Low Arousal (control) conditions of both experiments testifies to the experimental findings reported following the arousal manipulations. Also, the repeated-measures design of the experiments adds power to the results. For an individual to make different risk-related decisions on different occasions, despite probabilities and outcomes remaining constant, would be considered irrational behaviour by economic models. And yet, a subtle change in arousal in Experiment 6 evoked by just 3 minutes of exercise induced highly significant results, with participants making more choices of the least likely but higher paying (or lower losing) option. Despite a change in choice behaviour, neither experiment saw any effect of Arousal manipulation on mood, as measured by STAI and emotion visual analogues. As with the Iowa Gambling Task research (Experiments 2 and 3) these two studies also report a change in decision making behaviour in response to increased magnitude reinforcement (Experiment 5) and increased physiological arousal (Experiment 6). Although not ruling out an effect on more implicit learning, or somatic markers (Damasio, 1994; Naqvi et al., 2006), this is consistent with these experimental manipulations having an effect on risk-taking behaviour.

5.4.2 Economic Theory and Decision Making Under Risk

Within micro economic theory many models still assume that decision making under risk is purely the result of rational and analytic processes. For example, two prominent modern frameworks based on the economic utility model, Portfolio Theory and the Capital Asset Pricing Model both assume that decisions under conditions of uncertainty are a rational trade off between possible risk and return, with emotion playing no role (Mayo, 2000). Economic utility models generally posit that risky choice can be predicted by assuming the individual assesses the severity and the likelihood of the possible outcomes "albeit subjectively and possibly with bias or error, and integrate this information through some kind of expectation-based calculus to arrive at a decision. Feeling triggered by the decision situation and imminent risky choice are seen as epiphenomenal – that is, not integral to the decision making process" (Loewenstein et al., 2001, p. 267). Thus, traditional models of economic decision making (e.g., von Neumann & Morgenstern, 1944), and modern frameworks based upon them, propose that the individual weighs probabilities linearly, with risky decisions assessed according to their expected utility (i.e., Probability x Outcome).

Although this may be seen as an appropriate prescriptive model, as the way people *should* assess risky decisions, it is known that the way people actually behave deviates from this. Prospect Theory took account of people's deviations from expected utility theories in reacting to risk by proposing the S-shaped probability function (Kahneman, 2003; Kahneman & Tversky, 1979). This function represents the finding that low probabilities tend to be overweighted, whilst high probabilities are underweighted. Researchers from the JDM and economic perspective are now increasingly recognising that individuals may use two fundamentally different ways of thinking when assessing uncertainty (e.g., Kahneman, 2003; Slovic, Finucane, Peters, & MacGregor, 2004; Wang, 2006). The analytic or rational mode is relatively slow and requires conscious effort, using algorithms and normative rules, whilst the experiential, or affective mode, is rapid, intuitive, mostly automatic, and often inaccessible to conscious awareness, often described as 'affect heuristics'. This can be seen as analogous to the concept of 'hot versus cold' processing which has developed within psychology (e.g., Metcalfe & Mischel, 1999). It may be that a relative preference for using one system over the over when processing risky decisions constitutes an individual difference, with 'deliberate' decision makers more likely to process information on a cognitive level, in terms of estimated values, whilst 'intuitive' decision makers are more guided by affective reactions (Schunk & Betsch, 2006).

Proponents of traditional risk analysis models tend to view affective responses to risk as irrational, although much recent evidence disputes this, including the Iowa lab work based on the Iowa Gambling Task, as discussed in Chapters Three and Four (Bechara et al., 1994; Damasio, 1994; Naqvi et al., 2006). Loewenstein and colleagues proposed the 'risk as feelings' model to combine both the analytical and the experiential systems (Loewenstein et al., 2001). Within this model, risky situations are subject to evaluation by both systems, with analytical evaluations based on subjective estimates and anticipated possible outcomes, while affective reactions to risk are influenced by factors such as vividness and mood. It is claimed that decisions influenced by affect, although not always optimal, are therefore easier and more efficient than those made with the slower, more effortful, rational system. With regards to economic decision making, it has been proposed that while the deliberative system takes account of probability and outcome and adheres most closely to expected utility models, the affective system is responsible for the deviation from linear weighting towards the S-shaped function (Loewenstein & O'Donoghue, 2004). It is known that the affective system is more sensitive to outcomes and relatively insensitive to probabilities, for example, studies which have measured fear via responses of the autonomic nervous system activity have found reactions to an impending electric shock are mediated by the expected intensity (outcome) rather than the likelihood of it occurring (probability) (Bankart & Elliott, 1974; Monat et al., 1972). Also, it has been reported that probability weighting deviates more from the rational linear model (i.e. is more S-shaped) for emotional outcomes than unemotional ones (Hsee & Rottenstreich, 2004; Rottenstreich & Hsee, 2001). The effects seen in Experiment 6 and 7 can therefore be seen as an exaggerated deviation from linear probability weighting. Participants were more likely to choose the lower probability choice in the 14:2 Probability trials of the arousal conditions which is consistent with an increased overweighting of the low probability, and is therefore consistent with the idea of a relative shifting in balance from processing via a deliberative system to a more emotional mode of processing.

5.4.3 Mood Regulation Explanations of Risk Taking

As detailed in the introduction to this chapter, much research has been carried out on the effects on emotion on risk taking. These have often involved mood manipulations and the results have been inconsistent, with both negative and positive mood linked with increased risk taking. In taking account of the effects of mood on risk taking, researchers have often used models of mood regulation or mood maintenance. For example, the Affect Infusion Model (AIM) proposed that positive mood will increase risk taking (and negative mood lower it) (Forgas, 1995). This is because a current good mood primes positive cues and more positive material is available in working memory to draw upon. Thus a good mood leads to more focus on the positive cues in a situation, leading to optimism and greater willingness to take risks, whilst a bad mood could signify a dangerous situation, and will prime more negative materials in working memory, leading to more caution (Forgas, 1995). Whereas the AIM model focuses on the selective priming of memories, another approach to understanding affective influences on decision making has been to examine the impact of mood on cognitive style. It has been found that while positive mood is associated with relatively simple, heuristic-processing in making judgments, negative mood state is associated with the tendency towards more accurate, systematic-processing strategies. (Forgas, 1995, 1998; Schwarz & Bless)

The Mood Maintenance Hypothesis (MMH), advanced by Isen and colleagues, makes predictions in the opposite direction from the AIM. The MMH claims that people are driven to protect a positive mood and therefore will be more cautious when happy (unless risks are considered very small or of a trivial nature), whilst a bad mood will lead to greater recklessness since they have less to lose and are striving for a rewarding event which may improve the negative mood (Isen & Labroo, 2003). Similarly, the Hedonic Contingency Model predicts that more risk-taking will result from a tendency to engage in a wide range of activities in the presence of a negative mood since almost anything is likely to lift it. In contrast, a narrower range of activities will be engaged in by happy individuals as they striving to maintain their current affective state (Wegener & Petty, 1994).

This chapter's results demonstrate that risk-seeking behaviour can be induced by increased arousal without any change in mood. This is inconsistent with mood regulation accounts of the influence of affect on risk taking which claim that risk-taking is an active response to current affective state. As will be discussed further in the thesis general discussion, this may be more consistent with increased risk taking as resulting from a change in motivation or in sensitivity to reward, i.e. a switch from more analytical modes of decision making to a greater reliance on more rapid, emotional responding

5.4.4 Summary and Conclusion

Following demonstrated results of both MTI arousal and varying level of monetary reinforcement on the IGT, this chapter applied the same two manipulations to the EGT, a probabilistic gambling task with (unlike the IGT) no element of learning. It was found that higher arousal levels led to increased risk-seeking (defined as the choice of the lowest probability option) on the 14:2 Probability trials.

This suggests that some of the detrimental effect of these manipulations on the IGT may have been caused by a shift in assessment of probability, a tendency towards increased risk and higher potential reward (or lower loss), rather than purely an impairment of implicit learning. On both the EGT studies, arousal effects were focused on the most extreme Probability, the 14:2 Probability. More risky decision making was accompanied by shorter RTs following the MTI arousal manipulation although not in response to the increased monetary reinforcement. This may be due to a specific effect of the MTI arousal on behavioural activation. As with the studies on the IGT, arousal effects occurred without any change in reported subjective state. Thus, the studies in this chapter further demonstrate that non valenced arousal may lead to changes in decision making and risk-taking independent of any effect of specific mood. The current results also suggest that generalised arousal may be a more important factor than is generally accounted for in research of affective influences on risky behaviour.

CHAPTER SIX

THE EFFECTS OF MUSCLE TENSION-INDUCED AROUSAL ON SEXUAL JUDGMENT AND DECISION MAKING: EXPERIMENT 7

Following the demonstration of significant effects of MTI arousal on laboratory gambling tasks in Experiment 3 (IGT) and 6 (EGT), this research was extended to an area of real life decision making in which arousal is clearly implicated, namely sexual decision making.

Considering the importance of the topic, research on the effects of arousal on sexual behaviour is relatively scarce. We regularly hear reports of alleged loss of sexual self-control in well known public figures, individuals who often have much to lose as a result of their indiscretions. And, amongst society in general, failure to control sexual behaviour leads to all manner of problems from divorce to unwanted pregnancy and sex crimes. Within most societies there are sanctions in place, whether legal or religious, to regulate sexual behaviour, the implication being that individuals cannot be solely relied on to control their own sexual behaviour (Wiederman, 2004). Understanding the factors involved in sexual behaviour, and sexual risk-taking in particular, also has important implications for health interventions aimed at the prevention of HIV and other sexually transmitted infections (STIs). With the increasing significance of AIDS in recent decades, many empirical studies have been carried out on predictors of condom use. As an ignorance of AIDS and HIV become a less plausible reason for not using condoms, the most laudable explanation appears to be one of lack of self-control (Wiederman, 2004). And yet, most literature on interventions to reduce sexual risk-taking, usually aimed at promoting condom use, has taken a rational cognitive perspective, assuming adequate information and logical decision making processes and largely ignoring the role of emotion and arousal (Strong, Bancroft, Carnes, Davis, & Kennedy, 2005).

Going beyond introspection or vicarious experience there are good reasons to believe that sexual arousal will affect aspects of sexual judgement and decision making. Many appetitive systems in the brain, e.g. those involved with thirst or hunger, are designed to increase motivation during times of opportunity (Rolls, 1999). It has similarly been claimed (Buss, 2003; Rolls, 1999) that the brain circuitry concerned with sexual behaviour evolved to increase motivation during situations with an increased prospect of copulation. Hence when the brain receives cues commonly associated with opportunity for copulation, including the experience of a state of sexual arousal, a corresponding change in motivation would be expected, which would impact on sexual judgement. Relatively little is known about the neural mechanisms underlying sexual motivation in humans, although it is known that, as with other motivated states such as hunger and thirst, sexual behaviour is partially regulated by the hypothalamus and involves a common anticipatory motivation system utilising dopaminergic arousal. Unlike hunger and thirst, however, there is no obvious homeostatic control over human sexual motivation (Petri & Govern, 2003).

Consistent with this view that a change in sexual motivation could impact on judgment, previous research has shown that sexual arousal can distort estimations of risk relating to sexually transmitted disease (Blanton & Gerrard, 1997; Ditto et al., 2006). Loewenstein (1996; Loewenstein & Lerner, 2003) proposed that visceral factors (such as physiological activation induced by sexual desire or hunger) can lead to a narrowing of focus, where factors not associated with consumption of the desired item become less salient. This kind of change in motivation, or 'tunnel vision', is also apparent, albeit in a more extreme manner, in the drive states associated with alcohol and drug addiction, with an increase in behaviours likely to facilitate drug use and diminishment of non drug-related behaviours (Peele, 1988). Loewenstein (1996) proposed that these mechanisms, although most likely evolved to motivate goal-directed behaviour, can also be maladaptive, especially at high intensities.

Ariely and Loewenstein (2006) investigated the effect of sexual arousal on sexual decision making. The study administered a Sexual Decision Making Questionnaire covering 3 aspects of sexual judgment: preferences for different stimuli and activities, willingness to engage in morally questionable behaviour in order to gain sexual gratification and willingness to engage in unprotected sex. Male subjects were asked to answer the questions either in a non-aroused or in a sexually aroused state (masturbating while viewing erotic pictures). The authors reported that sexual arousal significantly increased subjective preferences for a wide range of sexual stimuli and activities, and led to a significant increase in judgements reflecting a greater willingness to engage in morally questionable means to obtain sex and to engage in unprotected sex. According to Loewenstein's (1996) concept of the 'hot-cold empathy gap' it would be expected that, when in a non-aroused ('cold') state, participants would be unaware or underestimate how their judgement could be affected when in a aroused ('hot') state. It is claimed that this concept can be applied to many emotional states such as hunger, sexual arousal, drug craving, pain, anger and fear, and can explain many later-regretted lapses in self-control. The 'hot-cold empathy gap' is a similar concept to the cool cognitive 'know' system and hot emotional 'go' system described by Metcalfe and Mischel (1999), which they also claim can enable or undermine the individual's attempts at self control.

