Running title: AUTONOMIC AROUSAL DURING GOOD AND BAD DECISIONS

Does autonomic arousal distinguish good and bad decision-making? Healthy individuals' skin conductance and heart rate reactivity during the Iowa Gambling Task

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Abstract

The Somatic Marker Hypothesis (SMH) proposes that physiological feedback to the brain influences cognitive appraisal and decision-making; however, the strength of evidence in support of the SMH is equivocal. In this study we examined the validity of the SMH by measuring physiological arousal in a population of healthy individuals playing the Iowa Gambling Task (IGT); a computerised card game designed to assess real-life decision-making. We also aimed to clarify uncertainty regarding the influence of reinforcer type and impulsiveness to IGT performance and the SMH. Skin conductance level (SCL) and heart rate reactivity were measured in forty-one participants performing the IGT using either facsimile or real money. Participants were categorised as non-impaired or impaired on the basis of their IGT performance, and any differences in performance and physiological between groups were examined. Heart rate data did not reveal any effects. Robust differences in SCL reactivity during the task were not found between impaired and non-impaired individuals; however, marginal SCL rises were observed when non-impaired individuals anticipated and received a reward from disadvantageous choices compared with advantageous ones. This effect was found only when using facsimile money and did not occur in impaired individuals, suggesting some effect of reinforcer type on physiological activity and performance, and a difference in the physiology of impaired and non-impaired individuals. No significant differences in impulsiveness were found between impaired and non-impaired individuals. The findings suggest that autonomic activity is independent of long-term good or bad decision-making, and may reflect differences between decks in the magnitude of gain and loss. It is concluded that further substantiating evidence is needed for the SMH to continue as an explanation for human decision-making.

Does autonomic arousal distinguish good and bad decision-making? Healthy individuals' skin conductance and heart rate reactivity during the Iowa Gambling Task

Since its introduction less than 15 years ago, the Somatic Marker Hypothesis (SMH) (Damasio, 1994; Bechara, Damasio, Damasio, & Anderson, 1994) has quickly become an influential account of human decision-making. The central proposal of the SMH is that physiological states of the body (somatic state) act to guide decisions. When a decision must be made, factual information regarding the possible response options and their likely outcomes is recalled; associated with each response option outcome is a somatic state, which represents the physiological response of the body to the given situation. When considering which response option to pursue, somatic states mark the 'goodness' or 'badness' of each outcome based on the consequences of previous encounters with the same or similar situations. These *somatic markers* thereby assist decision-making by rapidly rejecting bad choices and endorsing good ones, making the accompanying logic-based, cost-benefit analysis more manageable. This process often operates outside of conscious awareness, as somatic markers can act both overtly and covertly. Fortunately, indicators of autonomic nervous system activity, i.e. skin conductance level (SCL) and heart rate, may be used to signal somatic marker activity. Accordingly, the SMH predicts changes in SCL and heart rate when possible response options are being considered and somatic markers are acting to guide this process, i.e. in the period when a decision is being anticipated.

The Iowa Gambling Task (IGT) (Bechara et al., 1994) was created by Bechara and colleagues to provide an experimental measure of human decision-making and the SMH. The task was designed to mimic real life decision-making in the way reward, punishment and uncertainty are represented. Playing the task involves selecting sequential cards from four decks (A, B, C and D) in order to win money. The decks differ in the magnitude and frequency of money lost and won. Decks A and B are considered bad and indicative of disadvantageous decision-making in that frequently selecting from these decks leads to long-term losses. Conversely, decks C and D are considered good or representative of advantageous decision-making as frequently selecting from these decks leads to long-term gains. Normal performance on the task is characterised by selecting more cards from the good decks than the bad ones. Bechara et al. (2001) reported that healthy individuals playing the task develop a preference for the good decks (C and D), and generate anticipatory skin conductance response (SCR) prior to a selection from a bad deck (A or B). Carter and Pasqualini (2004) support the role of anticipatory somatic activity in guiding decisions in healthy individuals, reporting a positive correlation between anticipatory autonomic response and successful performance on the gambling task. Crone, Somsen, Van Beek, and Van Der Molen (2004) also found changes in SCL and heart rate activity preceded the risky choices of healthy individuals showing good, but not poor, performance.

Does Physiological Reactivity Guide Decisions?

Although the SMH emphasises the role of anticipatory somatic markers as chief in guiding future decisions, the development of anticipatory somatic markers is contingent on appraisal (i.e. outcome) physiology. Individuals acquire somatic markers via prior experience using feedback from appraisal physiology. Accordingly, individuals who show poor or absent appraisal physiology should be unable to develop anticipatory somatic markers to guide future decisions, and thus exhibit impaired decision-making. Consistent with this, Suzuki, Hirota, Takasawa and Shigemase (2003) found, in a population of 40 healthy individuals, that low appraisal SCRs in response to early trials were related to persistence in selecting risky choices on later trials. However, despite the existence of greater magnitude anticipatory SCRs in response to risky choices, the expected relationship between anticipatory SCRs and performance was not supported, nor was there evidence of anticipatory SCR development over time. These findings appear contrary to the assumption that decision-making performance depends on the development of anticipatory SCRs, and suggests that appraisal physiology underlie individual differences in decision-making. Conversely, Crone et al. (2004) found autonomic activity during appraisal to be independent from performance strategy, while heart rate slowing and SCL were greater preceding selections from bad but not good decks.

