The Role of Stake Size in Loss of Control in Within--Session Gambling Impact of Stake Size on Reflection Impulsivity, Response Inhibition and Arousal when Gambling on a Simulated...

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The Role of Stake Size in Loss of Control in Within-Session Gambling

Impact of Stake Size on Reflection Impulsivity, Response Inhibition and Arousal when Gambling on a Simulated Virtual Roulette Gambling Task: Implications for Gambling Related Harm

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1 Executive Summary

1.1 Background and Research Aims

- A recent review of literature regarding the impact of stake size for gambling-related harm concluded that of the few available empirical studies, the majority had substantial methodological flaws, making it unsafe to draw conclusions from such a literature base. It was recommended that for research to be valuable in helping to understand the link between stake size and gambling-related harm, participants must be able to win and lose significant monetary sums, and that the findings are gambling activity specific (i.e. EGM or Lottery specific).
- Problem gambling and gambling-related harm are characterised by a lack of control and impaired decision-making performance, with a disregard for future negative consequences of gambling. Research tends to represent such lack of control and decision-making impairments in problem gamblers as being a result of pre-existing individual vulnerabilities. The current study evaluates whether stake size can temporarily affect an individual's decision-making performance and behavioural control within a gambling context.
- Cognitive and behavioural control is organised and maintained by an individual's executive functions, which are primarily represented in the prefrontal cortex (PFC) area of the brain. Executive function represents a wide range of mental processes, such as attention, working memory and planning, that enables an individual to engage in goal-orientated behaviour.
- Simplistic and frequent behaviours, such as remembering one's route home, often do not require executive control because, for the most part, the brain processes and executes such behaviour automatically. However, when the behaviour becomes more complex, in terms of the event rapidly updating and changing, or the need to make multiple fast decisions under uncertainty, then executive control is required for the individual to achieve their aims and minimise potential negative consequences of specific events.
- It is argued that deterioration in control within gambling sessions (where participants engage in loss chasing and lose sums that create substantial negative consequences) can be explained by a temporary reduction in executive function performance.
- Executive control in electronic machine (EGM) gambling can be summarised as the PFC organising brain activity to favour processes, such as attention and task-switching, that will assist the individual in maintaining their predetermined goals of enjoying gambling as a leisure pursuit while simultaneously minimising any potential harm. However, executive

control can be jeopardised by interfering signals and stimulation during the gambling session.

- Interference can come from negative internal states in response to losing, and from conditioned patterns of behaviour where gamblers are motivated to continue to play because of the rewarding experience of gambling. Often the urge to persist in gambling despite the negative consequences (i.e. the interference) is stronger than the existing goal of gambling in a controlled manner, and as a result the gambler may update their 'goal' during the session from *controlled gambling* to gambling to recoup recent losses and remove negative mood states.
- A multitude of executive function deficits have been linked to addictive disorders and problem gambling. In the current study, three constructs were identified as being keys in understanding the loss of control within EGM gambling sessions: reflection impulsivity, behavioural inhibition and arousal response. The causal effect of stake size on each of these three constructs was measured within the current study.
- Reflection impulsivity refers to the tendency to gather and evaluate information prior to decision-making in contrast to the tendency to make an impulsive decision. There are three outcome measures of reflection impulsivity including speed of decision, amount of information gathered, and most importantly, the quality of decision made based on the available evidence at the time the decision was made (i.e. the probability of being correct).
- Reflection Impulsivity in gambling is argued to cause poorly conceived, maladaptive behaviour that will create negative consequences for the individual. In other words, rather than making controlled, rational gambling decisions, reflection impulsivity will lead to more reckless, emotional and short-term focused behaviour.
- Problem gamblers have been observed to display greater reflection impulsivity in comparison to normal populations, suggesting it may be a result of individual differences (i.e. pre-existing vulnerabilities in some individuals). The current study will measure whether gambling at higher stake size has a direct effect on players' level of reflection impulsivity.
- Response Inhibition is the ability to either cancel or withhold a prepotent response when the response is inappropriate or disadvantageous to the individual. A prepotent response refers to an action that has been previously and repeatedly associated with a positive outcome for the individual. The urge to continue to gambling on EGMs and to keep pressing the button could be argued to be a prepotent response because of the excitement associated with every spin, independent of whether the result is a win or loss. Essentially, the pressing of

the button and the excitement from the risk are being repeatedly paired, and therefore creating a conditioned response in the individual to continue gambling to receive further stimulation.

- Response inhibition is the ability to show restraint and 'override' interference from strong urges to complete a behaviour that has been conditioned, because ultimately it is no longer beneficial for the individual. Problem gamblers have been observed to have deficits in response inhibition in comparison to normal populations, suggesting it may be a result of individual differences. The current study will measure whether gambling at a higher stake size has a direct effect on players' response inhibition performance. In other words, does ability to withhold responses (i.e. urges) change in different gambling contexts?
- Arousal is a proposed factor that may contribute, in multiple ways, to loss of control within EGM gambling sessions. First, evidence demonstrates that some individuals are motivated to gamble to achieve rewarding states of arousal, and that gamblers may be motivated to continue gambling despite incurring losses because they find the experience rewarding.
- Research has also demonstrated that problem gamblers have a heightened arousal experience when gambling in comparison to non-problem gamblers. This heightened arousal experience may explain discounting of losses and perseverance within gambling sessions. It could be argued that any factor that increases the arousal experience may in turn increase a gambler's motivation to continue gambling in spite of negative longer-term consequences. The current study will assess whether gambling at higher stakes creates an 'enhanced' arousal experience in the short term, in comparison to gambling at lower stakes.
- Arousal may also be relevant to loss of control within EGM gambling sessions in terms of the *learning* experience of the gambler in response to wins and losses. The somatic marker hypothesis argues that various physiological responses to events, such as arousal, help the individual to associate specific events with either positive or negative outcomes. The value of this positive or negative feeling in response to specific events, such as EGM gambling, is that these evoked emotions help guide decision-making when such situations are encountered in the future. It is argued that this emotional bias is beneficial as it enables the individual to appropriately weigh the pros and cons of a decision.
- Within the gambling context, it is important for effective decision-making that in terms of associated learning, gamblers are able to somatically mark both wins and losses appropriately. It is argued that if there is an absence of markers in relation to wins (labelling the event as positive) or losses (labelling the event as negative), then the gambler will have an unbalanced conceptualisation of EGM gambling and this may impair quality of decision-

making. Put simply, a lack of somatic markers in response to losses may make the gambler biased towards potential wins when making decisions and this may lead to risky gambling behaviour and gambling-related harm. The current study will measure whether gambling at higher stakes on EGMs negatively affects the somatic marking of wins and losses in comparison to gambling at lower stakes.