Whereas it is to be expected that sexual arousal could cause a change in sexual decision making, somewhat less predictable is the finding that sexual arousal can also have an effect on financial decisions (Knutson et al., 2008; Wilson & Daly, 2004). Wilson & Daly (2004) showed that sexual arousal could lead to steeper discounting of financial rewards. Men discounted financial rewards more steeply when rating pictures of attractive females, compared to rating pictures of cars, and this effect was not found in female participants rating pictures of attractive males. The authors proposed that this effect occurred since men may have evolved to acquire resources to attract a mate. The pictures of attractive women, or "courtship-worthy targets", may therefore have acted as sexual cues, inducing a "mating-opportunity mindset" in which immediate rewards are prioritised over delayed ones since they have the added return of increasing the opportunity of attracting a female. It is unclear whether this effect is a specific one, relating to the fact that money can be used to acquire goods which directly adds to the mating effort, or whether the sexual cues lead to a discounting effect caused by men becoming more oriented to the present in general (Wilson & Daly, 2004). Another study of the effect of sexual arousal on financial decision making found that males were more likely to accept unfair offers in an ultimatum game following exposure to pictures of attractive females (Van den Bergh & Dewitte, 2006). These results on the ultimatum game, considered a laboratory model of collaborative hunting, alliance-forming or resource sharing (Page, Nowak, & Sigmund, 2000), could again be considered a case of preference for immediate, certain rewards over delayed or non-existent ones in the context of a mating opportunity.

Knutson et al. (2008) reported greater risk-taking on a financial task when men were shown sexual images, with this effect mediated by the nucleus accumbens (NAcc). Other fMRI studies have also shown that the NAcc, is activated by sexual images (Aharon et al., 2001; Hamann, Herman, Nolan, & Wallen, 2004). Knutson et al. (2008) point out that this basal ganglia region is connected to the orbitofrontal cortex which is activated by other rewards, such as monetary rewards (Breiter et al., 2001; Knutson et al., 2001) and sweet-tasting food rewards and the cues pertaining to them (O'Doherty, Deichmann, Critchley, & Dolan, 2002). It was proposed, therefore, that a possible explanation of the effect of sexual arousal on financial decision making could be that sexual and monetary cues share a common anticipatory reward-processing pathway. This pathway could, in turn, affect attention and information processing relevant to the stimulus, but could also be affected by incidental rewards (Knutson et al., 2008).

From a different perspective, theories relevant to the idea of cross domain effects of arousal, or of arousal 'leaking' into underlying motivational systems may also account for the data described above, e.g. Schachter & Singer's (1963) misattribution of affect theory and Zillmann's (1971) theory of excitation transfer. According to these theories, a 'common reward pathway' would not necessarily have to be involved, with the individual's misattribution of arousal levels key, arousal being related to either to positive or negative affect. The classic Schachter and Singer study (1963) demonstrated that arousal states, rather than being specific and clearly understood by the individual, can be ambiguous and reliant on interpretation according to an individual's cognitive evaluation of situational cues. Although Schachter and Singer (1963) originally proposed that an individual is unlikely to mislabel their feelings where there is an appropriate explanation for a state of arousal, misattributions of arousal under these circumstances have since been demonstrated. A number of studies have reported an increase in sexual or romantic attraction following fear, anger or physical exercise. However, rather than focusing on judgments regarding specific scenarios, as in the current experiment, previous experiments on the effects of exercise induced arousal on sexual attraction have focused on ratings of people's attractiveness (e.g., Dutton & Aron, 1974; Meston & Frohlich, 2003; White et al., 1981; White & Kight, 1984) According to Zillmann's (1971) theory of excitation transfer, emotional reactions are enhanced as arousal from different sources (current or previous; related or unrelated) is combined. The summation of these emotional reactions then act to intensify feelings which are cognitively determined by the individual in evaluating their immediate environment. Key to the excitation transfer theory is the time course difference between rapidly changing cognitive appraisal and relatively slowly dissipating arousal hormones in response to emotional events.

The current study employed a similar approach to those in which a domain–specific arousal effect has previously been found, namely the Ariely & Loewenstein (2006) sexual decision making study. However, the current study replaced the original arousal manipulation employed (sexual arousal) with a novel MTI arousal, unrelated to the sexual judgments required. The aim of this current study therefore, was to investigate whether a (non-rewarding) form of physiological MTI arousal could affect sexual judgement and decision making in the same direction as a more specific sexual arousal. An additional aim was to explore the extent of participants' awareness of their arousal levels and whether they had insight into any difference in their answers across the two conditions.

It was hypothesised that there would be a significant effect of (MTI) Arousal on responses on the Ariely & Loewenstein (2006) Sexual Decision Making Questionnaire; specifically, that there would be higher level of reported attraction towards sexual stimuli and activities, a higher level of reported willingness to engage in morally questionable behaviour to obtain sex and a higher level of reported risk taking evident in questions relating to condom use, pregnancy and STIs in the Aroused condition compared to the Non-Aroused condition. Consistent with previous findings in this thesis (Experiment 4) in which participants reported awareness of a 'slight' change in subjective arousal levels following use of the hand dynamometer, it was expected that there would be a significant effect of Arousal on transient subjective arousal, as measured on the Short Form Activation-Deactivation Adjective Check List (AD ACL) (Thayer, 1986), with higher scores in the Aroused condition compared to the Non-Aroused condition. Also, consistent with the Ariely & Loewenstein (2006) study, it was hypothesised that participants would have little, or no, insight into any difference in their answers, across the two arousal conditions, as measured on an 'Awareness' question in the second session.

6.1 Methods

6.1.1 Participants

Participants were 19 male psychology undergraduates, aged 18 - 26 (Age *M* = 20.0, *SD* = 1.97), recruited from the Bangor University Student Participation Panel and completing the study for course credit. On the Heterosexual-Homosexual Rating Scale (Kinsey, 1998) 12 participants described themselves as "Exclusively heterosexual with no homosexual", 6 participants as "Predominantly heterosexual, only incidentally heterosexual", and 1 participant as "Predominantly heterosexual, but more than incidentally homosexual".

6.1.2 Design

This experiment involved a 2 part repeated measures design. The independent variable was the arousal level: Aroused (use of hand dyno), or Non-Aroused (control condition: questionnaire without use of hand dyno). The order in which the sessions took place was counterbalanced across participants to avoid order effects. The dependent variables were the scores on the Sexual Decision Making Questionnaire and on the AD ACL.

The study was approved by the Research Ethics Committee of Bangor University and written consent was obtained. Participants were made aware of their right to withdraw at any time without penalty and of their right to decline to answer any questions, both at the time of signing up online, and immediately prior to testing both verbally and on the written consent form. Participants were assured of absolute confidentiality and anonymity (see details of data collection immediately below) and were fully debriefed following the second experimental session.

6.1.3 Measures

A questionnaire booklet was administered to the participants. Inside the booklet the participants were asked to generate a code made up from elements known to them (e.g. 'first letter of your mother's name') but not known to the researcher. This is a validated technique enabling anonymity but still allowing for data collected on different occasions to be linked (Yurek, Vasey, & Havens, 2008).

The first measure within the booklet was the Sexual Decision Making Questionnaire from the Ariely & Loewenstein (2006) study (questions can be seen in the Results section below). Section A contained 20 questions relating to the attractiveness of sexual activities and stimuli, Section B contained 5 questions regarding intentions to engage in morally questionable means to obtain sexual gratification and Section C contained 8 questions relating to use of condoms and judgments on risk of STI and pregnancy. Participant responses were indicated by placing a mark on a 14 cm line representing a continuum from

"No" (far left) to "Probably" (centre) to "Yes" (far right), with participants instructed to "feel free use the whole line to represent your answer as accurately as possible". A higher score on Section A represents a higher attractiveness rating and, on Section B, represents expression of a higher intention to obtain sexual gratification by morally questionable means. On Section C some questions are reversed, but these are reversed back before analysis such that a higher score always represents a more risk taking attitude when making judgments regarding STIs and pregnancy.

Two breaks were equally spaced within this measure to allow for either hand dynamometer use (Arousal condition), or a pause of equal length (Non-aroused condition). In the second session an additional 'Awareness' question was added to the end of this questionnaire booklet. This question read: *"Did you feel as if you answered the questions any differently this time?... compared to last time, did you feel as if your answers THIS time:" (Please circle one statement below)*. The options then given below were *"Definitely veered more towards 'NO' ", "Possibly veered more towards 'NO' ", "Were about the same", "Possibly veered more towards 'YES' ", "Definitely veered more towards 'YES'"*.

Immediately following the Sexual Decision Making Questionnaire, participants also completed the Short Form Activation-Deactivation Adjective Check List (AD ACL) (Thayer, 1986). The Short Form AD ACL is a list of 20 adjectives to which participants self-report; the four response options being "definitely feel", "feel slightly", "cannot decide", "definitely do not feel" .The scale was devised, and has been extensively validated, for rapid and unobtrusive assessment of transitory arousal.

In order to assess sexual orientation (the questions were designed for heterosexual men), the Heterosexual-Homosexual Rating Scale (Kinsey, 1998) was also administered. This is a 7-pont continuum scale, with participants asked to tick which phrase best describes their sexual orientation. The scale varies from 0, being "Exclusively heterosexual with no homosexual" through to 3, "Equally heterosexual and homosexual" and up to 6, "Exclusively homosexual".

6.1.4 Apparatus

As with previous studies in this thesis involving MTI arousal, a 0-100 kg Takei Kiki Kogyo hand dynamometer was used.

6.1.5 Procedure

In the Arousal condition, participants were first asked to squeeze the hand dyno as hard as possible in their dominant hand for 20 seconds. The reading was noted and a 75% of maximum individual level calculated. A 2 minute break was then given to prevent excessive muscle fatigue. Following this, the first arousal manipulation was administered, with the participant using the hand dyno in a constant pumping action at their individually calibrated level for 60 seconds.

Participants were then left to complete the questionnaire booklet in an adjoining room to the experimenter. The Sexual Decision Making Questionnaire was questionnaire booklet component 1. At two points, as informed by the booklet instructions (i.e. at points spaced approximately equally within the Sexual Decision Making Questionnaire), the participant closed the booklet and verbally summoned the experimenter into the room to oversee the second and third Arousal manipulation. Immediately after each use of the hand dyno, the participant was left alone again to allow for confidentiality. Questionnaire booklet component 2 was the AD ACL, component 3 was the Heterosexual-Homosexual Rating Scale, and component 4 was the 'Awareness' question (Session 2 only). When the booklet was fully completed, participants followed the written instructions to post it in a sealed box in front of them. The whole procedure took approximately 15 minutes.

In the Non-Aroused condition, the same procedure was applied but without initial hand dyno calibration and with the 60 seconds of hand dyno use replaced with a 60 second break in which the participants were supervised merely holding the hand dyno on the desk, without any exertion. The second session was carried out between 2 and 8 days after the first, in order to minimise contamination effects of answering the same questions. The two sessions were carried out at the same time of day to avoid confounds caused by circadian rhythms of arousal hormones (Refinnetti, 2006).

6.2 Results

It was found that there was a significant effect of Arousal on Section B (Willingness to engage in morally questionable means to obtain sexual gratification) of the Sexual Decision Making Question, but no significant effect of Arousal on Section A (Attractiveness of sexual stimuli and activities) or Section C (Pregnancy and STI risk). There was a significant effect of Arousal on Thayer's AD ACL, although knowledge of a heightened state of arousal did not translate into awareness of the effects of Arousal on Section B responses, with 16 out of 19 participants reporting that their answers were 'about the same' on the 2nd session 'Awareness' question.

6.2.1 Sexual Decision Making Questionnaire

Responses on the Sexual Decision- Making Questionnaire (i.e. line bisection marks) were measured and transformed into a score out of 100, as in the Ariely & Loewenstein (2006) study. Full results for all questions are shown in Table 6.1, mean scores for each section are depicted in Figure 6.1.