Tomb, Hauser, Deldin and Caramazza (2002) further challenge the notion that somatic states act to mark the long-term consequences of decisions. They propose that high magnitude physiological responses are elicited when healthy participants anticipate bad decks, because bad decks yield rewards and punishments of high magnitude compared to good decks. As such, the larger anticipatory SCRs observed for bad decks represents the magnitude of wins and losses rather than long-term outcomes. Tomb et al. (2002) provide support for this idea using a modified version of the gambling task, in which good decks were associated with a higher magnitude of reward and punishment than bad decks. They concluded that card selections are driven by long-term consequences, whereas anticipatory SCRs reflect the immediate choices at hand.

Further criticisms of the SMH are presented by Maia and McClelland (2004) who conclude that there is no reason to think that somatic markers, as indexed by SCRs, play a causal role in guiding decision-making. They base their conclusion on findings that healthy participants demonstrate sufficient conscious knowledge regarding the gambling task to behave advantageously.

Real versus Facsimile Money

The IGT has been subject to several variations in administration, one example of which is alteration in the type of reinforcer used to perform the task (e.g. real versus facsimile). Research indicates good reason to believe that provision of a financial incentive influences performance on decision-making tasks (Hertwig & Ortmann, 2001). With this in mind, it is non-trivial that the original gambling task involves players using facsimile or play money, whereas other researchers have altered this to using real money (e.g. Schmitt, Brinkley, & Newman, 1999; Bowman & Turnbull, 2003; Suzuki et al. 2003).

Bowman and Turnbull (2003) compared the effect of using real versus facsimile money during the gambling task. No significant differences were found as a consequence of money type; however, a non-significant variation between the two healthy groups' performance indicated steep avoidance of bad decks following substantial losses in the real money condition. Bowman and Turnbull (2003) suggest that this (non-significant) difference may indicate somatic markers of enhanced magnitude when using real money; however, their study did not incorporate physiological evidence to substantiate this claim. A subsequent study by Carter and Pasqualini (2004) explored Bowman and Turnbull's (2003) suggestion in a group of 30 healthy women, finding anticipatory SCR was related to amount of money won or lost, and indicating that stronger autonomic responses accompany better performance. However, contrary to Bowman and Turnbull's (2003) prediction, there was no difference in aSCR magnitude of real versus facsimile money conditions.

Financial incentive is suggested as the primary explanation for any effect of real versus facsimile money, and accordingly studies comparing these reinforcer types have allowed participants to keep all or a proportion of the final winnings (Schmitt et al., 1999; Bowman & Turnbull, 2003; Carter & Pasqualini, 2004; Fernie & Tunney, 2006). However, the mechanism by which money exerts an effect may not be straightforward. For example, providing a financial incentive may undermine intrinsic motivation, which can paradoxically lead to poorer performance (Hertwig & Ortmann, 2001). It is also possible that real money influences performance regardless of financial incentive. This idea is consistent with recent research into the psychological consequences of money, which demonstrates that the very thought of money can lead to striking changes in behaviour (Burgoyne & Lea, 2006; Vohs, Mead, & Goode, 2006).

Impulsiveness and Decision-making

The SMH is further complicated by reports from Bechara and colleagues (Bechara, Damasio, Damasio, & Lee, 1999; Bechara, Damasio, & Damasio, 2000; Bechara et al., 2001; Bechara & Damasio, 2002), of healthy participants (20-37%) whose performance on the gambling task is equally impaired to that of patients with damage to the ventromedial region of the prefrontal cortex (VMpfc), despite exhibiting anticipatory SCRs for bad decks. This finding appears contrary to the assumption that gambling task performance depends on the activity of somatic markers. Bechara and colleagues (Bechara et al., 2000; Bechara, Dolan, & Hindes, 2002) explain that this pattern of performance may be the result of such individuals being high risk takers, who choose to override the activity of somatic markers by conscious deliberation. It may similarly be speculated that impaired performance in healthy individuals is a consequence of cognitive impulsiveness, which manifests behaviourally as high risk-taking.

The Present Study

The overall strength of evidence supporting the SMH is equivocal. Whereas Damasio (1994) claims somatic markers are crucial in guiding decisions, other researchers (e.g. Schmitt et al. 1999; North & O'Carroll, 2001; Tomb et al. 2002; O'Carroll & Papps, 2003; Suzuki et al. 2003; Maia & McClelland, 2004) have failed to support the SMH's assumptions. This study aimed to clarify previously inconsistent findings. The study concentrated on the following questions: (i) does autonomic activity distinguish normal and impaired performance on the IGT in healthy individuals, (ii) does the use of real and facsimile money affect IGT performance and autonomic when there is no financial incentive, and (iii) does impulsiveness affect healthy individuals' IGT performance and autonomic activity?