1.2 Research Hypotheses

1. A player's level of reflection impulsivity will be higher after gambling at higher stakes in comparison to either gambling at lower stakes or not gambling (i.e. control condition).
2. A player's level of reflection impulsivity will be higher after losing bets in comparison to either winning bets or not gambling.
3. A player's level of reflection impulsivity will be higher after losing higher stake bets in comparison to either losing lower stake bets or not gambling.
4. A player's level of reflection impulsivity will be higher after winning higher stake bets in comparison to either winning lower stake bets or not gambling.
5. A player's ability to inhibit prepotent responses will be lower after gambling at higher stakes in comparison to either gambling at lower stakes or not gambling (i.e. control condition).
6. A player's ability to inhibit prepotent responses will be lower after losing bets in comparison to either winning bets or not gambling.
7. A player's ability to inhibit prepotent responses will be lower after losing higher stake bets in comparison to either losing lower stake bets or not gambling.
8. A player's ability to inhibit prepotent responses will be lower after winning higher stake bets in comparison to either winning lower stake bets or not gambling.
9. The percentage increase in arousal level will be higher when gambling at higher stakes in comparison to either gambling at lower stakes or not gambling (i.e. control condition).
10. The percentage increase in arousal level will be higher when losing higher stake bets in comparison to either losing lower stake bets or not gambling.
11. The percentage increase in arousal level will be higher when winning higher stake bets in comparison to either winning lower stake bets or not gambling.
12. Players are more likely to produce a somatic response when gambling at higher stakes in comparison to either gambling at lower stakes or not gambling.
13. Players are more likely to produce a somatic response when losing higher stake bets in comparison to either losing lower stake bets or not gambling.

14. Players are more likely to produce a somatic response when winning higher stake bets in comparison to either winning lower stake bets or not gambling.

1.3 Research Approach and Design

- The research design consisted of a repeated measures experiment, where each participant was required to undertake four separate gambling conditions and a control condition. In summary, the five experimental conditions were: £20 per spin winning condition, £20 per spin losing condition, £2 per spin winning condition, £2 per spin losing condition and a control condition where participants made a roulette betting choice and subsequently observed the spinning of the roulette wheel. The experimental conditions were counterbalanced to control for order effects.
- A sample of 32 regular adult gamblers (30 were male) was recruited through a range of public and private advertisements in the local area surrounding the University of Lincoln. Inclusion criteria required participants to have experience of playing a B2 gambling machine, and to not be experiencing any gambling-related problems.
- At the start of the experiment participants were provided with £132, and they were informed that the money was now theirs and that at the end of the experiment any money remaining and any money won was theirs to keep. In each experimental condition there were three separate bets on a virtual roulette simulation, where the participants were told at what stake to bet by the experimenter; with participants believing that the ensuing wins and losses were determined randomly. In order to standardise the experience in each condition participants were only permitted to make an outside bet with a 0.5 probability (i.e. choose whether the result would be red or black).
- Immediately after the result of the virtual roulette game, participants were asked to report their level of arousal by partially completing the Self-Assessment Manikan (SAM). After doing so, participants were asked to complete a Go/No Go Task, as a measure of response inhibition. This process was repeated three times in each condition. After the third Go/No Go Task ended, participants were visually reminded how much money they had won or lost in the condition, and then were asked to complete an Information Sampling Task (IST) as a measure of reflection impulsivity.
- During the entirety of the experiment, participants' electrodermal activity was recorded using a non-invasive technique, as a measure of arousal change and arousal response to various gambling outcomes (i.e. production of somatic markers).

- Data was subsequently analysed (using SPSS for Windows v. 21) to determine the effect of stake size on players' reflection impulsivity, response inhibition and arousal response.

1.4 Findings: Reflection Impulsivity

- In the high stake condition participants used less information and tolerated more uncertainty in their decision-making in comparison to the control condition. However, there was no significant difference in amount of information sampled between the high stake and low stake condition. In general, when losing, participants also sampled less information in comparison to the neutral control condition. When losing higher stake bets in comparison to the control condition, participants used less information when decision-making.
- There were no significant differences in decision-making latency across the various stake size conditions. Put simply, the length of time taken to evaluate decisions did not significantly differ after winning or losing at high stakes in comparison to low stakes or the control condition.
- However, after gambling at higher stakes in comparison to lower stakes, participants performed worse in decision-making with regard to the probability of their decisions being correct. Impairment in decision-making was also observed after gambling at the £2 stake condition in comparison to the control condition.
- This impairment in decision-making after higher stake betting was observed regardless of whether participants were winning or losing the bets. In general, participants were more likely to make predictions with lower probability of being correct after losing bets than after the control condition where there was no opportunity to win or lose money.

1.5 Findings: Response Inhibition

- When either winning or losing, participants gambling at higher stake sizes did not experience any deterioration in response inhibition in comparison to gambling at lower stakes. It was evident that the response inhibition executive function was not negatively affected by stake size in isolation.

1.6 Findings: Arousal Experience

- There were no significant differences in short-term arousal change from baseline when gambling at different stake sizes, regardless of whether participants were winning or losing.
- In terms of self-reported levels of arousal, participants reported experiencing higher levels of arousal when gambling at higher stakes in comparison to lower stakes or the control

condition. Participants also reported experiencing more arousal even when gambling at lower stakes in comparison to the control condition.

- As one would expect, participants reported more arousal when winning versus not winning, but they also found losing more arousing than the control condition where there was no opportunity to win or lose money. Winning at higher stakes was found to be more arousing than winning at lower stakes; however, there was no difference in arousal when losing at higher stakes in contrast to losing at lower stakes.

1.7 Findings: Arousal as Somatic Marker

- Participants were more likely to elicit a somatic marker, i.e. a skin conductance response (ER-SCR) in response to gambling at higher stakes in comparison to lower stakes, as one would expect given the added significance of gambling at higher stakes.
- In general, participants were more likely to produce a somatic marker after winning bets than after losing bets or after the control condition. However, there was no significant difference in somatic markers produced between the losing and control conditions.
- More specifically, participants were more likely have a somatic marker in response to winning bets at higher stakes in contrast to winning at lower stakes. However, there was no significant difference in somatic markers in response to losing at higher stakes, lower stakes or the control condition.