Table 6.1

Mean questionnaire scores by Arousal level (maximum score = 100)

Section A: Sexual stimuli and activities	Non-aroused	Aroused
1. Are women's shoes erotic?	25.07	25.64
	(28.92)	(29.21)
2. Can you imagine being attracted to a 12-year-old girl?	6.28	5.19
	(8.51)	(4.67)
3. Can you imagine having sex with a 40-year-old woman?	44.47	47.22
	(31.35)	(30.65)
4. Can you imagine having sex with a 50-year-old woman?	21.99	26.54
	(23.84)	(25.57)
5. Can you imagine having sex with a 60-year-old woman?	7.29	11.35
	(9.09)	(10.87)
6. Can you imagine having sex with a man?	18.99	17.89
	(26.44)	(24.11)
7. Could it be fun to have sex with someone who was extremely fat?	17.26	19.21
	(18.36)	(18.75)
8. Could you enjoy having sex with someone you hated?	45.56	49.2
	(31.79)	(30.66)
9. If you were attracted to a woman and she proposed a threesome with a man, would you do it?	39.62	40.7
	(33.46)	(34.95)
10. Is a woman sexy when she's sweating?	42.67	45.71
	(20.57)	(24.74)
11. Is the smell of cigarette smoke arousing?	8.20	18.42
	(8.10)	(20.05)
12. Would it be fun to be tied up by your sexual partner	63.2	59.89
	(25.18)	(27.75)

Table 6.1 (*continued*)

Section A: Sexual stimuli and activities	Non-aroused	Aroused
13. Would it be fun to tie up your sexual partner?	70.19	66.69
	(24.78)	(25.75)
14. Would it be fun to watch an attractive woman urinating?	10.00	9.47
	(14.60)	(11.55)
15. Would you find it exciting to spank your sexual partner?	55.26	50.79
	(22.98)	(29.51)
16. Would you find it exciting to get spanked by an attractive woman?	47.29	48.08
	(26.22)	(25.16)
17. Would you find it exciting to have anal sex?	53.08	47.86
	(29.88)	(32.24)
18. Can you imagine getting turned on by sexual contact with an animal?	15.60	11.99
	(27.49)	(20.46)
19. Do you prefer to have sex with the light on?	53.53	57.78
	(22.61)	(21.00)
20. Is just kissing frustrating?	27.74	38.00
	(25.45)	(28.96)
Section B: Willingness to engage in morally questionable means to obtain sex * $p = .014$		
1. Would you take a date to a fancy restaurant to increase your chance of having sex with her?	43.98	55.22
	(33.24)	(26.14)
2. Would you tell a woman that you loved her to increase the chance that she would have sex with you?	23.72	27.59
	(18.09)	(25.54)
3. Would you encourage your date to drink to increase the chance that she would have sex with you?	33.95	37.26
	(23.46)	(24.65)

Table 6.1 (*continued*)

Section B: Willingness to engage in morally questionable means to obtain sex * $p = .014$	Non-aroused	Aroused
4. Would you keep trying to have sex after your date says ''no.''	17.59	17.44
	(16.89)	(20.85)
5. Would you slip a woman a drug to increase the chance that she would have sex with you?	4.32	4.06
	(4.12)	(3.15)
Section C: Pregnancy and STI risk		
1. If you pull out before you ejaculate, a woman can still get pregnant	37.11	26.80
	(36.77)	(34.26)
2. A woman who is a good friend can give you a sexually transmitted disease	13.87	9.92
	(19.09)	(12.73)
3. Would you trust a woman you've just met who says she is using birth control?	40.98	41.32
	(31.57)	(30.82)
4. Birth control is the woman's responsibility	11.92	11.05
	(12.80)	(9.90)
5. A condom decreases sexual pleasure	56.88	57.14
	(28.67)	(32.02)
6. A condom interferes with sexual spontaneity	68.57	67.03
	(28.56)	(28.78)
7. Would you always use a condom if you didn't know the sexual history of a new sexual partner?	22.52	23.35
	(29.25)	(23.97)
8. Would you use a condom even if you were afraid that a woman might change her mind while you went to get it?	26.12	27.26
	(22.69)	(25.71)

Bracketed figures are standard deviations

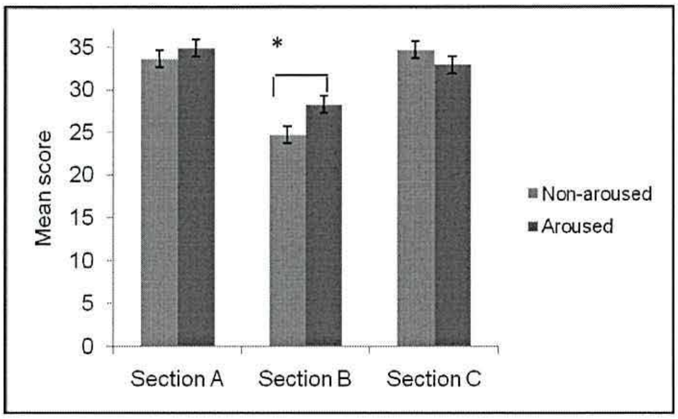


Figure 6.1. The effect of MTI Arousal on the Sexual Decision Making Questionnaire (Error bars represent SEM)

To test for effects of Arousal in different aspects of sexual decision making, each section was analysed separately.

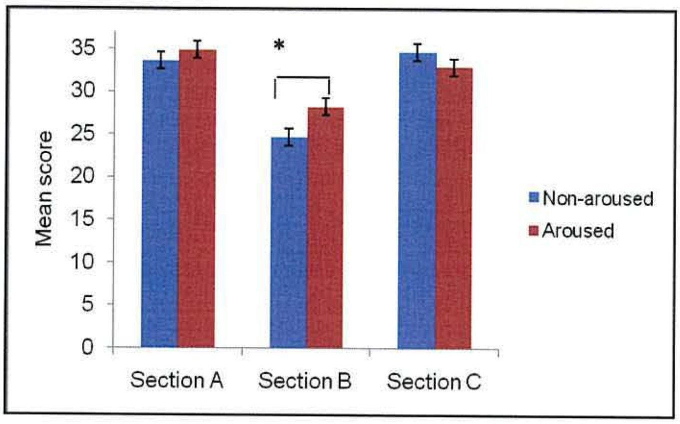
Section A – Attractiveness of sexual stimuli and activities

A repeated measures 1 factor ANOVA, Arousal (2 levels: Non-aroused, Aroused) was carried out. There was no effect of Arousal, F (1, 18) = .410, p = .530, *ns* (Non-aroused M = 33.67, SD = 11.50; M Aroused = 34.86, SD = 12.99).

Section B – Judgments on morally questionable means to gain sexual gratification.

A repeated measures 1 factor ANOVA, Arousal (2 levels: Non-aroused, Aroused) was carried out. There was a significant effect of Arousal, F (1, 18) = 5.77, p = .014 (one-tailed hypothesis), (Non-aroused M = 24.71, SD = 13.93; M Aroused = 28.32, SD = 14.46).

Following the significant effect on the ANOVA performed on the mean question score, above, the analysis was then repeated with a 2 factor, repeated measures ANOVA, Arousal (2 levels: Non-aroused; Aroused) x Questions (5 levels). This allowed for an



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Following the significant effect on the ANOVA performed on the mean question score, above, the analysis was then repeated with a 2 factor, repeated measures ANOVA, Arousal (2 levels: Non-aroused; Aroused) x Questions (5 levels). This allowed for an exploration of whether specific questions were differentially affected by Arousal. There was a significant main effect of Arousal, F (1, 18) = 5.77, p = .014 (one-tailed hypothesis), a significant effect of Questions, F (4, 72) = 19.72, p <.001, and non significant Arousal x Questions interaction, F (4, 72) = 2.361, p = .061.

Section C – Judgments of STI and pregnancy risk

A repeated measures 1 factor ANOVA, Arousal (2 levels: Non-aroused, Aroused) was carried out. There was no significant effect of Arousal, F (1, 18) = .310, p = .584, *ns*, (Non-aroused M = 34.74, SD = 14.50; M Aroused = 32.98, SD = 15.17).

6.2.2 Arousal scores

As is customary for studies focusing on high levels of arousal, only the 'Energetic' and 'Tension' components of Thayer's (1986) AD ACL were scored. 1 sheet was spoiled, therefore a paired t test on Thayer's AD ACL scores ('Energetic' + 'Tension'), collected post-testing, was carried out on 18 participants. There was a significant effect of Arousal, t (17) = 3.07, p = .007 (Non-aroused M =18.11, SD = 5.18; Aroused M = 21.44, SD = 4.93).

6.2.3 The 2nd session 'Awareness' question: "Do you think your answers were any different this time compared to last time?"

Where the Non-Aroused condition was the 2nd session the scores were reversed to give a score for how the much the participants believed the use of the hand dyno in the Aroused condition affected their responses compared to the Non-aroused condition without hand dyno use. Out of the 19 participants, 16 answered that they believed their answers were 'about the same'. With the remaining participants, as an approximate gauge of the accuracy of their belief, their mean Sexual Decision Making Questionnaire scores for Section B, Non-Aroused condition were compared with their mean Section B, Aroused condition scores. 1 participant answered (correctly) that they thought their answers with the Arousal manipulation, compared to the non-Aroused condition, 'veered slightly towards 'No', 2 participants answered that they thought their answers 'veered slightly towards 'Yes', out of which only 1 was correct.

6.2.4. The Heterosexual-Homosexual Rating Scale (Kinsey, 1998)

Results of this measure are detailed under the 'Participants' section. It was anticipated that any participant scoring 4 or over would be excluded from the analysis as the questions were designed for heterosexual men, however no exclusions were necessary.

6.3 Discussion

Following previous findings of an effect of sexual arousal on sexual decision making Ariely & Loewenstein (2006), the Sexual Decision Making Questionnaire was employed with a novel arousal manipulation, MTI physiological arousal. There was a significant effect of Arousal on Section B of the Sexual Decision Making Question, with responses in the Aroused condition indicating a greater willingness to engage in morally questionable means to obtain sexual gratification. There was, however, no significant effect of Arousal on Section A (Attractiveness of sexual stimuli and activities) or Section C (Pregnancy and STI risk). There was a significant effect of Arousal on Thayer's AD ACL, with significantly higher reported levels of transient arousal in the Aroused condition, although knowledge of a heightened state of arousal did not appear to translate into awareness of the effects of Arousal on Section B responses, with 16 out of 19 participants reporting that their answers were 'about the same' on the 2nd session 'Awareness' question.

Unlike the Ariely and Loewenstein (2006) research, this study did not find an effect of Arousal on Section A (Attractiveness of sexual stimuli and activities) or Section C (Pregnancy and STI risk). However, in the original experiment, computer presentation included a 'thermometer' on which participants were asked to note their subjective level of arousal, with questions only answerable at a level of at least 75% of maximum sexual arousal. In contrast, in the current study, only relatively mild arousal is induced, i.e. 3 minutes (total) of MTI arousal involving one arm. Although there was significantly higher self reported arousal in the Aroused compared to the Non-aroused condition, it could not be expected that the level of arousal be comparable with a high level of sexual arousal. The study has, however, been successful, in demonstrating that even a relatively mild change in general physiological arousal, not induced by sexual cues, can induce a change in motivation with regard to sexual intentions.

In keeping with the other findings in this thesis, in which MTI arousal induced greater risk-taking, engaging in morally questionable behaviour (as examined in Section B) could also be viewed as risk taking, with each option (whether to engage in the behaviour or not) involving potential costs and benefits. For example, engaging in a morally questionable behaviour involves the potential benefit of a greater likelihood of sex, versus the risk of social disapproval, and damage to one's reputation and to future prospects of attracting a mate.

6.3.1 Theoretical models of the arousal effect

The common anticipatory reward pathway

In the Knutson et al. (2008) study it was reported that sexual arousal, induced through viewing of erotic pictures, led to greater financial risk-taking and that this effect was mediated by the NAcc. The NAcc has been associated with positive arousal, including anticipation of monetary and non-monetary rewards and, in a previous financial decision-making task, the NAcc activity predicted shifts to the high risk option, whereas insular activation predicted shifts to the low risk option (Kuhnen & Knutson, 2005). Knutson et al. (2008) therefore proposed that positive arousal could affect the financial decisions on the task by increasing the salience of the wins. As predicted, it was found that incidental stimuli which raised positive arousal (i.e. sexual cues) increased shifts to the high risk option, and that this shift was mediated by the NAcc, thereby supporting the idea that incidental reward cues can influence financial risk taking by altering positive anticipatory affect and through 'common reward pathway' processing.

The NAcc is a basal ganglia structure rich in dopamine (DA) projections. Electrophysiological and neurochemical studies on animals have shown that this system is activated by many kinds of rewards. For example NAcc activity and DA release occur in response to the anticipation of pleasant food (Blackburn, Phillips, Jakubovic, & Fibiger, 1989; Richardson & Gratton, 1996; Schultz, Dayan, & Montague, 1997), heroin and amphetamine administration (Kiyatkin, Wise, & Gratton, 1993; Ranaldi, Pocock, Zereik, & Wise, 1999) and the opportunity for copulation (Fiorino, Coury, & Phillips, 1997; Pfaus, Damsma, Wenkstern, & Fibiger, 1995). NAcc activity and DA release are also elicited by secondary rewards, previously paired with food (Apicella, Ljungberg, Scarnati, & Schultz, 1991), or drugs (Di Ciano, Blaha, & Phillips, 1998). In humans, NAcc activation has been reported in response to many rewards, including many rewarding recreational drugs (Breiter et al., 1997; Sell et al., 1999), anticipation of monetary rewards (Knutson et al., 2001; Preuschoff, Bossaerts, & Quartz, 2006), and in response to sexual cues (Hamann et al., 2004). In was has been termed 'incentive salience', DA has been especially associated with anticipation or 'wanting' of rewards (Berridge, 2007; Berridge, Robinson, & Aldridge, 2009). It seems likely, therefore, that the effect of sexual arousal on financial risk-taking (Knutson et al., 2008) involved dopaminergic arousal.