To address the first question, we tested the following two predictions: (i) normal (non-impaired) performers of the IGT have greater *anticipatory* skin conductance rise and heart rate slowing preceding disadvantageous decisions than impaired performers, and (ii) normal (non-impaired) performers of the IGT have greater *appraisal* skin conductance rise and heart rate slowing preceding disadvantageous decisions than impaired performers. To address the second question, we tested the following three predictions: (iii) participants' performance on the IGT differs when using real money and facsimile money, (iv) *anticipatory* skin conductance rise and heart rate slowing will differ for real and facsimile money, and (v) *appraisal* skin conductance rise and heart rate slowing will differ for real and facsimile money. In light of conflicting literature, we made no apriori prediction regarding the direction of expected effects. To address the third question, we tested the following prediction: (vi) impaired performers of the IGT have greater levels of impulsiveness than non-impaired individuals. We also explored the role of impulsiveness on physiological indicators.

Method

Participants

Forty-one healthy individuals participated in the study, ranging in age from 18 to 28 (M = 20.5, SD = 2.8; 11 male, 30 female). All participants were right-handed with no reported history of neurological or psychiatric illness, or learning disability. English was their first language and all had normal or corrected-to-normal vision. Participants received course credit or were paid for their participation. The study was approved by the School of Psychology Research Ethics Committee and informed consent was obtained from all participants.

Iowa Gambling Task (Bechara et al., 1994)

The task used was a computerised version of the Iowa Gambling Task (IGT). The task was presented using a laptop computer with a 14-in monitor, and a 4-key response box. Participants sat approximately 60 cm from the monitor. They were presented with four decks of cards on the computer screen and the response box with buttons labelled (left to right) A, B, C and D. At the top of the screen was a green bar, the size of which changed to reflect a proportionate change in the amount of money won or lost by the participant. Immediately below the green bar was a red bar, which did not change during the task and represented the amount of money loaned to the participant at the beginning of the task. Using the response box the participant selected one card at a time from any of the decks. The computer (1) controlled the sequence of rewards and punishments from a pre-set schedule (Bechara et al., 1994) that did not differ across participants, (2) tracked the sequence of card selections from the various decks, and (3) recorded physiological activity during the task. Following a card selection the face of the card (coloured entirely black or red) appeared on top of the deck and a message was displayed indicating how much had been won or lost. A win / reward was accompanied by a smiley face, increase in size of the green bar and short sound similar to a casino slot machine followed by a man saying “you’ve been practicing”. A loss / punishment was accompanied by a sad face, decrease in size of the green bar and another short sound followed by a man saying “you lose!” The participant was free to ponder which deck to choose next once money had been added / subtracted and the face had disappeared. This period was indicated by a 5-second countdown displayed in the centre of the screen. A selection could only be made after the countdown had ended.

Performing the task involved using one of two reinforcer types: facsimile money (FM) or real money (RM). In the FM version, money was represented only as a number on the computer screen. In the RM version, real money (pounds sterling) belonging to the researcher was dealt out and taken away to reflect wins and losses on the computer screen. Participants were not allowed to keep any money.

The magnitude of all wins and losses were reduced by a factor of 100 compared to the original IGT, due to the use of real money. Every time a card was selected from decks A or B the participant won £1, and every time a card was selected from decks C or D they won £0.50. Punishment in decks A and B was such that a total loss of £12.50 was encountered in every 10 cards (net loss £2.50). Punishment in decks C and D resulted in a total loss of £2.50 in every 10 cards (net gain £2.50). The decks also differ in that decks A and C contained five small punishments per 10 card selections (i.e. punishment on 50% of selections). Decks B and D contained one large punishment per 10 card selections (punishment on 10% of selections).

The total number of trials was set at 100 card selections. The trial sequence started with the presentation of the stimulus display (as described above) and 5-second countdown. The end of the countdown indicated that participants should respond. Responses were made using the dominant hand. Following the response, a 2-second outcome display (smiley / sad face and win / lose message) replaced the stimulus display. Reponses were made approximately 500-1000ms following the countdown end, resulting in an intertrial interval of approximately 8 seconds. These timings were similar to studies by Bechara et al. (1996), Bechara and Damasio (2002), and Crone et al. (2004).

Impulsivity Measures.

Go/NoGo test (Zimmermann & Fimm, 1995). The Go/NoGo is designed to assess the ability of participants to suppress undesired motor responses and was used as a measure of motor impulse control. This computerised test presents participants with five visual stimuli (boxes filled with different patterns), two of which are targets. Stimuli appear in random order, one at a time in the centre of the computer monitor. Participants are required to respond, by depressing a response button as quickly as possible, whenever either of the two target items appear, and must suppress making unwanted responses to the three distractor stimuli. The outcome measure used in the present study was median reaction time.

Stroop test (Trenerry, Crosson, DeBoe, & Leber, 1989). The Stroop Colour-Word Interference Task is a widely used behavioural assessment of response inhibition. In this test participants are presented with 112 words of colour names printed in ink of a conflicting colour (e.g. the word RED printed in blue ink), and are asked to state the colour of the ink in which the word is printed. The task requires participants to suppress a habitual response (i.e. read the word) in favour of an unusual one (i.e. state the ink colour). The outcome measure used was total number of words for which ink colour is correctly stated (i.e. colour-word score).