1.8 Discussion, Conclusions and Recommendations: Reflection Impulsivity

- It was observed that after gambling at higher stakes an individual is more likely to make decisions of reduced quality in terms of probability of being correct, than after gambling at lower stakes or the control condition. Ultimately, while controlling for alternative causal factors, it was observed that after betting at either the £20 or £2 per spin level, participants made more impaired judgements in a decision-making task.
- In this experiment, it is unlikely that the change in reflection impulsivity was caused by individual differences, as the effect was shown within individuals across a single day. It is much more probable that the impact on reflection impulsivity is explained by short-term changes in internal state such as valence (i.e. level of positivity) and emotion.
- With respect to oscillations in internal state, the impairment in decision-making was still observed at the £20 stake level when the participant was winning and being successful. This suggests that the deficit in performance is not related to a negative valence component. In

turn this may mean that intensity of emotion, i.e. arousal rather than positivity, may be a key explanatory factor to consider.

- Participants did not experience a significant short-term change in arousal in response to betting in any experimental condition. However, prior to the IST commencing, participants were provided with a reminder of the total monetary outcome of that condition. Therefore it is possible that although participants did not experience a significant change in arousal after a singular high stake bet, they may have experienced a significant change in arousal in response to seeing the larger cumulative sums won and lost. In other words, the change in arousal experienced in response to the cumulative total may account for the increase in reflection impulsivity observed in the study.
- It cannot be stressed strongly enough that the findings of the experimental work must be applied with caution. It is unrealistic to consider that singular structural characteristics of EGMs, such as size of stake playable, will have an effect on gambling behaviour without influence from other structural features of the game such as event frequency. Therefore, in order to inform policy regarding stake size limits it is important to look at the effect of stake size when integrated with other structural and environmental characteristics of EGM gambling within various gambling environments.

1.9 Discussion, Conclusions and Recommendations: Response Inhibition

- Stake size, independent of other structural or environmental characteristics related to virtual roulette gambling, does not cause a temporary deficit in participant's response inhibition. This suggests that if loss of control in gambling behaviour is indeed caused by poor response inhibition then it is a result of: a) pre-existing neuropsychological vulnerabilities, b) different structural characteristics other than stake size, or c) an interaction of multiple structural and situational characteristics alongside stake size.
- It is recommended that the potential relationship between stake size and response inhibition is explored in more detail, specifically to examine if the null effect of stake remains when gamblers are: a) able to re-bet rapidly as one can in EGM gambling, b) losing their own money that they have personally acquired rather than 'house money', and c) exposed to gambling related cues in the betting shop, casino or online environment that may be conditioned in the individual to elicit aroused internal states.

1.10 Discussion, Conclusions and Recommendations: Arousal Experience

- Gambling at larger stakes on a virtual roulette simulation, independent of other variables, appears not to significantly increase percentage change in arousal between pre-betting and post-betting levels. It is probable that a significant increase in arousal experienced when gambling on EGMs is a consequence of multiple interacting environmental and structural factors rather than dependent on stake size alone.
- In terms of self-reported arousal experience, participants were more sensitive to the effects of winning and the magnitude of sums when winning, in contrast to the effects of losing and size of loss. This may cause individuals to bias decision-making towards previous and potential wins when determining whether to continue or cease gambling.
- Self-reported arousal levels appear to change significantly when winning and losing, and also when winning at different stakes. As arousal is one of the two dimensions of emotion, it is probable emotional experience may also change significantly when winning at different stake sizes. Therefore, it is recommended that further research is conducted to explore the impact of stake size and gambling outcome on valence, the second dimension of emotion, and emotion collectively.
- With respect to understanding the experience of arousal as a contributing factor in loss of control when gambling, it is recommended in future research designs to explore the impact of stake size in relation to other structural and environmental features rather than in isolation.

1.11 Discussion, Conclusions and Recommendations: Arousal as Somatic Marker

- In general, participants appeared to show deficits in somatic responding to negative gambling outcomes when gambling on a simulated virtual roulette activity, and this may have a negative effect on future gambling decision-making.
- When winning, participants produced more somatic markers when gambling at higher stakes. This is interpreted to be an adaptive response as it is of benefit to the individual to signal larger rewards in comparison to smaller rewards. However, this strong somatic response to rewards, in combination with a more muted response to punishment, may bias decision-making and create a preference for risk-taking when gambling.
- The potential maladaptive physiological response to losing in a virtual roulette gambling simulation observed here is reflective of the findings from the self-report arousal data previously discussed. Therefore, there is a strong rationale for studying the differential physiological and somatic responses of individuals in EGM gambling, when losing and

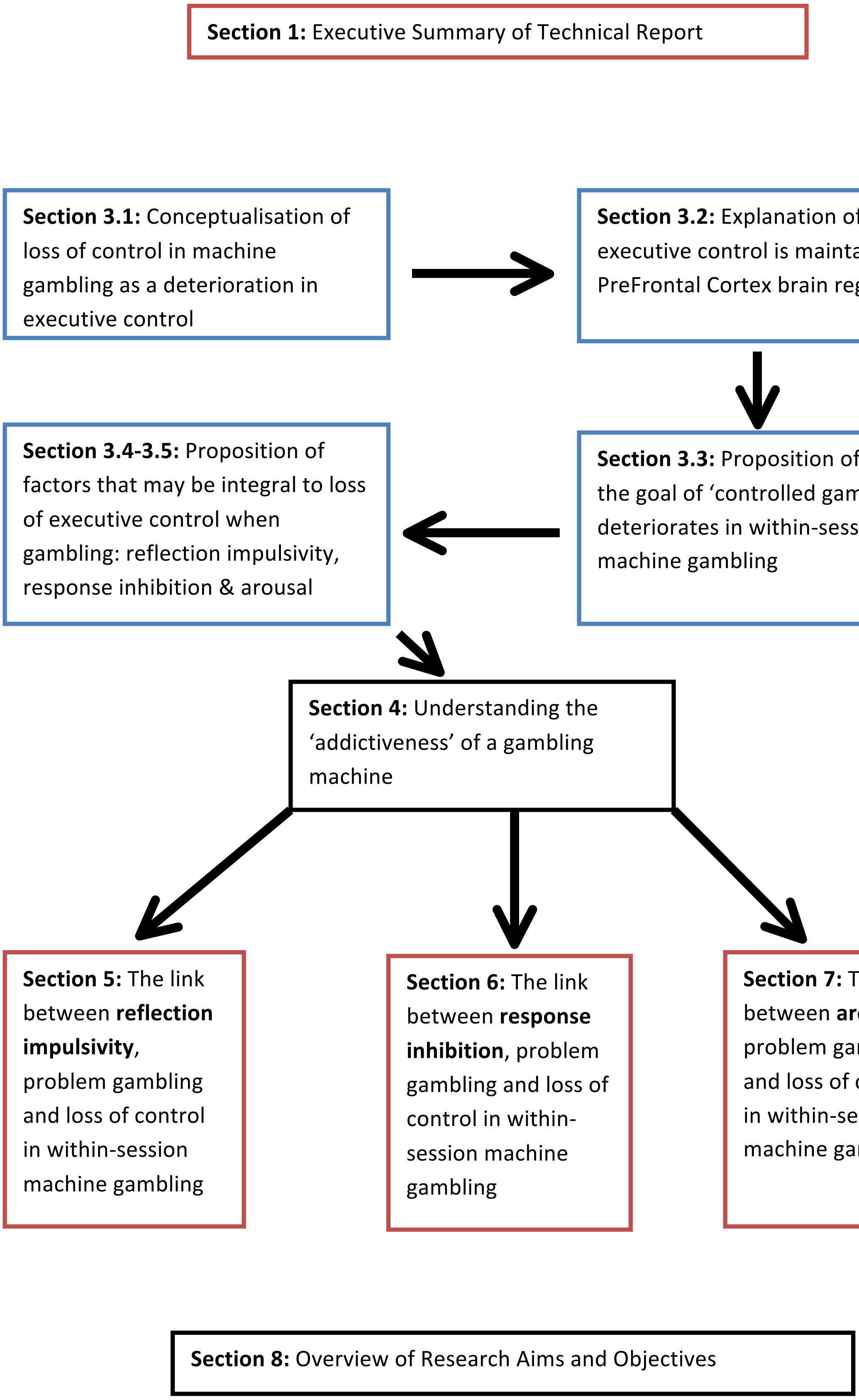
winning at higher and lower stakes. This lack of sensitivity to monetary loss when gambling may assist in understanding decision-making deficits and loss of control in within-session EGM gambling.