In an investigation of a different cross-domain effect of arousal, the current study employed mild exercise as a form of arousal to examine its effect on sexual decision making. It has long been accepted that exercise increases noradrenaline (NA) and adrenaline levels (Banister & Griffiths, 1972, as cited in Ohman & Kelly, 1986), with serum NA concentrations correlated with exercise intensity (Hartley et al., 1972, as cited in Ohman & Kelly, 1986). It is likely therefore that the exercising with the hand dyno, causes NA release, and previous research proposed that MTI arousal effects also involve adrenaline, since arousal-modulated memory effects were not present in subjects taking beta-blocker medication (Nielson & Jensen, 1994). Use of the hand dyno at 75% maximum is likely to be perceived as a slightly negative experience (although this is unlikely to have an excessive effect on mood since ratings taken in Experiment 3 and 6 showed that participants allocated to the hand dyno arousal condition reported themselves as no less happy post-testing compared to control participants). Although participants were aware they could stop for a break if necessary and no-one complained that it was excessively painful, use of the hand dyno for 60 seconds at 75% maximum does appear tiring (although quickly recovered from) in many participants.

Knutson et al. (2008) used the concept of incidental reward cues inducing risk taking through common reward pathways in the brain (the NAcc) to explain the NAcc mediated effects of sexual arousal on financial risk taking. However, the current study's finding of effects of a *non-rewarding* form of general physiological, presumably NA mediated, arousal on sexual decision making cannot be explained by the concept of the common reward pathway. As such, some of the effects reported by Knutson et al. (2008) may have been due to a form of misattribution of arousal, or a more general arousal-induced change in motivational state which, although leading the individual to be more reward-seeking in the presence of financial opportunity, does not necessarily have to be reward-related initially.

However, it may not be possible to completely distinguish a 'common reward pathway' theory of sexual arousal on financial risk taking from a general arousal effect involving neutral or negative valence since, although it is known that exercise operates via noradrenergic arousal, and that anticipation of many rewards, or 'wanting' involves DA (Berridge, 2007; Berridge et al., 2009), there remains the potential for NA and DA to interact. There is a growing consensus that arousal neurotransmitters are unlikely to operate in a totally independent manner and there is some evidence that release of many neurotransmitters may be affected by exercise to some extent (Meeusen & Demeirleir, 1995). It has been noted that there are striking commonalities between anatomical organisation of modulatory (ascending arousal) systems as well as direct interactions between these systems, particularly with regard to neuropsychiatric illness (e.g., Briand et al., 2007; Carlsson, 2001; Carlsson et al., 2001; Robbins et al., 2006), suggesting that these systems may operate in a more orchestrated way than initially presumed. To date, however, research about specific interactions of the ascending arousal systems, both at neuronal level and with regard to function remains relatively scarce.

Misattribution of Arousal

It is possible that the effects of MTI arousal on sexual decision making in the current study arose through a misattribution of the heightened arousal levels induced by use of the hand dyno. Although Schachter and Singer (1963) originally proposed that individuals would be unlikely to mislabel their feelings where there is an appropriate explanation for a state of arousal, misattributions of arousal under these circumstances have since been reported. For example, male tourists were more likely to exhibit sexual attraction when approached by an attractive female researcher on a high, fear-inducing bridge than on a low control bridge, (Dutton & Aron, 1974). Also, when asked to rate a photograph of a person of the opposite gender for attractiveness and reported desire to date, ratings were significantly higher on participants exiting a roller coaster ride that those entering (Meston & Frohlich, 2003). This effect was not seen in those individuals seated next to a romantic partner, and this was interpreted in terms of the partner providing a moderating contextual cue towards which the participant could attribute the increased sexual attraction. MTI arousal may have been misattributed as sexual arousal in the context of a questionnaire which asked participants to imagine they were in a range of sexual scenarios. It is likely that individual differences in the extent of the effect of arousal on the Section B questionnaire responses could have been moderated by how difficult the participants found the use of the hand dyno, how quickly they worked through the questionnaire (since this affected how closely together the hand dyno bursts occurred) and how aware they were of their own heighted arousal. For those who found the use of the hand dyno relatively difficult, or those who were especially aware of a heighted arousal state *before* starting the questionnaire, then these factors may have acted as contextual cues in labelling their arousal state and attenuated the effect of MTI arousal on the Section B responses.

According to Zillmann's (1971) theory of excitation transfer, arousal from different sources is pooled. When the individual evaluates their immediate environment, the summation of these emotional reactions (either related or unrelated to the current events) then acts to intensify the cognitively determined feelings. Key to the excitation transfer theory is the time course difference between cognition and arousal in response to emotional events. I.e., whereas cognitions involve fast neural mediation and can change almost instantly to account for altered situations, the sympathetic nervous system hormones associated with emotional arousal decay more slowly, a relatively long time after the triggering event. If the Sexual Decision Making Questionnaire items cue a mild sexual arousal, through scenarios suggested and associated imagery evoked, then residual arousal feelings from hand dyno use could be combined with this arousal. This could results in a change in motivation and judgment, as seen in a shift in Section B questionnaire responses, as if the individual was sexually aroused.

Classic studies on rats have shown that mild stress induced through a tail pinch can lead to an increase in arousal and in the rat's motivational state. Rather than eliciting any specific action, a tail pinch can lead to one of a number of behaviours, depending on the contextual cues, for example maternal behaviour, aggression, defence actions, copulation, eating or drinking (e.g., Katz, 1978; Szechtman, 1977). Antelman and Caggiula (1980), similarly, propose that any form of stress or arousal could make any kind of behaviour more likely, the behaviour dependent on context. Brehm and Self (1989) referred to this concept as motivational arousal, and proposed that motivational arousal is increased by many different needs and mild stressors. According to the misattribution of affect and the excitation transfer theories (Schachter & Singer, 1963; Zillman, 1971; Zillmann, 1971), it is therefore possible that at least some of the effects of sexual arousal on risk-taking in monetary experiments could be explained by a general cross-domain effect of incidental arousal, which doesn't necessarily involve reward or common reward processing pathways.

6.3.2 Empathy and interpretation 'gaps'

Ariely and Loewenstein (2006) concluded that the effects of sexual arousal on the Sexual Decision Making Questionnaire in their study further supported the idea of the 'hot-cold empathy gap'. They believed that if individuals had adequate insight into the effects of sexual arousal on their judgment and preferences then their answers in the non-aroused condition would not be significantly different from those given in the aroused condition, since they would be able to compensate adequately for their current lack of arousal when considering their responses. This is of relevance to the current study also, in that, although participants were aware of their heightened state of arousal in the Aroused condition (as measured on Thayer's (1986) AD ACL) they seemed largely unaware of the affect of heightened arousal on their responses on the Sexual Decision Making Questionnaire. This demonstrates the existence not only of an empathy gap but, also, of an awareness or interpretation gap; participants were aware of being more aroused by use of the hand dyno but not of the resultant effects on sexual motivation. It is claimed that the 'hot-cold' empathy gap concept can be applied to many emotional states such as hunger, sexual arousal, drug craving, pain, anger and fear, and can explain many later-regretted lapses in self-control. For example, participants estimations of how concerned they would be to be lost without food or water in the future depended on their own current level of exercise-induced thirst (Van Boven & Loewenstein, 2003), and people who are hungry are more likely to choose an unhealthy snack for future consumption than those who are sated (Read & van Leeuwen, 1998). Also, men who are sexually aroused predict they are more likely to engage in sexually aggressive behaviour in a future date-rape scenario than those who are in a non-aroused state (Loewenstein et al., 1997).

At their most extreme, the questions probe intentions to commit a criminal act ("Would you slip a woman a drug to increase the chance that she would have sex with you?"; and possibly, "Would you keep trying to have sex after your date says 'no' ".) Many criminal acts, especially those involving an element of aggression, involve a level of emotional arousal – whether it is anger, fear or lust. Acknowledging this, Katz (1988, p. 4) describes the commission of crime as a sensual phenomenon: "The assailant must sense, then and there, a distinctive constraint or seductive appeal that he did not sense a little while before in a substantially similar place.....Thus the central problem is to understand the emergence of distinctive sensual dynamics", While Baumeister, Heatherton & Tice (1995, p. 3) have claimed that "self-regulation failure is the major social pathology of the present time", with societal ills stemming from an inability of individuals to control themselves in varied aspects of their lives, whether with regard to food, use of alcohol and other drugs, sexual behaviour, impulsive spending or impulsive crime.

Further research into the effects of arousal on sexual decision making is of potential importance in developing more effective individual strategies in avoiding sexual risk-taking and reducing the incidence of HIV, STIs and unwanted pregnancy. Research on sexual risk-taking traditionally took a 'rational' cognitive perspective, presuming that adequate knowledge of the risks was sufficient to change behaviour (Strong et al., 2005). It is now increasingly recognised, however, that sexual arousal may have a 'heat of the moment' effect which makes sexual decision making qualitatively different from many other kind of risk-taking behaviour (Gerrard, Gibbons, & Bushman, 1996; Gold & Skinner, 1997; Kelly &

Kalichman, 1995). Strong et al. (2005) propose that there is an adaptive neurophysiological mechanism which exists across species to inhibit sexual activity in situations where this is likely to be too risky and disadvantageous. Based on a study of several thousand men, they report the existence of individual variability, with a minority of men having a low propensity for sexual inhibition and remaining sexually aroused in spite of the awareness of considerable risk. It is believed that there are different kinds of sexual risk taking seen in different individuals. There are individuals who require education on the risks and others who, although well-informed about the health implications, persist in indulging in risky behaviour (Strong et al., 2005). Health interventions for the latter kind of individual could most effectively include promoting an understanding of this aspect of their personality and of how arousal tends to alter judgment and advice on how to plan ahead and avoid situations which lead to risk-taking. If cross-domain effects of arousal can occur, such that exercise, for example, could lead to a greater propensity for sexual risk-taking, it would be advisable for this factor to be further explored and possibly included in health interventions.

6.3.3 Limitations

The current study does not measure *actual* behaviour, but assumes that self-report measures will be indicative of a change in motivation and a possible behavioural effect. This study does not, however, rely on recall or insight into past events which can be inherent problems with research into sexuality (see Wiederman, 2002). Some items may however be subject to a social desirability response bias, especially with regard to items which question actions which could be criminal or which many would consider deviant. The results are concerned with *change* in response across the two conditions, however, rather than one absolute response, and any effect of social desirability is likely to be equal across the two conditions.

Section B (willingness to engage in morally questionable behaviour) only contains 5 questions, and a near significant Arousal x Question interaction on Section B (p = .061) highlights the trend for Questions 1-3 to be more affected by Arousal than Q4 and Q5. Q4 and Q5 represented scenarios which involved criminal or potentially criminal actions (Q.4: '*Would you keep trying to have sex after your date had said 'No'?'* ; Q. 5: '*Would you slip a woman a drug to increase the chance that she would have sex with you*?') and so it is perhaps to be expected that these are the items with the lowest scores, the items being less likely to change in the Aroused condition, and possibly those actions which, should any men consider engaging in, would be least likely to be admitted to, for fear of consequences. The significant effects of Arousal on Section B appear, therefore, to be largely concentrated on only 3 out of the 5 questions. A scale with more items would provide a more valid measure, and it was felt that not only could this section be expanded on, but that the questions could possibly be made more relevant to the young student population studied. For example, Q.3 asked whether the participant, in order to gain sex, would encourage a date to drink and Q.5 asked whether the participant would slip a drug into the date's drink. It seems there was much middle ground here not covered, for example, whether the participant would lie about the strength of a drink he'd bought for a date (e.g. claim it was a single measure when in fact it was a double) or whether he would encourage the his date to knowingly take an illegal substance in the hope of obtaining sex. If further research with the Sexual Decision Making Questionnaire was planned, use of appropriate focus groups could be useful in exploring relevant scenarios and possibly expanding and improving on the questions. It is worth noting that Section A showed a numerical, although non-significant, increase in the Aroused condition, and so supports the validity of the significant results of Arousal on Section B.

This study has been carried out on young males and, as such, caution should be applied when extrapolating the results to a wider population. Studies of sexual behaviour have generally been carried out on young males since they were traditionally the most willing volunteers, and also because females were perceived as being less homogenous in regard to stimuli they would find sexually arousing. Further research would be necessary to ascertain whether a similar effect would be found in females or, indeed, in older males.