Barratt Impulsivity Scale (BIS, version 11; Barratt & Patton, 1983). The BIS-11 is a 4-point Likert scale containing 30 items, covering three domains: Attentional Impulsiveness (AI), Motor Impulsiveness (MI) and Non-planning impulsiveness (NP). AI evaluates actions precipitated by lack of attention; MI evaluates hyperactivity due to need of movement; and NP evaluates attitudes and conclusions precipitated by lack of reflection. Responses describe the frequency with which a given item is characteristic of the individual's behaviour / thinking, on a scale ranging from '*rarely*' to '*always*'. The combined score of AI, MI and NP (i.e. BIS-11 total score; maximum possible score = 120) was used as the outcome measure in the present study.

Physiology Recording and Reduction

An IBM-compatible computer controlled the timing and presentation of all stimulus materials and recorded all performance data. SCL was recorded continuously during the task as per the procedure of Crone et al. (2004). SCL was measured in microsiemens (μS) using silver/silver chloride electrodes filled with 0.05M of electrode gel and attached to the distal phalanx of the index and ring finger of the non-dominant hand. The electrode sites were cleansed with an isopropyl alcohol swab beforehand. Blood pulse volume (BPV) was measured using a photoplethysmography sensor attached to the distal phalanx of the middle finder of the non-dominant hand. Because of the influence of hand or arm movements on the photoplethysmograph recording, participants were instructed to keep their non-dominant hand still during the task. SCL and BPV were fed into a Thought Technology ProComp+ real-time physiological monitoring unit. Peak pulse amplitudes served to trigger a cardiotachograph, which recorded the interval between successive pulse volume peaks (in ms). Peak-peak intervals were converted to HR (in bpm). SCL, BPV and cardiotachograph output were graphically displayed and recorded on an IBM-compatible laptop PC. The graphical display enabled visual detection of artefacts arising from spurious peak amplitude identifications or no detection of peak amplitudes that were very small. Any artefacts were removed and a mean of the HR and SCL values immediately preceding and following the artefact inserted.

Baseline Physiology. Baseline measures were taken from continuous recording of SCL and HR data from the last 50 seconds of a 5 minute pre-experimental relaxation period. The average SCL and HR during this period was calculated. 50 seconds were selected owing to software limitations, which meant that the maximum period of data recording visible at any one time was 50 seconds.

Anticipatory Physiology. Anticipation responses were measured during the 5 s countdown prior to each card selection. Raw SCL and HR were averaged over these 5 seconds. In order to minimise any pre-existing individual differences in physiology, change scores were calculated by subtracting values derived from the last 50 s of the pre-experimental baseline from the raw score (Myrtrek & Foerster, 1986). Mean SCL change in the 5 s time window preceding a card selection was considered an event-related response elicited by the anticipated decision.

Appraisal Physiology. Two types of appraisal were assessed: (1) Punishment - after turning a card for which there was a reward immediately followed by a penalty, and (2) Reward - after turning a card for which there was a reward not followed by a penalty. Raw reward / punishment SCL and HR were calculated by averaging the 2-seconds immediately after each card selection. Change scores for these periods were calculated as above. Mean reward / punishment SCL change in the 2 s time window following a card selection was considered an event-related response elicited by the outcome stimulus.

The duration of our anticipation and appraisal time windows were selected to reflect those of existing research (Bechara et al.. 1996; Bechara and Damasio, 2002; Crone et al., 2004) and permit comparison with these studies. Additionally, Dawson, Schell and Filion (2000) state that an electrodermal response beginning 1-4 seconds following stimulus onset is considered to be elicited by that stimulus; they further recommend a time windows of 1-4 s or shorter to avoid stimulus related activity being contaminated with non-specific changes in autonomic arousal. Our timings considered the ability to capture stimulus elicited changes in physiology, while maintaining a reasonable length of time for participants to complete the task.

Procedure

On arrival at the laboratory (light, temperature, and sound controlled) participants were given an overview of the experimental procedure. They were then attached to the physiological apparatus and asked to relax for 5 minutes, during which time baseline measures of SCL and HR were taken. Participants then completed the three impulsivity measures and gambling task in random order. For the gambling task participants were randomly allocated to one of two reinforcer types prior to commencement of the task: (a) facsimile money (FM) or, (b) real money (RM). All participants received a standard set of verbal instructions identical to those of Bechara et al. (1999), apart from an additional statement to participants in the RM condition that RM would be dealt out and taken away during the task, but that this money could not be kept at the end of the experiment. Following receipt of instructions, participants performed a practice trial, consisting of 5 card selections, to ensure they fully understood the nature of the task and knew how to respond. Once the practice was complete participants were given the opportunity to ask questions and, where necessary, clarification was offered by paraphrasing the instructions. The experimental task then began, with participants instructed to continue playing until the computer stopped. Following 100 card selections the experiment ended and the total money the participant possessed was displayed on the screen. Participants were then unwired, thanked and debriefed.

Data Analyses

IGT performance data was available for 41 participants (FM = 20, RM = 21). Complete physiological data was available for 39 participants. Physiological data was incomplete for a further two participants due to (1) equipment malfunction resulting in no SCL data being recorded (1 participant), and (2) a failure of the equipment to detect a BVP signal (1 participant). Where available, physiological data from these two participants was used in analyses, otherwise missing data values were entered.