1.12 Final Statement

- This study finds initial support for a new stake-related risk factor for gambling-related harm, other than *rate of loss*, as it was demonstrated that gambling at higher stakes impairs decision-making, which in turn may reduce self-control when gambling.
- One of the key questions that remains to be addressed is the impact of event frequency (i.e. opportunity to re-bet at different speeds) on players' reflection impulsivity, response inhibition and arousal response when gambling. More specifically, how the observed impacts of stake size on player reflection impulsivity, response inhibition and arousal response are affected by differing event frequency levels.
- Of all the structural characteristics of EGMs, it is most important to understand the interaction of stake size and event frequency on gambling cognition and behaviour, because in Great Britain gambling machines are to an extent categorised primarily across these two dimensions. For example, although a B2 has a higher theoretical loss per hour in comparison with a B3, it is possible that the faster rate of play on B3 machines may have a more significant and negative effect on executive control in machine gambling than rate of loss.
- The gambling task used in this experimental design was developed to represent a simplified version of virtual roulette. It is also important to determine how stake size may interact specifically with other electronic gambling formats such as blackjack and slot content. It is possible that differences in game structure of content of commercial forms of virtual roulette, or indeed any other form of gambling, may also affect a player's executive control, either directly or indirectly.
- Because of the need to standardise the experience in terms of bet size, type and result in the experiment, to enable any difference in dependent variable to be concluded as being caused by stake size, it was necessary to conduct the study within a laboratory setting. However, there is now justification to fund more expansive research and explore the relationship between stake size and executive control within a range of real gambling environments. This would improve internal and external validity of the study by: a) looking at effect of stake size in combination with other structural and environmental characteristics, and b) observing the effect of participants losing their own personally acquired funds rather than money provided by the research team.

- In the current study, for practical and ethical reasons it was only possible to observe the effect of stake size on reflection impulsivity at £20 per spin, £2 per spin and a control condition where there was no opportunity to win or lose money. Although it is possible to determine whether higher stake gambling increases the level of reflection impulsivity in participants in contrast to lower stake gambling, it is not possible to fully understand and explain the precise relationship between stake size and reflection impulsivity deficits. It is important for future research to employ a design to measure the impact on reflection impulsivity when participants are winning and losing at a wide variety of stake sizes, ranging across the full spectrum from micro-limits to £100.

Overview of Introduction (Sections 1-7)



2 Purpose of the Research

This research forms part of a series of research projects commissioned by the Responsible Gambling Trust to consider two questions set out by the Responsible Gambling Strategy Board (RGSB). These two questions were:

a) Can we distinguish between harmful and non-harmful gaming machine play?

b) If we can, what measures might limit harmful play without impacting on those who do not exhibit harmful behaviours?

A series of core research reports specifically attempts to identify the types of patterns that could plausibly indicate risk of harm using industry held-data for Category B2 gaming.

This particular research project (one of four contextual projects in the broader research programme) contributes to our understanding regarding both objectives by examining the potential causal relationship between stake size and loss of control.

3 Theoretical Context and Paradigmatic Approach

3.1 The Relationship between Executive Control and Gambling-related Harm

Goudriaan et al. (2005) emphasised the overt dysfunctional nature of problem gambling by noting the phenomenology of the disorder is characterised by impaired decision-making that leads to negative consequences. At face value, it appears that problem gamblers are acting impulsively, and gambling recklessly with a disregard for the negative outcomes that may result in over-spending. Indeed, impulsivity has been studied extensively as a mechanism for understanding addictive disorders in general (Bickel, Jarmolowicz, Mueller, Gatchalian & McClure, 2012).

'Impulsivity' can be defined as actions that are prematurely expressed, unduly risky, poorly conceived and result in undesirable consequences (Durana & Barnes, 1993), and this definition is also a reasonable description of the pattern of problem gambling behaviour. However, the majority of research studies exploring the relationship between impulsivity and problem gambling investigate impulsivity as an enduring trait rather than a temporal 'state' (Bickel et al., 2012), therefore limiting understanding of how structural or situational characteristics may create short-term or temporary impulsivity that may help explain loss of control when gambling. Bickel et al. (2012) contends that given the overlap between impulsivity and executive functions, and that they are fundamentally antipodes, progress in understanding multiple psychological disorders, including problem gambling, can be made by studying executive functions.

'Executive functions' can be defined as categories of self-directed behaviour to change one's future reinforcement (Barkley, 2004). In other words, executive functions consist of a range of cognitive processes (e.g., attention, planning) that enable an individual to engage and benefit from goal-orientated behaviour. Control, via executive functions, is required when tasks are unfamiliar and complex, either through lack of previous experience or because the task relates to rapidly updating and changing circumstances (Miller & Cohen, 2001). Simplistic behaviour that is well established becomes autonomic in its execution and therefore does not require 'top down' control, i.e. control processes of evaluation and decision-making (Miller & Cohen, 2001).