6.3.4 Summary and conclusion

In conclusion, this study utilised the questionnaire from the Ariely & Loewenstein (2006) study of the effects of sexual arousal on sexual decision making. Instead of sexual arousal, MTI arousal was employed and, although relatively brief (3 minutes), still resulted in significantly higher self-reported willingness to engage in morally questionable means to obtain sexual gratification. The three parts of the questionnaire appear to tap into quite different aspects of sexual behaviour. Interestingly, it appears that significant effect of the MTI arousal were specific to moral judgements (Section B). Judgments of the attractiveness of stimuli (Section A), which could be considered more sensory judgments, were affected less so and judgments regarding the pregnancy and STI risk (Section C), which involved processing of more factual information, were not affected at all. The induced arousal was relatively mild, however, and it would be interesting to investigate in the future whether more prolonged exercise would lead to altered judgment in these areas, also. Of note, also, is that although they reported knowledge of the heightened state of arousal, participants were largely unaware of the effect this had on their judgments.

This is believed to be the first study to demonstrate that arousal, other than sexual arousal, could impact on motivation and judgments regarding sexual behaviour intentions. The results were interpreted in terms of a misattribution of arousal effect altering motivation and subsequent judgments regarding sexual scenarios. Research into the factors affecting sexual behaviour could be important in developing strategies on sexual crime prevention and in promoting sexual health and reducing unwanted pregnancy. This study also highlights that increased risk-taking may result from an unrelated form of arousal which may itself be non-rewarding. The results provide further support for the idea that even a mild change in (incidental) arousal levels can affect decision making and promote risk-taking, and that individuals may be unaware of these effects on subsequent judgments, consistent with the hot-cold empathy gap concept (Ariely & Loewenstein, 2006; Loewenstein, 1996).

CHAPTER SEVEN

GENERAL DISCUSSION

7.1 Summary of Thesis Results

This thesis sought to examine the effects of arousal on decision making, and specifically on risk-taking. Arousal level was manipulated either by increased level of monetary reinforcement, money being a powerful secondary reinforcer, or through increased MTI arousal via use of a hand dyno. One gambling task employed was the Iowa Gambling Task (IGT), a paradigm which aims to simulate real life decision making, by factoring rewards, punishments and uncertain outcomes. The IGT involves learning that the optimal strategy is to choose from the 2 'good' card decks which pay less immediately but, through lower losses, secure a long term gain, and avoiding the 2 'bad' decks which have larger immediate wins but larger losses, leading to a long term shortfall. The IGT is purported to make use of emotional arousal via somatic markers which allow for the learning of the deck contingencies on the IGT. The second gambling task was a novel probabilistic gambling task, named the Explicit Gambling Task (EGT) (piloted in Experiment 1 /Chapter Two), which aimed to investigate risk taking behaviour without the element of strategy learning involved on the IGT. An element of risk-taking was inherent to the EGT, with the least probable option of the two choices always associated with the highest possible win or the lowest possible loss.

In an investigation into the effects of increased monetary reinforcement on the IGT (Experiment 2), it was found that increased cash reinforcement led to impaired performance compared to the standard cash amount version. This effect was only found when participants knew the winnings would be paid out, compared to when they were informed it would not, demonstrating an effect of type of reinforcement also, and consistent with the effect being mediated by a greater emotional engagement on the task. These findings also add to other criticisms of the SMH, since this demonstration of highly task relevant emotional arousal disrupting decision making on the IGT is clearly inconsistent with the claims of the SMH (Bechara & Damasio, 2005; Naqvi et al., 2006). The MTI arousal manipulation also impaired IGT performance (Experiment 3). This detrimental effect of non-valenced arousal appears inconsistent with the predictions of the SMH which posit that a strong but neutral somatic background should amplify somatic signals and thus enhance decision making (Bechara & Damasio, 2006). The disproportionate effect of MTI Medium Arousal level, compared to the High Arousal condition was interpreted in terms of a misattribution of arousal (Schachter & Singer, 1962), consistent with a mismatch between actual exertion and subjective reported arousal level reported in Experiment 4. The reported effects of reinforcement type and level and physiological arousal on performance has implications for future use of the IGT, a commonly used test in both healthy and neuropsychological populations.

Although there are many reports of mood effects on risk-taking, the direction these effects take is highly inconsistent. The two arousal manipulations in this current body of work both led to increased risk-taking on the EGT (Experiments 5, increased monetary reinforcement; Experiment 6, MTI arousal), suggesting that general arousal may be a confounding factor neglected in previous experimental studies of (categorical) affective influences on risk. In addition, Experiment 5 indicated that the type and level of reinforcement may be an important variable in gambling experiments more generally. In both experiments, risk-taking effects were seen where the option probabilities were more extreme and, in response to MTI arousal-induction, these effects were more evident in Lose trials. Inconsistent with mood maintenance/ regulation models previously applied to affective influences on risk-taking (e.g., Forgas, 1995; Isen & Labroo, 2003; Wegener & Petty, 1994), risk-taking was induced without any change in subjective mood. Although not ruling out impaired implicit learning as a factor in the IGT studies, the finding of increased risk-taking on the EGT as a result of the same arousal manipulations suggests that increased risk-taking may be a factor in interpretation of the IGT results (Experiment 2 and 3).

The final experiment (Experiment 7) aimed to investigate whether MTI arousal could affect behaviour on an area of real-world decision making in which arousal is clearly implicated: sexual decision making. It was found that MTI arousal increased the reported likelihood of engaging in 'morally questionable means to obtain sexual gratification' on a Sexual Decision Making Questionnaire (Ariely & Loewenstein, 2006). The results, interpreted in terms of misattribution of arousal (Schachter & Singer, 1962) or excitation transfer (Zillmann, 1971), provided a further example of task irrelevant, or incidental, arousal effects and is believed to be the first study to demonstrate an effect of non-sexual arousal on sexual behaviour intentions, and moral judgements in particular.

No effects of arousal were found on subjective state measures in any of the gambling experiments in this thesis, despite behaviour arousal effects. In the investigation into Sexual Decision Making (Experiment 7) arousal effects on the questionnaire scores were accompanied by higher scores on Thayer's AD ACL (Thayer, 1986) but, when specifically questioned on awareness of MTI arousal effects on their questionnaire responses, participants exhibited a lack of any appreciation of the arousal-induced shift. The lack of any reported difference in subjective state in the gambling experiments fits with the idea that affect-driven processes are often not available to consciousness (Bechara et al, 1997; Loewenstein et al. 2001; Kahneman, 2003). Loewenstein and colleagues claim that a lack of introspective access to the processes from which the biases are derived means that individuals are often unable to correct for affective biases, even if they wish to make unemotional judgments (Ariely & Loewenstein, 2006; Camerer, Loewenstein, & Prelec, 2005).

7.2 Implications of the Experimental Results for the Somatic Marker Hypothesis (SMH)

7.2.1 Did induced arousal affect implicit learning or explicit risk-taking?

The arousal–induced detrimental effects on IGT performance effects were not accompanied by any significant difference in subjective deck ratings. This could mean either that participants in the arousal conditions who performed badly choose to ignore conscious knowledge, preferring the riskier option, or that conscious knowledge alone is not sufficient to guide behaviour. In order to explore these possibilities, past debate on the extent of explicit/ implicit knowledge will be considered.

It is claimed that the IGT is reliant on intuitive, emotional learning processes which precede any explicit knowledge (Bechara & Damasio, 2005; Bechara et al., 1997; Damasio, 1994). Bechara and colleagues (Bechara et al., 1997) compared the development of knowledge on the IGT in healthy controls and VMPFC patients. They reported that, in most healthy controls, aSCRs developed in response to disadvantageous choices and good deck selection increased in the pre-hunch period (approximately card 10 -50). Patients did not develop aSCRs to the bad decks and never experienced the 'hunch' phase (development of a gut feeling and the ability to guess at which decks were good or bad, approximately card 50-80). Also, three of the controls never reached the 'conceptual' phase (ability to accurately report deck contingencies) but performed normally. These findings were taken as support for intuitive processes, or implicit knowledge, preceding explicit awareness. The aSCRs are claimed to reflect complex covert biases which reflect the accessing of an individual's past records of reward and punishment, as relevant to the decision at hand, with damage to the ventromedial cortices preventing access to these personal records.

Especially relevant to this thesis' findings is the interpretation given of control participants who report explicit knowledge but perform poorly. It has been claimed that such controls (e.g., Bechara et al., 1997; Maia & McClelland, 2004) are analogous to the three VMPFC patients who performed poorly on the IGT despite developing conceptual knowledge (although never went through the 'hunch' phase) (Bechara et al., 1997). In the same way, such patients tend to report advantageous personal and social decision making yet seem unable to actually execute such decisions well in real life. This is said to be an indication that conscious knowledge of the correct strategy is not sufficient to decide advantageously, either on the IGT or in the real world (Naqvi et al., 2006). This can be seen as relevant to the poorly performing participants in the arousal conditions of both IGT experiments in this thesis who reported explicit knowledge (as measured by the deck ratings) comparable with Control (or Low Arousal condition) participants.

Whether the somatic biases which are proposed to aid decision making on the IGT operate consciously or unconsciously, and at what point any explicit knowledge of IGT contingencies develops has been much debated (e.g., Dunn et al., 2006). Studies which have questioned participants have demonstrated the existence of explicit knowledge far earlier than original accounts suggest (Bowman et al., 2005; Maia & McClelland, 2004). For example, Maia and McClelland (2004) used more detailed questions and found that good performance was nearly always associated with the ability to verbally report fairly accurate qualitative and quantitative knowledge of the deck contingencies which could be used to guide behaviour. This led Maia and McClelland (2004) to conclude that non conscious somatic markers are not required in the decision making process. Bowman et al. (2005) also demonstrated knowledge above chance level as early as after the first block of 20 cards. This was also the case with control participants in this thesis (Experiments 2 and 3). The current results showed that explicit knowledge, as measured by subjective deck ratings developed the same in normal and impaired performance. In a rebuttal to the Maia and McClelland (2004) paper, it was claimed that if the IGT can be cognitively penetrated, unlike previously thought, then this need not pose a problem for the SMH: 'The central feature of the SMH is not that non-conscious biases accomplish decisions in the absence of conscious decisions but rather than emotion-related signals assist cognitive processes even when they are non-conscious.' (Bechara et al., 2005, p. 159). They also point out that the Maia & McClelland (2004) study did not measure SCRs or the effects of brain damage and therefore cannot disprove that VMPFC mediated visceral responses are involved in decision making, only showing that advantageous decision making occurs at around the same time as conscious awareness. Some authors, however, have seen this as a major retreat from earlier papers which stressed the unconscious nature of somatic markers. Dunn et al. (2006) consider that the now proposed parallel development of overt awareness alongside covert biases is problematic for the SMH, undermining the validity of and the and necessity for somatic markers, making the SMH a far less parsimonious account of emotionally-biased decision making. Dunn et al. (2006) have also proposed that the existence of participant awareness earlier than previously claimed means that the aSCRs found on the IGT could represent conscious knowledge of the situation rather than being causally involved in deciding on which card to choose. It may be of interest to this debate to carry out further research to examine whether the effects of arousal level on IGT found in this thesis are mediated by SCRs or other physiological measures.

Within psychology, the concept of implicit learning itself is not without controversy (Shanks, 2005). In particular the use of direct questioning to access knowledge has been criticised, since participants may fail to mention factors which they feel are irrelevant or in which they have little confidence. The nature of the bias which shifted behaviour on the IGT despite conscious knowledge can be speculated upon, although since this influence can be induced through physical exercise it is likely to be some form of arousal-based feedback. The finding of poor performance in the arousal conditions despite explicit knowledge may signify the impairment of the emotion-based processes necessary (in addition to conscious knowledge of strategy) for advantageous decision making (Navqi et al., 2006). However, the finding of increased risk-taking on the EGT when the same arousal manipulations were applied may suggest that impaired IGT performance was mediated by an increased salience of reward and tendency to take risks. A full exploration of the development and contribution of implicit versus explicit knowledge was not an initial aim of this research and, as discussed in Chapters Three and Four, such an investigation would benefit from fuller questioning in order to tap conscious knowledge on the IGT, since the deck ratings in the current research may only equate to the 'hunch' period rather than full conceptual knowledge.

It may be that more complex dissociation procedures (e.g., Anderson et al., 1997; Jacoby, 1991; Stocco & Fum, 2008) are needed to assess the extent of explicit versus implicit knowledge necessary for advantageous performance on the IGT. A dissociation task is one in which participants complete a task followed by a secondary task in which implicit and explicit knowledge drive behaviour in opposite directions. However, as will now be discussed, it may be that the distinction between explicit conscious processes and emotional unconscious influences is more of a continuum than a clear dichotomy which can be experimentally dissociated.