Performance. Behavioural performance on the task was analysed following the method of Bechara et al., (1994). The 100 card selections were subdivided into five blocks of 20 cards each and a net score was derived for each block by summing the number of selections from decks C and D (good) and subtracting the number of selections from decks A and B (bad) (i.e. net score for block = (C+D) – (A+B)). Net scores below zero indicate bad or disadvantageous selecting, whereas net scores above zero indicate good or advantageous selecting. Furthermore, we followed the convention set by Bechara (Bechara et al., 2001; Bechara & Damasio, 2002) to subdivide participants into impaired and non-impaired performance on the basis of their maximum net score; whereby a maximum net score of <10 represents impaired performance. A final behavioural measure derived from the task was the total amount of money lost or gained.

Analysis of performance comprised 2 (reinforcer type: FM, RM) by 2 (performance group: impaired, non-impaired) ANOVAs calculated for total net score and final money amount separately. Group differences in measures of impulsiveness were examined using Mann-Whitney *U* tests, with performance group (impaired, non-impaired) as the independent variable and BIS-11 total score, Stroop Colour-Word score, and Go/NoGo median reaction time as dependent variables. Non-parametric tests were used for the latter analysis as impulsiveness data were not normally distributed.

Physiological activity. Analysis of physiological activity pooled data from bad decks (A+B) and good decks (C+D), as is typical in previous studies (e.g. Bechara et al., 1996).

Physiological activity during anticipation and appraisal (reward and punishment) periods were analysed separately, as were SCL and HR activity. To check for pre-existing differences between reinforcer and performance groups, SCL and HR during the pre-experimental baseline were submitted to separate 2 (reinforcer type: FM, RM) by 2 (performance group: impaired, non-impaired) ANOVAs. Subsequent 2 (deck type: bad, good) by 2 (reinforcer type) by 2 (performance group) mixed ANOVAs were calculated for SCL and HR activity during anticipation and appraisal periods, with repeated measured on the first factor. We also explored the relationship between measures of impulsiveness and physiological activity by calculating 2-tailed correlations between these two variables.

Results

Performance

Table 1 summarises the total net score and final amount of money won or lost according to reinforcer type and performance group.

Table 1 about here

Total amount of money won or lost on the task did not differ significantly between FM and RM conditions, $F(1,37) = 1.70$, $p = .20$; however, total net scores were marginally greater using FM than RM, $F(1,37) = 3.58$, $p = .066$. Using the criteria applied by Bechara and colleagues (Bechara et al., 1999; Bechara et al., 2000; Bechara et al., 2001; Bechara & Damasio, 2002) 25 out of 41 (61%) participants were impaired in their performance on the gambling task. As expected, impaired individuals showed significantly poorer performance than non-impaired individuals, in terms of both final money, $F(1, 37) = 13.60$, $p = .001$, and total net score, $F(1,37) = 43.06$, $p < .001$. There was no interaction of performance group with reinforcer type, as measured by final money or total net score (both *p*s > .10), indicating that marginal differences in performance when using different reinforcer types were not influenced by whether overall performance was impaired or non-impaired. Finally, examination of impulsiveness measures revealed no significant differences between impaired and non-impaired individuals (all *p*s > .10).

Physiological Reactivity

All analyses were conducted for measures of both SCL and HR; however, no significant main effects or interactions were identified using the HR data. For brevity, the HR results are not reported. Means and standard deviations of SCL activity during the task are summarised in table 2. There were no pre-existing differences in the baseline SCL of individuals in the FM and RM group, or impaired and non-impaired group.

Table 2 about here

SCL in anticipation of choices. A main effect of deck type was borderline significant, $F(1,36) = 4.08$, $p = .051$, indicating that anticipatory SCL rise was greater preceding selections from bad decks compared to good ones. However, SCL did not differentiate impaired and non-impaired performance on the task, $F(1,36) = .10$, $p = .751$. Contrary to prediction, greater anticipatory SCL rise did not precede disadvantageous choices in non-impaired individuals; this was qualified by the absence of a deck type by performance group interaction, $F(1,36) = .43$, $p = .516$, which indicated that skin conductance activity preceding disadvantageous and advantageous choices did not differ as a function of overall impaired or non-impaired performance on the task.

There was no main effect of reinforcer type, $F(1,36) = .11$, $p = .744$; however, a marginally significant deck type by reinforcer type interaction, $F(1,36) = 3.84$, $p = .058$, showed larger SCL rises preceding selections from disadvantageous decks than advantageous decks when using FM, $F(1,18) = 10.92$, $p = .004$, but no differential anticipatory SCL when using RM, $F(1,18) = .001$, $p = .97$.

SCL following choices resulting in a reward. A main effect of deck type, $F(1,36) = 8.34$, $p = .006$, indicated SCL activity following a reward was greater for disadvantageous decks than advantageous decks. No main effect of reinforcer type, $F(1,36) = .14$, $p = .710$, but a deck type by reinforcer type interaction, $F(1,36) = 8.92$, $p = .005$, indicated that SCL following a reward differed as a function of reinforcer type. Larger SCL rise followed rewards from bad decks than good decks when using facsimile money $F(1,18) = 23.79$, $p < .001$, but no difference in SCL occurred when using real money, $F(1,18) = .003$, $p = .95$. Furthermore, a marginally significant three-way interaction between deck type, reinforcer type and performance group, $F(1,36) = 3.64$, $p = .065$, suggested that the deck type by reinforcer type interaction differed for impaired and non-impaired individuals. Examining impaired performers in isolation revealed no main effect of deck type, $F(1, 22) = 1.76$, $p = .198$, nor a deck type by reinforcer type interaction, $F(1,22) = .70$, $p = .411$. This indicated that the main effect of deck type and deck type by reinforcer type were solely the result of the reward SCL in non-impaired individuals. Unlike individuals whose performance on the task was not impaired, impaired individuals' reward SCL activity did not differentiate good and bad choices when using FM.