It is argued that gambling behaviour on EGMs requires executive control because a multitude of interacting factors must be considered before an appropriate response or advantageous goal can be determined. For example, it is probable that the gambler has a predetermined amount of money that they can afford to lose without negative consequences, and equally an amount of time they can afford to spend gambling. However, once gambling, they are also likely to experience positive reinforcement from the emotional states created when gambling. Moreover, and particularly relevant to EGM gambling, they will be required to make rapid and continually changing estimations of net spend. It is also probable that such predetermined spending and time limits are not inflexible, meaning the player is likely to be re-evaluating such targets, and retrieving memories from past experience to inform such re-evaluations. It is proposed that when gambling on EGMs, players will be required to cognate large amounts of competing information within short periods of time.

In this report, a clear argument will be presented regarding the central role of executive functioning in problem gambling, presenting loss-chasing and over-expenditure in EGM gambling as a result of within-session deterioration in executive control. Moreover, the impact of stake size on executive control will be directly investigated in relation to a virtual roulette gambling activity.

3.2 Maintaining Executive Control: the Role of the PreFrontal Cortex

The prefrontal cortex (PFC) is the area of the brain that is central to maintaining self-regulation through executive control (Goldstein & Volkow, 2002; Miller & Cohen, 2001). Essentially, the PFC is the mechanism through which individuals can coordinate and organise the multitude of information available (from sensory modalities, memories and internal states such as affect) into a coherent 'representation' and enable goal-orientated behaviour (Miller & Cohen, 2001). Underlying this concept of executive function are the principles of the Biased Competition Model (Desimone & Duncan, 1995), emphasising the competitive nature of neural activity in the brain. More specifically, there will be a mass of sensory input presenting a range of possible behavioural responses, and there is a need for 'top down' organisation to identify task-relevant signals and thus promote a biased favourability for such signals (Miller & Cohen, 2001). The PFC biases the flow of neural activity that is task-relevant and effectively applies selective 'attentional plates' that are determined to be effective guidelines for achieving the specified goal. In other words, the PFC makes it easier for an individual to achieve their goals by prioritising the flow of information that is goal-related while inhibiting less relevant information. The appropriate attentional plate may be readily available based on inferences of what worked effectively in previous similar situations, or it may be less established and guided more tentatively by general principles, or *cognitive rules of thumb* (Miller & Cohen, 2001).

Once an attentional plate or mapping has been determined, the PFC must actively maintain this 'set of rules' until the task is completed or at least is no longer an objective. As a result, one of the fundamental requirements of the PFC in establishing executive control is being capable of updating the mapping in response to new task-relevant information while simultaneously being resilient to interfering and irrelevant stimuli. Furthermore, it is often the case that such interference signals are more established than the current task mapping and therefore provide strong interference in relation to the more weakly established current mapping.

The PFC "*favours task-relevant sensory inputs (attention), memories (recall) and motor outputs (response selection) and thus guides activity along the pathways that connect them (conditional association)*," (Miller & Cohen, 2001, p.178). Within the context of EGM gambling in general, it is understood that one of the primary motivating factors for participation is the search for excitement (McCormick, Delfabbro & Denson, 2012; Moodie & Finnigan, 2005). Furthermore, it is reasonable to infer that experienced EGM gamblers are aware of the negative financial consequences that can emerge from participation. Therefore, the player is likely to resolve this motivation to gamble and their awareness of risk with a 'mapping' of a decision to gamble in a manner that will enable them to experience the positive reinforcement of gambling, while minimising the potential negative consequences such as spending more than they can afford. If the starting point for the non-problem gambler is to gamble in a controlled manner as a leisure pursuit, the key question to address is how and why the mapping of 'controlled gambling' in the PFC deteriorates and executive control diminishes. More specifically, does stake size play a causal role, either directly or indirectly, in the loss of executive control in EGM gambling?

3.3 Deterioration of Executive Control in EGM Gambling

The transition from controlled gambling to patterns of gambling that will lead to harm can be characterised by the chasing of incurred losses, i.e. the pursuit of higher risk or higher yield betting to recover past losses (Lesieur, 1979; Walker, 1992). Loss chasing is a common behavioural pattern among gamblers (Campbell-Meiklejohn, Woolrich, Passingham & Rogers, 2008; Dickerson, Hinchy & Fabre, 1987). Loss chasing is recognised to have the capacity to accelerate participation in gambling with significant negative consequences (Corless & Dickerson, 1989), including social and health implications for the individual and the community (Korn & Shaffer, 1999; Neal, Delfabbro & O'Neil, 2005).

Considering over-spending and chasing of losses as a key component of gambling-related harm further, it is important to note that loss chasing within a gambling session is considered to be a developmental forerunner to between-session loss chasing (O'Connor & Dickerson, 2003), where substantial debts can be accumulated and the individual progresses towards problem gambling (Lesieur & Rosenthal, 1991). This process can also be explained via executive functioning and the PFC; as the frequency of the pattern of losing control when gambling increases, the stronger the pathway will become because of associated learning. Essentially, the repeated pairing of a goal (machine gambling) with a response (over-spending and loss chasing) will create an attentional plate or mapping that is strongly established and therefore reduces the need for executive control during the task, and therefore less PFC activation will occur (Miller & Cohen, 2001) when gambling on EGMs in future.

Kreusch, Vilienne and Quertermont (2013) argue that with respect to loss of control of alcohol consumption, repetitive and chronic disordered alcohol use leads not only to impaired executive functioning but also to an automatic tendency to over-consume when presented with alcohol cues. From an EGM gambling perspective, it is evident that loss chasing and experiencing gambling-related harm can become a habitual pattern of behaviour. Moreover, the more often the pattern is repeated, the more automatic it becomes, with the player less sensitive to the need to establish executive control. It is concluded that as the chasing of losses is the most significant step towards problem gambling (Lesieur, 1979), that understanding the mechanism of how a non-problem gambler loses control within an EGM gambling session is fundamental to developing harm-minimisation strategies to reduce gambling-related harm.

3.4 Potential Factors in Loss of Control in EGM Gambling

The most probable explanatory factor to account for deterioration of controlled EGM gambling is that through interference from strong signals such as internal states (e.g., emotion and reward circuitry), the goal of controlled gambling is replaced, or at least is no longer actively maintained.