7.2.2 Judgment and decision making theory perspective on conscious and unconscious processes and 'intuition'.

Within judgment and decision making theory (JDM) a two system dichotomy of processes has now become very influential (Camerer et al., 2005; Kahneman, 2003; Slovic et al.,, 2004; Wang, 2006). Within this framework the S1 system describes processing which is automatic, rapid, effortless, inaccessible to consciousness and difficult to modify, while the S2 system refers to processes which are slower, serial, involve deliberate effort and control, and are relatively flexible. Epstein (1994) referred to the two systems as the 'experiential' and the 'rational', respectively, although Slovic et al. (2004) renamed the 'rational' as the 'analytical' in recognition that there are elements of the rational in both systems with an interplay between both systems often leading to optimum behaviour. Price and Norman (2008) point out, however, that within the S1/S2 dichotomy there is confusion over where exactly 'intuition' falls in the distinction between conscious and non-conscious processes. It is unclear whether intuition is a mere behavioural disposition, not directly available to consciousness, or whether intuition is able to generate conscious impressions, or hunches.

Drawing on Mangan's revival of the Jamesian concept of fringe consciousness (Mangan, 2003) and Koriat's concept of experience-based metacognitive judgment (Koriat, 2007), Price and Norman (2008) believe that intuition should be classified as 'an informative conscious feeling without conscious access to the antecedents of the feeling' (2008, p.28), and, ' a vital component of consciousness that functions as an interface between the non-conscious and the conscious' (2008, p.33). This would seem to equate to the idea of 'hunches' and 'gut feelings' proposed to guide behaviour on the IGT and in the real world, according to the SMH (e.g., Bechara & Damasio, 2005; Bechara et al., 1997). It is thus claimed that rather than a strict conscious/ unconscious dichotomy, it may be more appropriate to conceive of a continuum between the two types of processing (Hastie, 2001; Price & Norman, 2008), with intuitive feelings allowing for greater control over behaviour than would be allowed by purely implicit biases. With regard to the EGT, the shift in choice behaviour and quicker responses in the MTI arousal conditions may reflect a relative shift along the continuum from the S2 system to the more rapid, heuristic S1 system.

7.2.3 Task relevant versus task irrelevant arousal effects on the IGT

Chapter Three (Experiment 2) is an example of increased cash reinforcement, a highly task relevant form of emotional arousal interfering with performance on the IGT. This is inconsistent with the claims made that the disruptive influences of excessive emotional arousal on decision making only occur when that emotion is irrelevant to the task at hand. Instead it appears that, even with task relevant emotional arousal, an optimum level may exist, and where this level is exceeded behaviour may shift to become disadvantageous over the long term. The nature of this shift towards the decks with higher payouts but lower long term outcome, over those with more modest payouts but higher long term net gain is discussed in terms of a greater tendency toward pre-potent reward driven responding over a more cognitive consideration of long term consequences, or a relative shift from 'cooler' cognitive processing to 'hot' emotional processing (or from S2 to S1 according to the previous section's nomenclature). It is interesting that such a shift from 'cold' to 'hot' processing can be induced by task relevant emotion on the IGT, when it has been claimed that learning on the task occurs through emotion-based processes often, initially, without conscious awareness (Bechara et al., 1997; Bechara & Damasio, 2005). Also, a shift in behaviour in response to this task relevant arousal (increased monetary reinforcement) was found on the EGT, a task without the proposed involvement of emotion-based, unconscious learning. This suggests that, successful learning on the IGT may also involve some input from cooler cognitive and presumably explicit, processes.

MTI arousal could be considered a task irrelevant arousal manipulation. However, it could also be viewed as inducing a stronger but neutral background somatic state, which would then be predicted to amplify somatic signals from the IGT and enhance decision making and long term considerations (Bechara & Damasio, 2005). MTI arousal was found to impair performance, however, consistent with the concept of an optimum level even for a relatively neutral background somatic state. Again, effects of the same task irrelevant arousal manipulation were also seen on the EGT, suggesting that at least part of the effect of both increased monetary reinforcement and MTI arousal on the IGT involved an increased tendency towards risk-taking behaviour rather than purely a deficit in implicit learning.

It should also be noted that the two tasks may therefore not be fundamentally different, with the EGT measuring probabilistic risk-taking without any element of learning and less working memory load, while the IGT most likely involves a combination of explicit and implicit processes. These findings add to further criticism of the SMH which has been largely based on data from the IGT. As well as debate over the extent of conscious versus unconscious knowledge and controversy over what the SCR measures represent, it has also been argued that impaired performance on the IGT, rather than being attributable to a disruption in emotion based learning processes and a 'myopia for the future' could be attributed to risk-taking tendencies, or impairments of working memory or reversal learning (for review, see Dunn et al., 2006).

7.3 Effects of Monetary Reinforcement on Gambling Tasks

Contrary to previous research (Bowman & Turnbull, 2003; Fernie & Tunney, 2006) this research has shown that type and level of reinforcement has an effect on IGT behaviour; the finding that a condition with 5 x the standard cash amount disrupted performance, while the same condition with participants made aware the winnings would not be paid did not, suggests that this was due to the level of arousal induced by increased monetary reinforcement. Behaviour on the EGT was also affected by paying real cash compared to points, and it seems intuitive that giving participants the chance to play with real cash in gambling experiments would result in a greater level of emotional engagement. The current research therefore has implications for future gambling experiment testing suggesting that, where practical and ethical to do so, the use of real cash may allow for more ecologically valid results.

7.4 Emotion and Cognition as 'Hot' versus 'Cold' Influences on Decision Making

In accounts of self-control it appears that a dichotomy of emotional versus rational modes has been ubiquitous throughout studies of behaviour, from multiple perspectives. From the early days of Greek philosophy and the debates on the relative virtues of passion and reason, to Freudian accounts of the struggles between the primitive, pleasure-driven 'id' and the reality-governed ego (Freud, 1924), to more recent accounts within psychology (e.g., Chaiken & Trope, 1999; Metcalfe & Mischel, 1999), modern psychodynamic theory (Epstein, 1994) and recent advancements concerning the S1/S2 system distinction within economics (e.g., Camerer et al., 2005; Kahneman, 2003; Slovic et al., 2004) . Metcalfe and Mischel (1999) proposed two interconnected systems, the 'hot' emotional system and the cognitive 'cool' system. The cool system is an unemotional cognitive system, which is slow and contemplative, allowing for rational and reflective behaviour. In contrast, the hot system facilitates fast and simple emotional processing. The hot system is largely automatic, useful from an evolutionary perspective in that it enables simple stimulus-response type appetitive behaviours or 'fight or flight' reactions in the presence of triggering stimuli. The two systems are proposed to be closely interconnected and constantly interacting, such that hot processing can be triggered by cool, cognitive deliberation and emotional processing can be reined in by effortful control and willpower exerted by the cool cognitive system. It is assumed that the hot/cool balance depends on the stress level, both as triggered by the situation and as characteristic for that individual. Whereas at mild to moderate levels of stress the cool system is largely in control, at higher levels of stress its influence may be greatly reduced or totally absent. As such, delayed gratification becomes especially difficult under times of stress. Similarly, Loewenstein and O'Donoghue (2004) assume behaviour is an interaction between a 'deliberate' and an 'affective' system. They propose that the affective system is usually in control, but that the deliberative system can influence the affective through the exertion of cognitively costly willpower. It is presumed that the physical proximity of a desired object, or an indication of proximity, will promote more appetitive responses or 'hot' influences on decisions and therefore these decisions will be more impulsive (Loewenstein, 1996; Metcalfe & Mischel, 1999). Risk-taking decisions can be considered to involve interactions between many cognitive factors upon which affect may have an influence, such the availability of cognitive resources, memory processes and the choice of decision making strategy (Yuen & Lee, 2003).

The idea of a dual mode of processing is upheld by neuroscience research. Although the exact neural substrates of these two systems remain to be located more precisely, it is thought that the cool system is associated with the hippocampus and (dorsolateral frontal lobes (Lieberman, Gaunt, Gilbert, & Trope, 2002; Metcalfe & Mischel, 1999) while the locus of the hot system is thought to be the amygdala and ventromedial prefrontal cortex (Gray, 1987; LeDoux, 1996). LeDoux (1996) has also made the distinction between 'quick and dirty' unconscious, sub-cortical emotional processing and slower, more reasoned, cortical input. In a PET study, Drevets and Raichle (1998) reported that many areas associated with emotional processing, such as the amygdala and the ventral anterior cingulate experienced enhanced blood flow during emotional task, with reduced activity during attentionally demanding cognitive tasks. Conversely, many areas associated with cognitive processing, such as the such as the dorsal anterior cingulate and the dorsolateral prefrontal cortices exhibited increased activity during the cognitive tasks but decreased activity during pathological or experimentally induced emotional states. The authors believe this demonstrated an important cross modal interaction within mental processing. With regard to delay of gratification, McClure et al. (2004) also reported a cognitive / emotional dissociation in brain activity consistent with the two systems driving behaviour in contrary ways on an intertemporal choice task. The relative activity of affective dopaminergic midbrain areas versus regions considered more cognitive, such as the lateral prefrontal and posterior parietal cortex, predicted choices of earlier or later receipt, respectively. Another fMRI study found that presentation of emotional distracters not only induced activity in typical emotional processing areas, such as the amygdala and ventrolateral prefrontal cortex but that they simultaneously reduced activation in working memory areas and had a detrimental effect on working memory (Dolcos & McCarthy, 2006).

These results hold implications for the mechanisms by which cognition and emotion may interact, and suggest an underlying process by which affective state could affect the quality of decision making. It has been claimed that the SMH is an example of the interaction of hot/ cold systems, with the ventromedial prefrontal cortex conceptualised as the cool system and the amygdala as the hot system (Mischel & Ayduk, 2004). The amygdala is essential for experiencing the emotional states and the ventromedial prefrontal cortex is crucial in the integration of the emotional information in a coherent manner, to be used as feedback in subsequent decisions. Patients with damage to either part of the system experience decision making deficits, highlighting the need for both interacting systems to be intact in order to choose to delay gratification for a larger reward. However, although many studies have demonstrated a relative functional specificity of brain areas according to whether they are involved in emotional or more cognitive processing, it has also now been proposed that there is a level of processing at which functional divisions disappear and emotion and cognition jointly contribute to thoughts and behaviour (Gray, Braver, & Raichle, 2002; Pessoa, 2008)

7.4.1 Pre-potent responding

It has been proposed that different brain systems contribute at different stages of advantageous IGT performance (Bechara & Damasio, 2005). In the early stages the dopaminergic reward system is relatively active, necessary for integrating wins and losses as cards are initially sampled, while the latter stages require serotonin-mediated self-control. Other authors have also suggested that midbrain dopaminergic and systems and dorsal raphe serotonin may act as opponent systems in reward learning (for review, see Daw, Kakade, & Dayan, 2002). These proposed opponent brain systems seem to map onto the concept of pre-potent responding. Pre-potent responding describes the tendency towards simple stimulus-response, reward-driven responding behaviour, driven by internal motivational states (analogous to the S1 or hot system). It has been proposed that an inhibitory control mechanism exists in the prefrontal cortex which can control this kind of behaviour (analogous to the S2 or cold system) (Dias et al., 1997). In this way behaviour can be influenced more by slower cognitive processes and the consideration of long term considerations rather than allowing innate or conditioned appetitive responses and reflexes mediated by sub cortical structures to dominate. According to this concept a shift between the two systems focuses on a relative shift in balance between action ('hot') and deliberation ('cold'). A tendency to take risks or act impulsively would most likely have conferred an evolutionary advantage; on seeing desirable food the optimal strategy would have been to eat it and refraining from the chance for sexual intercourse would not have promoted propagation of genes. However, with emotional impulses driving behaviour towards stimuli despite, or in absence of any cognitive evaluation, this pre-potent response mechanism can therefore be maladaptive in complex, modern human society (Arnsten & Goldman-Rakic, 1998), and the inability to inhibit pre-potent affective responding has been linked with addiction and pathological gambling (Bechara, 2003).

7.4.2 Risk as feelings

This concept of dual processes can be useful when considering decision making under risk. Loewenstein et al. (2001) proposed the risk as feelings hypothesis (RAFH) specifically to account for the role of affect in response to risky situations, including decision making. The RAFH proposes that we evaluate risk on two levels; we experience an emotional reaction and also evaluate them in a more dispassionate, analytical way. Whereas cognitive evaluations are deliberate analysis of probability estimates and assessment of potential outcomes, emotional reactions to risk are an immediate, visceral reaction resulting in part from direct, i.e. not cortically mediated, affective responses (LeDoux, 1996; Zajonc, 1980). Thus, emotional responses are often conditioned responses, more enduring than other forms of learning and not available to consciousness. Emotional reactions are especially influenced by mental imagery and vividness, evolutionary preparedness, current internal motivational state and temporal proximity. In this way, whereas cognitive evaluations take probability into account, emotional reactions to risk are often insensitive to probability and more focused on outcome, i.e. on receipt of reward or avoidance of punishment (e.g., Monat et al., 1972; Viscusi, Magat, & Huber, 1987). It could be seen that the expected utility model of decision making under risk, upon which some modern economic frameworks are still based (Mayo, 2000), coincide with the rational system but largely ignore the other, interconnected, emotional system. Whereas the SMH stresses the complementary role of emotion and cognition, the RAFH stresses that emotional and cognitive processes, although interrelated, may lead to different evaluations of the same circumstances and drive behaviour in opposite directions. For example, we may overreact to unfamiliar risks which we know are statistically highly unlikely. This explains, for example why fear of terrorist acts may be disproportionately high while people will under react to more everyday, higher probability risks, such as driving, or why an individual cannot rationalise themselves out of the improbable harm associated with a phobia (Barlow, 1988).