SCL following choices resulting in a punishment. Analysis of SCL for punishment failed to reveal any main effects or interactions (all *p*s > .10)

Relationship between impulsiveness and physiology. BIS-11 total score correlated marginally with SCL following a choice resulting in a punishment ($r_s = .30$, $p = .06$). All other correlations were non-significant (see table 3).

Table 3 about here

Discussion

This study concentrated on three questions: (i) does autonomic activity distinguish normal and impaired performance on the IGT in healthy individuals, (ii) does the use of real and facsimile money affect IGT performance and autonomic activity when there is no financial incentive, and (iii) does impulsiveness affect healthy individuals' IGT performance and autonomic activity?

Does autonomic activity distinguish normal and impaired performance on the IGT in healthy individuals?

We made two predictions regarding the effect of autonomic activity on IGT performance in healthy individuals: (i) normal (non-impaired) performers of the IGT have greater anticipatory skin conductance rise and heart rate slowing preceding disadvantageous decisions compared with impaired performers, and (ii) non-impaired performers of the IGT have greater appraisal skin conductance rise and heart rate slowing following disadvantageous decisions compared with impaired performers. First, the distinction between impaired and non-impaired performance was validated by a significant difference between the two groups' performance, in terms of overall net scores and final money. Furthermore, differences in anticipatory and reward SCL were detected between disadvantageous and advantageous decks, indicating that autonomic activity is sensitive to differences between the two deck types. Consistent with the work of others, greater SCL rise preceded selecting from disadvantageous decks (e.g. Bechara et al., 1999; Bechara & Damasio, 2002; Bechara et al., 2002; Crone et al., 2004) and following rewards (Suzuki et al., 2003), but not punishments.

However, we found no evidence to support our first prediction: that *anticipatory* SCL and heart rate discriminated impaired and non-impaired performance groups, and little evidence to support our second prediction: that *appraisal* SCL differs in impaired and non-impaired individuals. An exception was a marginally significant three-way interaction, which suggested that non-impaired individuals experience greater SCL rise following a reward from a disadvantageous deck (when using facsimile money), whereas impaired individuals show no differentiation in SCL. This finding lends support for the suggestion of Suzuki et al. (2003), that appraisal physiology relates to risky choices and poor performance. We found a trend to suggest that changes in SCL following a reward from a risky choice are absent in individuals whose performance is impaired. However, this finding should be interpreted cautiously, as the interaction was only marginally significant.

On the whole, the predictions arising from the SMH were not well supported, suggesting that good and bad performance may be independent of physiological reactivity. This is consistent with Maia and McClelland (2004), who conclude there is no evidence to suggest that decision-making on the IGT depends on differences in somatic state. Likewise, Tomb et al. (2002) believe that performance (i.e. card selection) on the IGT is guided by long-term consequences, but that higher anticipatory skin conductance reactivity to bad decks simply reflects the higher *magnitude* of potential reward or punishment with which they are associated. Our finding of higher SCL rise when anticipating and being rewarded from disadvantageous decks (high magnitude) compared with advantageous decks (low magnitude) is consistent with Tomb et al's (2002) explanation.

Does the use of real and facsimile money affect IGT performance and autonomic activity when there is no financial incentive?

To address the second question, we tested the following three predictions: (i) participants' performance on the IGT differs when using real money and facsimile money, (ii) *anticipatory* skin conductance rise and heart rate slowing differ for real and facsimile money, and (iii) *appraisal* skin conductance rise and heart rate slowing differ for real and facsimile money. Regarding the first prediction, results of the present study indicated marginally greater net scores when the task was performed using facsimile money. This suggests some difference in performance as a consequence of reinforcer type, although the marginal effect means this conclusion cannot be stated with a high degree of certainty. Secondly, the use of real versus facsimile money was found to influence autonomic activity during the task, despite no difference in financial incentive of the two conditions. Greater SCL rise occurred in *anticipation* of a selection from disadvantageous decks compared with advantageous decks when facsimile money was used. This SCL rise did not occur when real money was used. An identical pattern of SCL rise occurred *following a reward* from disadvantageous decks when using facsimile, but not real, money.

The direction of effects found is somewhat surprising. The behavioural data indicate better performance when using facsimile money and, consistent with this, physiological data indicated greater changes in SCL activity when using facsimile money only. Paradoxically, Bowman and Turnbull (2003) did not find significant differences in overall performance on the IGT using real and facsimile reinforcers; however, they propose that using *real money* leads to a steeper learning curve and greater magnitude somatic markers. Also contrary to findings of the present research, Carter and Pasqualini (2004) found participants in a real money condition won marginally greater money, but did not differ from a facsimile money condition on mean anticipatory SCR.