Research indicates that a motivation to chase losses is often the removal of 'bad feelings' or negative affect (Corless &Dickerson, Demaree et al., 2012). Campbell-Meiklejohn et al. (2008) argues that loss of control and loss chasing is driven by a mixture of strong emotions. Lesieur (1984) characterises this emotional experience as a balance between anxiety and distress associated with already accumulated losses, and the persistent belief that it is possible to recover losses with continued gambling. These strongly experienced negative internal states are likely to interfere with goals of controlled gambling; particularly if the relationship between negative affect and loss of control in gambling is an established association, i.e. habitual.

Furthermore, beyond the eagerness to remove negative mood states such as anxiety and frustration, the loss of control and chasing of losses is also motivated by uncontrollable urges to continue gambling (Campbell-Meiklejohn et al., 2008). With reference to EGM gambling in general, given the high event frequency of EGMs it is probable that this urge to continue is a manifestation of a prepotent response. A prepotent response is conceptualised as a response that over time has consistently provided immediate reinforcement, to the extent that relevant external cues will create an automatic response in the individual without conscious thought (Barkley & Murphy, 2005). It is widely accepted that the arousal and subjective excitement engendered by gambling is a primary motivating factor (Boyd, 1976), and maintenance of persistent gambling is best accounted for through classical conditioning where the player is positively reinforced with every bet or spin (Anderson & Brown, 1984). Given the rapid speed of play of EGMs in relation to alternative gambling activities, and the classically conditioned reinforcement of excitement with every spin, it is argued that this urge to continue gambling could be based on the development of a prepotent response.

Ultimately, it is proposed that the deterioration of controlled gambling in the PFC (i.e. the loss of control when gambling on EGMs) is caused by interference from the strong urge to remove negative mood states, and the development of persistent gambling as a prepotent response that the PFC finds difficult to inhibit.

3.5 The Role of Stake Size in Interference of Executive Control in EGM Gambling

3.5.1 Key Executive Functions in Controlled EGM Gambling

It must be acknowledged that stake size, although a critical and central structural characteristic, remains a singular variable, and is likely to have varying impacts on gambling behaviour as it interacts with other structural and environmental characteristics of each specific gambling product (Parke & Parke, 2013). As a result, it is important to consider the impact of stake size in the context of other situational and structural characteristics of EGMs, i.e. high event frequency.

One of the challenges of investigating executive control in appetitive behaviour is the wide range of executive functions that have been demonstrated to be linked with addictive patterns of behaviour (Bickel et al., 2012); including behavioural inhibition (Barkley, 1997, 2004), attention (Garavan & Hester, 2007; George & Koob, 2010), valuing future events (Bechara, 2005), emotional activation and self-regulation (EASR: George & Koon, 2010), behavioural flexibility (Robbins, 1996) and planning (Bickel, 2012). When considering impulsivity as the antipode of executive control, we also acknowledge that impulsivity is reliably separated in the literature into two distinct components, namely response inhibition and impulsive choice (Congdon & Canli, 2008; Fineberg, Potenza, Chamberlain, Berlin, Menzies, Bechara et al., 2010; Moeller, Barratt, Dougherty, Schmitz & Swann, 2010). Although impulsive action (behavioural disinhibition) and impulsive choice (cognitive impulsivity) appear at face value to be manifestations of the same underlying vulnerability, it has been determined that they are indeed distinct concepts and dependent on different mechanisms (Caswell, Morgan & Duka, 2013).

Rather than investigate the impact of stake size on impulsive uncontrolled EGM gambling, it seemed more prudent to explore the relationship at a more fundamental and simplistic level by breaking down the component mechanisms involved in loss of control in gambling into *response inhibition* and *reflection impulsivity*.

3.5.2 Arousal as Potential Mediating Factor in Loss of Control

As previously identified, it is widely accepted that the primary reinforcer for gambling behaviour is the excitement and arousal that is provided with each bet or spin (Anderson & Brown, 1984; McCormick et al., 2013). Anderson and Brown (1984) argued that the autonomic nervous system plays a significant role in the conditioning process of problem gambling because it explains the reinstatement phenomenon (i.e. continuance of gambling despite significant negative consequences). In simple terms, independent of winning or losing, a strong urge to continue gambling may be a response to strong arousal cues experienced by the gambler. The ability of the individual to modify mood states through excitation or even depression of the nervous system was also a central feature of Jacob's explanatory model, the General Theory of Addiction (Jacobs, 1986).

Furthermore, when considering the substantial evidence available demonstrating that participants experienced increased arousal when the size of the win is increased (Wulfert, Roland, Hartley, Wang & Franco, 2005; Wulfert, Franco, Williams, Roland & Mason, 2008) and when a monetary win is played for in comparison to a token win (Meyer, Schwertfeger, Exton, Janssen & Knapp, 2004), and also the motivational drive to seek excitement via gambling, it appears important to evaluate the impact of stake size on physiological measures of arousal when gambling on EGMs.

4 Paradigmatic Approach to Evaluating 'Addictiveness' of EGMs

First, it is important to acknowledge the misconception regarding the development and maintenance of addiction and the misattribution of the term 'addictiveness'. It is erroneous, and more importantly unhelpful, to consider substances or behaviours such as gambling as being inherently addictive. Essentially, an addictive disorder is a repeated pattern of behaviour that that is characterised by a lack of control, increasing tolerance of, and experiences of withdrawal towards, substances or behaviours that lead to significant negative consequences and deleterious effects for the individual (DSM V: American Psychiatric Association, 2012). Fundamentally, it is important to recognise that it is the individual's behavioural and cognitive response to the product or substance that is disordered, rather than the product being 'addictive'.

Nevertheless, it is also acknowledged that specific types of gambling activities are more commonly associated with problem gambling than others. Furthermore, research also demonstrates that one of the gambling activities most commonly associated with problem gambling is EGMs, and category B2 machines in particular (GamCare, 2012). It is accepted that the driving force behind gambling-related harm is the negative consequences of losing significant sums of money (Blaszczynski et al., 2005; Neal et al., 2005), and if one combines the rapid speed of play of EGMs with the opportunity to risk high stakes (as with category B2 machines and online slots), there appears to be a greater potential to experience gambling-related harm. It is the combination of high event frequency and the potential to risk high stakes per bet enabling a higher *cost of play* which in turn may present increased risk for the public (Parke & Parke, 2013; Productivity Commission, 2010; RGSB, 2013).

Therefore, it is proposed that specific structural and environmental characteristics of gambling activities can impact the player in such a way as to increase the probability of the individual's losing control and subsequently experiencing gambling-related harm. The current research approaches the experiment from the perspective that specific structural characteristics of EGMs, in this case stake size, may have a causal effect in the deterioration of executive control in within-session gambling.