By experimentally increasing arousal the research in this thesis can be viewed as altering the 'hot' affective system indirectly and examining those effects on cognition. In this body of work, arousal can be viewed as shifting the balance between hot and cold systems; a shift which is likely to be mediated by central arousal neurotransmitters, such as dopamine. The current research involving MTI arousal and arousal induced via increased magnitude monetary reinforcement demonstrated a shift towards more risk-taking behaviour (as measured by choice of the lowest probability option) on the EGT (Experiments 5 and 6). Since it has been shown that emotional reactions to risk, in contrary to cognitive evaluations, are largely insensitive to probability this suggests that the arousal manipulations succeeded in shifting the balance from a reliance on largely cognitive, 'cool' evaluations to a greater reliance on hot emotional influences on decision making, as seen in a higher level of lower probability but higher reward (or lower punishment) choices in the arousal conditions. Where it is proposed that affective influences mediate the S-shaped probability curve which is generally seen in economic decision making (i.e. the deviation from the 'rational' linear probability weighting) (Loewenstein & O'Donoghue, 2004), this can be seen as a further exaggerated deviation from linear probability weighting, i.e. even greater overweighting of the low probability options. The IGT studies (Experiment 2 and 3), in addition to a study of implicit learning (as discussed above), can also be seen as involving a tension between the instant gratification of the higher paying out decks at the detriment of longer term consequences. Both arousal manipulations effected a shift in behaviour on the IGT, resulting in a relative preference for the higher payout/ low long term gain decks. The effects of MTI arousal on Sexual Decision Making (Experiment 7) can be seen as demonstrating a relative shift towards appetitive responses regarding sexual gratification (Experiment 7) and away from cooler cognitive moral reasoning. This result could also be viewed as increased risk-taking since an increased motivation to engage in morally questionable means to obtain sex could result in damage to reputation and to future attempts to obtain sexual intercourse and peer and societal disapproval. Overall, these experimental results demonstrate that changes in risk-taking behaviour can be seen without increasing the physical or temporal (actual or perceived) proximity of the desired object (sexual gratification or money). In this way general arousal not linked to a specific object or directly related to an internal state can shift the balance between 'hot' and 'cold' processes, making the reward in the experimental tasks more salient, hot representations more available, and reducing the influence of the cold cognitive system. Loewenstein (1996) stated that sexual desire is especially influenced by temporal proximity; however MTI arousal was able to alter motivation regarding sexual gratification, without increasing the proximity of any sexual stimuli, or of sexual arousal specifically. The demonstrated effects of generalised arousal on risk taking in this thesis suggest that the theories of excitation transfer (Zillmann, 1971) or misattribution of arousal (Schachter & Singer, 1962) may be more relevant to studies of affective influences on risk-taking than current research focus would suggest.

7.4.3 Physiological arousal and neurotransmitter interactions

It has been speculated that the arousal effects documented in this thesis may have arisen from interactions between exercise induced NA release and other neurotransmitters. Although studied as unitary systems until relatively recently there is now emerging evidence that neurotransmitter systems may interact directly. For example, rat in vivo electrophysiological studies demonstrated that the firing activity of DA, NA and 5-HT neurons is affected by the lesioning of other neurotransmitter neurons (Guiard, El Mansari, Merali, & Blier, 2008), it has been proposed that a comprehensive account of schizophrenia may involve possible interactions between DA, glutamate, GABA, 5-HT and NA (Carlsson et al., 2001) and, in investigating the wake promoting mechanisms of the drug modafinil, DA dependent NA activity was discovered (Wisor & Eriksson, 2005). Also, there is evidence that release of most neurotransmitters may be affected by exercise (Meeusen & Demeirleir, 1995). (Also, for reviews of neurotransmitter interactions within the prefrontal cortex, see Briand, et al., 2007; Robbins et al., 2006).

7.5 Methodological Issues

7.5.1 MTI arousal

MTI arousal was shown to affect decision making behaviour and increase risk-taking on all three decision making tasks. An alternative explanation, however, would be that use of the hand dyno caused a general impairment in cognitive processing, since it has been shown that muscle fatigue can impair cognitive performance (Lorist, Kernell, Meijman, & Zijdewind, 2002). Although the exact nature of this competition is unclear, this phenomenon is explained in terms of increasing demands on the central nervous system. In sub-maximal muscle contractions a constant force can be maintained for a period by the central nervous system either recruiting increasingly greater number of motor neurones and /or by increasing the rate of discharge. It is hypothesised that cognitive impairment occurs through the increasing demands fatiguing muscles place on a central command mechanism. However, the hand dyno use in the current research was very brief (3 x 1 minutes) whereas other studies that have shown a detrimental effect of exercise on cognition have involved prolonged periods of more intense physical activity, often maximal anaerobic exercise and usually performed concurrently with the cognitive task (for review, see Tomporowski, 2003). In addition, the specificity of the MTI arousal effects (i.e. greater risk taking with the more extreme probabilities and amounts, in the EGT) suggests that the results were not merely attributable to a general impairment of cognitive processing.

MTI arousal increases bodily sensations of arousal but clearly lacks an emotional focus. However, according to classic attribution of arousal studies (Schachter & Singer, 1962) this physiological arousal would form the underlying physiological processes deemed necessary (when combined with cognitive appraisal of the environment) for emotion to occur. And, as previously discussed, a positive correlation has been demonstrated between heartbeat awareness and right anterior insula activation (Critchley et al., 2004), with activity in this area also correlated with individual ability to experience emotion. This is consistent with a view of subjective emotional experience arising at least in part from brain activity relating to physiological sensations of arousal.

7.5.2 Physiological measures of arousal

Although no physiological measures were taken in the current studies, it has been shown that just 1 minute of hand dyno use increases heart rate (Williamson et al., 2002) and, especially at the higher rate of 75% individual maximum, participants physiological exertion is obvious. As such, it has been assumed that hand dyno use in the current work also induced significant physiological arousal. Further research could record objective measures of arousal such as heart rate or SCR, although it should be noted that psychophysiological measures of arousal are not without difficulties. For example, it has been found that different measures of autonomic, cortical and somatic arousal tend not to correlate highly with one another (Barrett, Quigley, Bliss-Moreau, & Aronson, 2004). Classic studies demonstrated that the commonly used physiological measures of arousal (e.g. heart rate, skin conductance) show relatively little intra-subject reliability, therefore employing physiological measures, either singly or in combination is problematic (Thayer, 1967). Also, it may be over-simplistic to interpret visceral changes from SCR alone, since bodily responses to environmental stimuli may involve a complex collection of bodily responses (Lacey, 1967). Subjective measures (felt arousal) have been reported as being more representative of general activation than any one physiological measure (Thayer 1967, 1970). More recent studies have shown that felt arousal and physiological arousal are related (Coventry & Hudson, 2001; Logan et al 2001) and, as a result many researchers have used felt arousal as the sole measure of physiological arousal (e.g., Kerr & Tacon, 1999; Kerr, Yoshida, Hirata, Takai, & Yamazaki, 1997; Pietrowsky, Rudolf, Molle, Fehm, & Born, 1997).

Future experiments could make use of SCR measures on the IGT studies to examine whether the profile pattern differed significantly in the arousal conditions compared to control conditions, for example whether the increased arousal led to a more 'noisy' background state. It should be noted however, that interpretation of SCR data has not been straightforward. According to the SMH, the recording of elevated anticipatory SCRs prior to disadvantageous deck choices reflects developing awareness of the punishing long term consequences of the 'bad' decks (e.g., Bechara & Damasio, 2005). However, Dunn et al. (2006) discuss evidence that the recording of elevated anticipatory SCRs prior to disadvantageous deck choices may interpreted in alternative ways. For example, anticipatory

SCR changes may reflect variance between decks, or reflect expectancies of reward and punishment after the moment of deciding.

In most experiments the arousal/visual analogue measures employed were necessarily short. As opposed to lengthy questionnaires, the best measures for studying transient arousal and other emotions were considered to be those that would require as little as possible of the participant's time and attention. Brief measures thus enable reactions to be obtained relatively unobtrusively as close as possible to the event.

7.6 Implications and Future Directions

In a reversal of the main framing effect of Outcome Type on the control (Low Arousal) conditions of the EGT, it was found that the arousal manipulations led to increased risk taking seen especially in the Lose trials, consistent with economic theory predictions (Kahneman, 2003; Kahneman & Tversky, 1979) In future, design changes to the EGT could enable decision making behaviour to be assessed in terms of expected value; this would facilitate exploration of arousal effects on financial decision making from the perspective of economic theory.

Given that 3 minutes of hand dyno use evoked arousal induced effects, it would be interesting to investigate the effects of a more prolonged, and possibly more naturalistic, form of exercise on the experimental tasks. In particular it would be of interest to investigate whether a higher level of incidental arousal could cause a significant change in the other two aspects of the Sexual Decision Making Questionnaires, i.e. the attractiveness of sexual stimuli and activities and perception of risk regarding STIs and pregnancy, or whether the cross domain effect of arousal was specific to moral reasoning. Such research has clear implications for sexual health education and especially when aimed at individuals who persist in engaging in risky sexual behaviour despite being fully informed regarding the dangers (Strong et al., 2005). MTI arousal experiments have shown that a mere 3 minutes of exercise can have effects on experimental gambling tasks. It follows, therefore, that a participant rushing to an experiment late may have a very different background arousal level upon testing than one who arrived ten minutes early and sat calmly reading prior to the experiment. This has implications for testing on gambling experiments generally and particularly for the IGT, which may be used as a neuropsychological tool and where variability in healthy controls may be an issue (Adinoff et al., 2002; Bechara et al., 2002; Crone, et al., 2004) .

The current research has also highlighted that reinforcement level and type maybe a factor on gambling task generally and the IGT specifically and has challenged the SMH predictions regarding the influence of task relevant and task irrelevant, but neutral, arousal on decision making.

This research has highlighted that inconsistent results of mood on risk taking may be due to a lack of attention on arousal level. Mood maintenance models (e.g., Forgas, 1995; Isen & Labroo, 2003; Wegener & Petty, 1994) could conceivably be viewed more as cognitive models than of emotional 'hot' processing since they assume we are able to think ahead and take account of how we may feel as a result of our actions, with less focus on how affective state may impact more directly on decision at hand. It has been demonstrated, however, that we are often very poor at predicting and taking account of future emotions (Ariely & Loewenstein, 2006, Loewenstein, 1996, 2005). Although research involving the impact of emotional states on decision making has generally involved specific mood, either natural or experimentally induced, there have been some notable studies which have reported arousal as an important mediating factor (Ariely & Loewenstein, 2006; Ditto et al., 2006; Knutso et al., 2008; Loewenstein, 1996; Loewenstein et al., 1997; Mano, 1992; Wilson & Daly, 2004). These studies and the experimental results of this thesis are more consistent with a dimensional model of emotion, where emotions are seen as occurring along two continuous dimensions of arousal and valence (e.g., Yik, Russell, & Barrett, 1999) rather than a view of emotions as discrete, bounded categories (e.g., Ekman, 1992).

7.7 Concluding Comments

The work in thesis has demonstrated that even subtle increases in non-specific arousal, may produce a shift in behavioural responding. In the experiments reported here, heightened arousal (non-valenced, task-related or incidental), led to an increase in risk-taking behaviour, without reported subjective awareness or change in subjective state. It is concluded, therefore, that arousal may be an important mediating factor in the shift in relative balance between 'cold' deliberative reasoning (S2 processes), which may better take account of long-term considerations, towards a greater reliance on 'hot' emotional (S1) processing, more concerned with immediate reward (or avoidance of punishment). Thus, increased arousal increases the tendency to engage a pre-potent, stimulus-bound response (as opposed to a more deliberate one), leading to behaviour which is more stimulus-bound and impulsive. Arousal level may therefore be a neglected factor in research into affective influences on risk-taking, which have largely focused on specific mood.

It has been argued that all behaviour is choice behaviour and therefore any studies of decision making are crucial to a general theory of human functioning (Rachlin, 1989). Understanding the shift from a decision making process which takes account of future consequences to a more emotional, short term, reward-driven mode of processing is important since failures of self control have implications that extend beyond the individual, to affect their immediate social group and society at large. It can be seen that risk-taking and lack of control underlies many societal problems, whether that involves an individual's failure to control their finances, their weight, their temper, a craving for drugs or alcohol, or sexual impulses. With regard to relative merits of hot emotional systems versus cooler cognitive analytical processing, it can be seen that both systems have their advantages and their limitations, and it is known that emotion is essential for optimal 'rational' decision making. A future challenge for psychology may be to creatively explore how cooler cognitively-moderated willpower and self-restraint can be harnessed to rein in the strong emotions induced in circumstances involving risk.