It is not clear why our findings conflict with those of previous research. One possible explanation pertains to the novel methodological aspect of the present research, whereby participants were not permitted to keep any money they won regardless of reinforcer type. This manipulation served to examine whether using real money would influence behaviour when there is no financial incentive. Research into the psychological consequences of money suggests the very presence of money can lead to considerable changes in behaviour

(Burgoyne & Lea, 2006; Vohs et al., 2006). It is possible that previous null findings of real versus facsimile money could be explained by an undermining of the intrinsic motivation of participants when a financial incentive is offered (Hertwig & Ortmann, 2001). We did not offer a financial incentive, thereby rendering facsimile and real money essentially analogous. Unfortunately, we are unable to provide a speculation as to why facsimile money leads to better performance and more pronounced changes in physiology than real money when financial incentive is eliminated.

Does impulsiveness affect healthy individuals' IGT performance and autonomic activity?

To address the third question, we tested the prediction that impaired performers of the IGT have greater levels of impulsiveness than non-impaired performers. We also explored the role of impulsiveness on physiological indicators.

Bechara and Damasio (2002) claim that healthy individuals who perform as impaired on the gambling task are likely to be high-risk takers and thrill seekers in real life. These risk-seeking individuals over-ride the action of somatic markers by conscious deliberation, resulting in poor performance despite guiding somatic activity. Crone et al. (2004) suggest that poor IGT performance may be a secondary consequence of the behavioural characteristics of impulsivity. Using several measures of impulsiveness, we failed to find evidence of any differences in the impulsiveness of impaired and non-impaired individuals. These findings go some way to supporting Bechara and colleagues (Bechara et al., 2000; Bechara et al., 2002), in suggesting impaired gambling task performance is not related to motor impulsiveness / response inhibition as measured with a Go/NoGo task and Stroop test.

We also attempted to investigate the relationship between risk-taking and impaired IGT performance, by assessing motor and attentional impulsiveness, and non-planning behaviour using the BIS-11. We found self-reported impulsive behaviour and thinking were no greater in individuals with impaired performance than non-impaired individuals. However, a marginally significant, weak correlation was found between BIS-11 score and punishment SCL for disadvantageous decks. This finding should be interpreted cautiously as, although impulsiveness of the kinds measured by the BIS-11 has been related to risk-taking (Eysenck & Eysenck, 1977), no direct behavioural or self-report measure of risk-taking was taken.

Conclusion

The present study did not find a consistent pattern of findings to indicate that decision-making in healthy individuals depends on physiological arousal. In agreement with Maia and McClelland (2004), we believe additional evidence is required for the SMH to continue as a prominent explanation of human decision-making.

References

Barratt, E. S., & Patton, J. H. (1983). Impulsivity: Cognitive, behavioral and psychophysiological correlates. In M. Zuckerman (Ed.), *Biological bases of sensation seeking, impulsivity, and anxiety* (pp. 77-116). New York: Harcourt Brace Jovanovic.

Bechara, A., Damasio, A. R., Damasio, H., & Anderson, S. W. (1994). Insensitivity to future consequences following damage to human prefrontal cortex. *Cognition, 50,* 7-15.

Bechara, A., Damasio, H., Damasio, A. R., & Lee, G. P. (1999). Different contributions of the human amygdala and ventromedial prefrontal cortex to decision-making. *The Journal of Neuroscience, 19,* 5473-5481.

Bechara, A., & Damasio, H. (2002). Decision-making and addiction (part 1): impaired activation of somatic states in substance dependent individuals when pondering decisions with negative future consequences. *Neuropsychologia, 40,* 1675-1689.

Bechara, A., Damasio, H., & Damasio, A. R. (2000). Emotion, decision making and the orbitofrontal cortex. *Cerebral Cortex, 10,* 295-307.

Bechara, A., Dolan, S., Denburg, N., Hindes, A., Anderson, S. W., & Nathan, P. E. (2001). Decision-making deficits, linked to a dysfunctional ventromedial prefrontal cortex, revealed in alcohol and stimulant abusers. *Neuropsychologia, 39,* 376-389.

Bechara, A., Dolan, S., & Hindes, A. (2002). Decision-making and addiction (part 2): myopia for the future or hypersensitivity to reward? *Neuropsychologia, 40,* 1690-1705.

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

Bowman, C. H., & Turnbull, O. H. (2003). Real versus facsimile reinforcers on the Iowa Gambling Task. *Brain and Cognition, 53,* 207-210.

Burgoyne, C. B., & Lea, S. E. G. (2006). Money is material. *Science, 314,* 1091-1092.

Carter, S., & Pasqualini, M. C. S. (2004). Stronger autonomic response accompanies better learning: A test of Damasion's somatic marker hypothesis. *Cognition and Emotion, 18,* 901-911.

Critchley, H. D., Mathias, C. J., & Dolan, R. J. (2001). Neural activity in the human brain relating to uncertainty and arousal during anticipation. *Neuron, 29,* 537-545.

Crone, E. A., Somsen, R. J. M., Van Beek, B., & Van Der Molen, M. W. (2004). Heart rate and skin conductance analysis of antecendents and consequences of decision making. *Psychophysiology, 41,* 531-540.