5 Reflection Impulsivity and Problem Gambling

'Reflection impulsivity' refers to the tendency to make an impulsive decision in contrast to the tendency to gather and evaluate information prior to decision-making. Reflection impulsivity was initially conceptualised as an explanatory factor in the impulsive and uninhibited behaviour in non-adult populations (Kagan, 1966; Mitchell & Ault, 1979); and early conceptualisations were focused on the latency within the decision-making processes for children (Kagan, Rosman, Day, Albert & Phillips, 1964). Essentially, it was concluded that "*the Reflective not only spends more time evaluating hypotheses but also gathers more information on which to base his decisions and he gathers it more systematically than the Impulsive*," (Messer, 1976, p.1028, *as cited in* Mitchell & Ault, 1979). However, more recently in reference to adult psychopathology more weighting has been given to the dependent outcome of accuracy of decision-making in response to available information rather than being centrally focused on the latency of decisions (Block, Block & Harrington, 1974; Clark, Robins, Ersche & Sahakian, 2006).

Clark et al. (2009) proposed that reflection impulsivity would lead to behaviour that was poorly conceived, prematurely expressed, and inappropriately risky in response to a specific situation. There is a significant literature base available demonstrating more reflection impulsivity, in comparison to controls, in a range of substance abuse and dependent populations (Clark et al., 2006; Clark et al., 2009; Cohen, Nesci, Steinfeld, Haeri & Galynker, 2010; Quednow, Kuhn, Hoppe, Westheide, Maier, Daum et al., 2007).

There also appears to be an inherent link between reflection impulsivity, i.e. poor decision-making performance under uncertainty, and the processes central to gambling-related harm, such as the urge to chase losses to remove negative mood states and to recover past losses. As Goudriaan et al. (2005) noted, despite this seemingly obvious link between reflection impulsivity and gambling-related harm in general, there are few studies exploring the relationship, and furthermore the handful of existing studies have significant methodological limitations. For example, one of the studies demonstrating diminished performance of pathological gamblers in a decision-making task (Cavedini, Riboldi, Keller, D'Annucci & Bellodi, 2002) used the Iowa Gambling Task (IGT) as the test for the dependent variable. Given the gambling cues present in the IGT there are likely to be confounding factors influencing performance, and it is not surprising to find problem gamblers making maladaptive decisions in response to gambling contexts. Another substantial methodological limitation of existing studies of decision-making performance in problem gamblers was the heterogeneity of gambling activities under assessment (Goudriaan et al., 2005). Put simply, given the substantial differences in the structural and situational characteristics of gambling activities, it is probable, for example, that problem gamblers who primarily play EGMs are likely to have different levels and types of decision-making deficiencies than problem gamblers who are primarily poker players. Finally, many of the existing studies have failed to control for the confounding factor of comorbidity and medication use on decision-making performance, making it difficult to conclude that any deficiency is a result of the gambling disorder (Goudriaan et al., 2005).

Research has demonstrated that on the Card Playing Task (CPT: Newman, Patterson & Kosson, 1987), a measure of response preservation, in comparison to controls problem gamblers were more likely to sub-optimally persevere with the gambling task, as one would expect (Goudriaan et al., 2005). However, with specific reference to reflection impulsivity, it was observed that in comparison to controls problem gamblers gambled faster (reduced latency) when they were losing (Goudriaan et al., 2005). Furthermore, with respect to IGT performance, problem gamblers sampled less information to assist decision-making, demonstrated less awareness of the most favourable response and made decisions significantly more rapidly than the control population (Goudriaan et al., 2005). In a similar study, Lawrence et al. (2009) also found problem gamblers displayed more reflection impulsivity in comparison to control populations, sampling less information and tolerating more uncertainty in determination of responses. Furthermore, using the Cambridge Gamble Task (Rogers et al., 1999) as an additional measure of decision-making performance with explicit probabilities rather than uncertainty, problem gamblers were also shown to have impairments in risky decision-making in comparison to controls (Lawrence et al., 2009).

Goudriaan et al. (2004) argued that deterioration of self-regulation, or controlled behaviour, is a result of an inability to inhibit an urge and then select a more adaptive response. It is argued that a deficiency in reflection impulsivity, where individuals do not actively attend to available information to make an appropriate decision, may be a risk factor for problem gambling and gambling-related harm. Therefore, in the current study, the impact on reflection impulsivity of gambling on a virtual roulette gambling simulation at varying stake sizes will be directly investigated.

6 Response Inhibition and Problem Gambling

Response inhibition is a fundamental component of executive control and therefore central to serving future-orientated goals (Miller & Cohen, 2001; Miyake, Friedman, Emerson, Witzki, Howerter & Wagner, 2000). According to Wright et al. (2014) response inhibition has two forms: cancellation or withholding. 'Cancellation' refers to stopping a response after it has been initiated in the individual, whereas 'withholding' refers to stopping a prepotent response, i.e. showing restraint in response to a strongly conditioned cue (Wright et al., 2014). Poor response inhibition performance, often referred to as 'behavioural disinhibition', demonstrates an inability to restrain a response that is no longer adaptive, or at least no longer appropriate (Chamberlain et al., 2007; Strakowski et al., 2009; Winstanley, Eagle & Robbins, 2006). Barkley (1997) argues that response inhibition involves three interrelated responses including inhibiting a prepotent response, and thus allowing a delay before responding, and finally the protection of this delay from competing signals, i.e. resisting interference.

There is a substantial amount of evidence demonstrating deficits in response inhibition in populations with substance abuse and addictive disorders in comparison to control populations (Fillmore & Rush, 2002; Lawrence et al., 2009; Monterosso, Aron, Cordova, Xu & London, 2005; Solowij et al., 2012; Wright et al., 2014). It is therefore unsurprising that response inhibition is considered to be a central factor in explanatory models of development and maintenance of addictive patterns of behaviour (Goldstein & Volkow, 2002; Koob & Le Moal, 2001). Kreusch et al. (2013) concludes that if poor response inhibition is not a developmental causal factor it is certainly a maintaining factor in addiction.

There is also direct evidence demonstrating response inhibition deficits in problem gambling populations in comparison to control populations (Carlton & Manowitz, 1992; Goudriaan et al., 2006; Vitaro, Arsenault & Tremblay, 1999). The relationship between response inhibition deficits and problem gambling appears inherent when considering the key characteristics of problem gambling; namely, being unable to resist urges to continue gambling despite incurring negative consequences, alongside the strong urge to recoup losses to remove negative affect. It is argued that without the suppression of such urges it is not possible to self-regulate and engage in controlled responses to the event (Barkley, 1997; Taylor & Jentsch, 1999). Essentially, without pausing for reflection the individual will have poor associative learning regarding the negative consequences and be primed to act immediately in response to conditioned cues or prepotent responses (Patterson & Newman, 1993).