Appendix A : IGT participant instructions for Experiment 2, (excluding Fake x5 condition)

Welcome ...your goal is to win as much money as possible!

- You will be shown 4 decks of cards and you must decide which deck you wish to draw from. Selection is made by pressing the numbers 1, 2, 3 or 4.
- On every card you will win some money, but on some you will also lose money.
- After you've picked from a deck, the outcome will be displayed on the deck you selected (e.g. "You won 10p .. and lost 5p,").
- Throughout the game your Total Winnings will be displayed above the decks and also as a chart at the top of the screen.
- There will be a long series of card selections - keep playing until the game stops.
- You are free to swap decks at any time and as often as you wish.
- It is impossible for you to work out when you will win or lose money. Some decks are worse than others, but no matter how much you find yourself losing, you can still win if you stay away from the worst decks.
- You start with a £2 loan and, when you finish the experiment, **the cash winnings are yours!**

If you have any questions, feel free to ask the experimenter now.

Appendix B: The Explicit Gambling Task participant instructions, Experiment 1

In this gambling game you will start with 300 points. Your aim is to increase this score by as much as possible by making whatever choices you think necessary. These choices may involve either conservative or more risky decisions.

You will see a grid made up of coloured boxes. One of these boxes hides a reward and you need to choose the colour of the box you believe the reward is hidden in by pressing the appropriately coloured key on the keyboard.

Each colour is associated with an amount you can win if correct and an amount you can lose if incorrect. On some trials you will not lose points if incorrect, only score points if you are correct, whilst on other trials you will not win points if correct, only lose points if incorrect. This information is shown to you on the screen before you make your choice and should be used to help make your decision. When the boxes containing the Win/Lose amounts appear on the screen you will need to wait a moment until the amounts become black before you can make your choice. There is no time limit.

Following each decision, you will be shown the position of the reward and informed whether you won or lost. Throughout the experiment you will also be able to see your score.

The position of the 2 colours on the grid, the accompanying win or lose amounts and the location of the reward on the grid varies but there is an equal probability that the reward could be hidden in any of the 16 boxes.

To familiarise yourself with the task you will have a practise run before the main experiment; please ask if you need further clarification.

Appendix C: IGT participant instructions, Experiment 2, Fake x5 condition

Welcome ...your goal is to win as much money as possible!

- The game starts with a loan of £2.
- You will be shown 4 decks of cards and you must decide which deck you wish to draw from. Selection is made by pressing the numbers 1, 2, 3 or 4.
- On every card you will win some money, but on some you will also lose money.
- After you've picked from a deck, the outcome will be displayed on the deck you selected (e.g. "You won 10p .. and lost 5p,").
- Throughout the game your Total Winnings will be displayed above the decks and also as a chart at the top of the screen.
- There will be a long series of card selections - keep playing until the game stops.
- You are free to swap decks at any time and as often as you wish.
- It is impossible for you to work out when you will win or lose money. Some decks are worse than others, but no matter how much you find yourself losing, you can still win if you stay away from the worst decks.
- Please be aware that **the winnings are for the purpose of the game only and will not be paid out.**

If you have any questions, feel free to ask the experimenter now.

Appendix D: Win and Loss schedule for the IGT, Control condition, Experiment 2; all conditions Experiment 3.

Deck A (each card wins 10p)	**Deck B** (Each card wins 10p)	**Deck C** (Each card wins 5p)	**Deck D** (Each card wins 5p)
-15p		-5p	
-30p		-5p	
-20p		-5p	
-25p	-£1.25	-5p	
-35p		-5p	-25p
-35p		-3p	
		-8p	
-25p	-£1.25		
-20			
-30p		-3p	
-15p		-8p	
		-5p	-25p
	-£1.25		
-30p			
-35p		-5p	
		-2p	
-20p		-5p	
-25p			
-15p			
		-8p	-25p
		-5p	
-35p			
-20p	-£1.25		
-25p			
		-2p	
		-2p	-25p
-15p		-8p	
-30p			
		-5p	
		-8p	

Appendix E: Win and Loss schedule on the IGT, Experiment 2, Cash x2.5 condition.

Deck A (each card wins 25p)	**Deck B** (Each card wins 25p)	**Deck C** (Each card wins 13p)	**Deck D** (Each card wins 13p)
-15p		-13p	
-30p		-13p	
-20p		-13p	
-25p	-£1.25	-13p	
-35p		-13p	-63p
-35p		-7p	
		-20p	
-25p	-£1.25		
-20			
-30p		-7p	
-15p		-20p	
		-13p	-62p
	-£1.25		
-30p			
-35p		-13p	
		-7p	
-20p		-5p	
-25p			
-15p			
		-20p	-63p
		-13p	
-35p			
-20p	-£1.25		
-25p			
		-7p	
		-7p	-62p
-15p		-20p	
-30p			
		-13p	
		-20p	

Appendix F: Win and Loss schedule on the IGT, Experiment 3, Cash x5 and Fake x5 conditions.

Deck A (each card wins 50)	**Deck B** (Each card wins 50p)	**Deck C** (Each card wins 25p)	**Deck D** (Each card wins 25p)
-75p		-25p	
-£1.50p		-25p	
-£1		-25p	
-£1.25p	-£6.25	-25p	
-£1.75p		-25p	-£1.25p
-£1.75p		-25p	
		-40p	
-£1.25p	-£6.25		
-£1			
-£1.50p		-15p	
-75p		-40p	
		-25p	-£1.25p
	-£6.25		
-£1.50p			
-£1.75p		-25p	
		-10p	
-£1		-25p	
-£1.25p			
-75p			
		-40p	-£1.25p
		-25p	
-£1.75p			
-£1	-£6.25		
-£1.25p			
		-10p	
		-10p	-£1.25p
-75p		-40p	
-£1.50p			
		-25p	
		-40p	

Appendix G : Visual Analogues of subjective experience

Please mark a dash along the line - as a subjective rating of how you currently feel

How happy are you?

Not ____ Very

How tired are you?

Not ____ Very

How tense/anxious are you?

Not ____ Very

How emotionally aroused are you?

Not ____ Very

Appendix H: IGT participant instructions for Experiment 3.

Welcome ...your goal is to win as much money as possible!

- You will be shown 4 decks of cards and you must decide which deck you wish to draw from. Selection is made by pressing the numbers 1,2,3 or 4.
- On every card you will win some money, but on some you will also lose money.
- After you've picked from a deck, the outcome will be displayed on the deck you selected (e.g."You won 10p .. and lost 5p").
- Throughout the game your Total Winnings will be displayed above the decks and also as a chart at the top of the screen.
- There will be a long series of card selections - keep playing until the game stops.
- You are free to swap decks at any time and as often as you wish.
- It is impossible for you to work out when you will win or lose money. Some decks are worse than others but, no matter how much you find yourself losing, you can still win if you stay away from the worst decks.
- The game will stop once for you to use the hand grip device again - the experimenter will instruct you.
- You start with a £2 loan and, when you finish the experiment, **the cash winnings are yours to keep!**

If you have any questions, feel free to ask the experimenter now.

Appendix I: The Explicit Gambling Task participant instructions, Experiment 5, Low Arousal condition

In this gambling game you will start with 300 points. Your aim is to increase this score by as much as possible by making whatever choices you think necessary. These choices may involve either conservative or more risky decisions.

You will see a grid made up of coloured boxes. One of these boxes hides a reward and you need to choose the colour of the box you believe the reward is hidden in by pressing the appropriately coloured key on the keyboard.

Each colour is associated with an amount you can win if correct and an amount you can lose if incorrect. On some trials you will not lose points if incorrect, only score points if you are correct, whilst on other trials you will not win points if correct, only lose points if incorrect. **This information is shown to you on the screen before you make your choice and should be used to help make your decision.** When the boxes containing the Win/Lose amounts appear on the screen you will need to wait a moment until the amounts become black before you can make your choice. There is no time limit.

Following each decision, you will be shown the position of the reward and informed whether you won or lost. Throughout the experiment you will also be able to see your score.

The position of the 2 colours on the grid, the accompanying win or lose amounts and the location of the reward on the grid varies but there is an equal probability that the reward could be hidden in any of the 16 boxes.

To familiarise yourself with the task you will have a practise run before the main experiment; please ask if you need further clarification. **If this is not your first session in this study you should not rely on your memory of where you think the correct response is, as each game will differ.**

Appendix J: The Explicit Gambling Task participant instructions, Experiment 5, Medium Arousal condition

In this gambling game you will start with £3. Your aim is to increase this score by as much as possible by making whatever choices you think necessary. These choices may involve either conservative or more risky decisions. The total cash winnings are yours to keep and will be paid out at the end of today's experiment.

You will see a grid made up of coloured boxes. One of these boxes hides a reward and you need to choose the colour of the box you believe the reward is hidden in by pressing the appropriately coloured key on the keyboard.

Each colour is associated with an amount you can win if correct and an amount you can lose if incorrect. On some trials you will not lose points if incorrect, only score points if you are correct, whilst on other trials you will not win points if correct, only lose points if incorrect. This information is shown to you on the screen before you make your choice and should be used to help make your decision. When the boxes containing the Win/Lose amounts appear on the screen you will need to wait a moment until the amounts become black before you can make your choice. There is no time limit.

Following each decision, you will be shown the position of the reward and informed whether you won or lost. Throughout the experiment you will also be able to see your score.

The position of the 2 colours on the grid, the accompanying win or lose amounts and the location of the reward on the grid varies but there is an equal probability that the reward could be hidden in any of the 16 boxes.

To familiarise yourself with the task you will have a practise run before the main experiment; please ask if you need further clarification. **If this is not your first session in this study you should not rely on your memory of where you think the correct response is, as each game will differ.**

Appendix K: The Explicit Gambling Task participant instructions, Experiment 5, High Arousal condition

In this gambling game you will start with 300 points. Your aim is to increase this score by as much as possible by making whatever choices you think necessary. These choices may involve either conservative or more risky decisions. A high point score may win you a £35 cash prize!

You will see a grid made up of coloured boxes. One of these boxes hides a reward and you need to choose the colour of the box you believe the reward is hidden in by pressing the appropriately coloured key on the keyboard.

Each colour is associated with an amount you can win if correct and an amount you can lose if incorrect. On some trials you will not lose points if incorrect, only score points if you are correct, whilst on other trials you will not win points if correct, only lose points if incorrect. This information is shown to you on the screen before you make your choice and should be used to help make your decision. When the boxes containing the Win/Lose amounts appear on the screen you will need to wait a moment until the amounts become black before you can make your choice. There is no time limit.

Following each decision, you will be shown the position of the reward and informed whether you won or lost. Throughout the experiment you will also be able to see your score.

The position of the 2 colours on the grid, the accompanying win or lose amounts and the location of the reward on the grid varies but there is an equal probability that the reward could be hidden in any of the 16 boxes.

To familiarise yourself with the task you will have a practise run before the main experiment; please ask if you need further clarification. **If this is not your first session in this study you should not rely on your memory of where you think the correct response is, as each game will differ.**

Appendix L: The Explicit Gambling Task Instructions, Experiment 6

In this gambling game you will start with £3. Your aim is to increase this score by as much as possible by making whatever choices you think necessary. These choices may involve either conservative or more risky decisions. The total cash winnings are yours to keep and will be paid out at the end of today's experiment.

You will see a grid made up of coloured boxes. One of these boxes hides a reward and you need to choose the colour of the box you believe the reward is hidden in by pressing the appropriately coloured key on the keyboard.

Each colour is associated with an amount you can win if correct and an amount you can lose if incorrect. On some trials you will not lose points if incorrect, only score points if you are correct, whilst on other trials you will not win points if correct, only lose points if incorrect. This information is shown to you on the screen before you make your choice and should be used to help make your decision. When the boxes containing the Win/Lose amounts appear on the screen you will need to wait a moment until the amounts become black before you can make your choice. There is no time limit.

Following each decision, you will be shown the position of the reward and informed whether you won or lost. Throughout the experiment you will also be able to see your score.

The position of the 2 colours on the grid, the accompanying win or lose amounts and the location of the reward on the grid varies but there is an equal probability that the reward could be hidden in any of the 16 boxes.

To familiarise yourself with the task you will have a practise run before the main experiment; please ask if you need further clarification. **If this is not your first session in this study you should not rely on your memory of where you think the correct response is, as each game will differ.**

Before the experiment begins and twice during the experiment, when the game pauses, you will be asked to exercise for 1 minute using an instrument which measures hand grip strength. There is a scale which measures the strength of your grip and you will be asked to try to keep within certain limits. The experimenter will advise you if you need to grip harder or less strongly, as necessary.

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