Damasio, A. R. (1994). *Descartes' Error: Emotion, reason, and the human brain*. New York: G. P. Putnam's Sons.

Dawson, M. E., Schell, A. M., & Filion, D. L. (2000). The electrodermal system. In J. T. Cacioppo, L. G. Tassinary, & G. G. Bernston (Eds.), *Handbook of psychophysiology* (2nd ed., pp.200-223). Cambridge, UK: Cambridge University Press.

Eysenck, S. B., & Eysenck, H. J. (1977). The place of impulsivness in a dimensional system of personality description. *British Journal of Social and Clinical Psychology, 51,* 768-774.

Fernie, G., & Tunney, R. (2006). Some decks are better than others: The effect of reinforcer type and task instructions on learning in the Iowa Gambling Task. *Brain and Cognition, 60,* 94-102.

Hertwig, R., & Ortmann, A. (2001). Experimental practices in economics: A methodological challenge for psychologists. *Behavioral and Brain Sciences, 24,* 383-451.

Maia, T. V., & McClelland, J. L. (2004). A reexamination of the evidence for the somatic marker hypothesis: What participants really know in the Iowa gambling task. *Proceedings of the National Academy of Sciences of the United States of America, 101,* 16075-16080.

North, N. T., & O'Carroll, R. E. (2001). Decision making in patients with spinal cord damage: afferent feedback and the somatic marker hypothesis. *Neuropsychologia, 39,* 521-524.

O'Carroll, R. E., & Papps, B. P. (2003). Decision making in humans: the effect of manipulating the central noradrenergic system. *Journal of Neurology, Neurosurgery and Psychiatry, 74,* 376-378.

Schmitt, W. A., Brinkley, C. A., & Newman, J. P. (1999). Testing Damasio's somatic marker hypothesis with psychopathic individuals: Risk takers or risk averse? *Journal of Abnormal Psychology, 108,* 538-543.

Suzuki, A., Hirota, A., Takasawa, N., & Shigemase, K. (2003). Application of the somatic marker hypothesis to individual differences in decision making. *Biological Psychology, 65,* 81-88.

Tomb, I., Hauser, M., Deldin, P., & Caramazza, A. (2002). Do somatic markers mediate decisions on the gambling task? *Nature Neuroscience, 5,* 3-4.

Trenerry, M. R., Crosson, B., DeBoe, J., & Leber, W. R. (1989). *Stroop Neuropsychological Screening Test*. Florida: Psychological Assessment Resources.

Vohs, K. D., Mead, N. L., & Goode, M. R. (2006). The psychological consequences of money. *Science, 314,* 1154-1156.

Zimmermann, P., & Fimm, B. (1995). *Test for Attentional Performance*. Herzogenrath: Psytest.

Table 1.

Average net score and monetary outcome as a function of performance and reinforcer type.

Outcome	Performance type	Reinforcer type	*M*	S.D.
Net Score	Overall	Facsimile money	11.00	23.26
		Real money	-0.10	15.99
	Impaired	Facsimile money	-3.64	15.56
		Real money	-8.71	11.94
	Non-impaired	Facsimile money	28.89	18.09
		Real money	17.14	4.88
Final money	Overall	Facsimile money	19.03	7.63
		Real money	16.45	5.08
	Impaired	Facsimile money	14.95	6.29
		Real money	15.07	4.73
	Non-impaired	Facsimile money	24.00	6.16
		Real money	19.21	4.93

Table 2.

Mean baseline SCL and change scores as a function of performance, reinforcer and deck type.

	Impaired performance		Non-impaired performance	
	Real money	Facsimile money	Real money	Facsimile money
	Mean (S.D)	Mean (S.D)	Mean (S.D)	Mean (S.D)
Baseline	4.05 (1.04)	3.81 (1.83)	4.19 (1.78)	3.68 (1.83)
Anticipation				
Disadvantageous	3.04 (2.51)	2.94 (2.66)	2.37 (1.72)	3.20 (2.11)
Advantageous	3.00 (2.58)	2.84 (2.71)	2.41 (1.68)	2.86 (2.20)
Reward				
Disadvantageous	3.03 (2.50)	2.89 (2.58)	2.32 (1.78)	3.36 (2.13)
Advantageous	2.99 (2.60)	2.74 (2.67)	2.36 (1.75)	2.87 (2.13)
Punishment				
Disadvantageous	2.71 (2.41)	2.66 (2.54)	2.06 (1.74)	2.68 (2.09)
Advantageous	2.59 (2.53)	2.51 (2.71)	2.13 (1.71)	2.48 (2.16)

Table 3.

Impulsiveness and physiological reactivity correlations.

	BIS-11	Stroop	Go/NoGo
	r_s (*p*-value)	r_s (*p*-value)	r_s (*p*-value)
Anticipation			
Disadvantageous	.25 (.11)	.01 (.96)	-.12 (.47)
Advantageous	.25 (.12)	-.04 (.79)	-.17 (.29)
Reward			
Disadvantageous	.26 (.11)	.03 (.86)	-.17 (.30)
Advantageous	.25 (.13)	-.02 (.91)	-.18 (.27)
Punishment			
Disadvantageous	.30 (.06)	.01 (.96)	-.15 (.35)
Advantageous	.26 (.10)	-.03 (.85)	-.21 (.21)