Goudriaan et al. (2004) argued that given the centrality of response inhibition in addiction models, and the observed deficits in response inhibition across problem gamblers, research that could provide more insight into the influence of reward, punishments and cues on response inhibition in problem gambling is required. The current study will achieve this by exploring the impact of winning and losing various stake sizes in a virtual roulette gambling simulation on performance in a response inhibition task, to evaluate the potential causal role of stake size in deficient executive control in gambling contexts.

7 Arousal and Problem Gambling

7.1 Arousal as a Motivating Factor in Problem Gambling

As discussed previously, problem gamblers can experience significant changes in mood state when immersed in gambling, similar to states of intoxication or 'highs' found in those who are addicted to substances (Blum et al., 2000). Such states of arousal and excitement are considered to be a primary motivation for gambling (Bruce & Johnson, 1986; Gilovich & Douglas, 1986, Goudriaan et al., 2004). Therefore, it makes sense that arousal states may also be a central component in explaining loss of executive control when gambling on EGMs.

Arousal is a complex physiological system that still is not fully understood; therefore it is not surprising that a review of literature looking at the relationship between arousal and problem gambling does not provide clear cut definitive answers (Goudriaan et al., 2004). However, there are some reliable trends in the literature; principally that when gambling, and in response to gambling cues, frequent gamblers (Leary & Dickerson, 1985; Moodie & Finnegan, 2005; Pascual-Leone, Campeau & Harrington, 2012) and problem gamblers (Sharpe et al., 2005; Brown et al., 2004) experience higher arousal in comparison to less frequent and non-problem gamblers. Furthermore, although winning expectancy is a significant part of arousal in gambling (Ladouceur et al., 2003), problem gamblers are aroused by both losses and wins, whereas non-problem gambling populations tend only to experience higher arousal in response to winning (Sharpe, 2004). It could be argued that problem gamblers experience higher autonomic arousal in response to general gambling cues (Sharpe et al., 1995) and therefore that persistent gambling is classically conditioned, with arousal being the primary reinforcer rather than monetary reward (Anderson & Brown, 1984).

The implication of a conditioned response of increased arousal to gambling cues is that there will be increased motivation (and urges) to gamble despite negative consequences, whereas *unconditioned* non-problem gamblers will respond more adaptively to losses. As discussed previously, Newman and Patterson (1993) argued that 'disinhibited' groups have difficulty in learning from punishment because they experience it abnormally in comparison to normal populations. Goudriaan et al. (2004) apply this principle to gambling contexts, with problem gamblers engaging in the activity with a strong *approach set* when participating in reward-related tasks, and effectively having a hypersensitivity to reward. For vulnerable gamblers, alongside winning and the opportunity to win increasing arousal, if the player loses and becomes frustrated this too will also increase arousal (Goudriaan et al., 2004).

7.2 Arousal as Somatic Marker in Response to Gambling Outcomes

A possible explanation for the observed maladaptive learning in response to rewards and punishment could be the absence of guidance from the limbic system as proposed in the somatic marker hypothesis (Damasio, 1994). The central proposition of the somatic marker hypothesis is that, in normal samples, emotional bodily processes known as somatic markers act essentially as internal 'preferences' to help guide decision-making. These 'preferences' are created through associative learning, where bodily states are associated with positive and negative events, and after repeated pairings this somatic response becomes established (Mardaga & Hansenne, 2012). Such preferences (somatic markers) will emerge again in anticipation of either the reward or punishment in question, and act as a form of guidance to help *weight* more logical reasoning.

Essentially, where previously it was assumed that emotion can only reduce the quality of rational decision-making, it has recently become widely accepted that emotional and arousal states can be an important component in decision-making (Mardaga & Hansenne, 2012). Somatic markers are also argued to improve decision-making by enabling the individual to consider long-term consequences based on the stimulated emotional states. Damasio (1994; 1999) argues that somatic markers assist decision-making by enabling individuals to generate a range of options and avoid inactivity that could arise by not being able to conclude from extensive, complex evaluation. As Tranel et al. (2000, *as cited by* Colombetti, 2008, p.57) summarised: "*In the absence of somatic markers, response options and outcomes become more or less equalised. Subjects may then resort to a strategy of deciding on an option based on extremely slow and laborious logic operations over many potential alternatives … and hence fail to be timely, accurate and propitious. Another possible consequence of missing somatic markers is that decision-making may become random or impulsive.*"

It has been demonstrated that a lack of somatic marker after an outcome that provides negative feedback is a predictor of future poor decisions (Suzuki, Hirota, Takasawa & Shigemasu, 2003), suggesting therefore that decision-making deficits can be a result of dysfunctional emotion-based associative learning. It could therefore be argued that consistent loss of control when gambling on EGMs may, to some extent, be based on dysfunctional somatic responses to gambling wins and losses. It is difficult to propose with authority the specific role of arousal (as somatic markers) in the loss of control in EGM gambling, because the specific impact of somatic markers in decision-making is not fully established in the literature (Colombetti, 2008). In short, the somatic marker hypothesis requires further exploration to isolate which element of decision-making it specifically affects (e.g., attention, working memory) and to explore the role of other somatic markers beyond skin conductance responses (Colombetti, 2008; Dunn, Dalgleish & Andrew, 2006).

Given that the focus of the experimental work is to understand the impact of stake size as a potential risk factor for the loss of control in EGM gambling, it is important to consider the impact of stake size on arousal in terms of evoking somatic markers, in addition to its role as a primary motivation to gamble. By observing whether gambling on virtual roulette at larger stake sizes evokes a different somatic response pattern than lower stake sizes, the probable value of future research into exploring this complex and under-developed explanatory model can be evaluated. If there is no variation in somatic response across stake size, it would indicate that any impact of stake size on loss of control cannot be explained via the somatic marker hypothesis.

8 Overview of Research Aims and Objectives

Despite the intuitive relationship between loss of control, problem gambling, arousal and executive functioning, there remain relatively few studies available that develop our understanding of the deterioration of executive control as a causal factor in development and maintenance of problem gambling (Goudriaan et al., 2004, 2006). Furthermore, within the existing studies there are a range of significant methodological limitations that restrict understanding, including a lack of observation of differential effects across different gambling products or across different gambling outcomes, i.e. winning and losing.

Another limiting factor of existing research is that the comparison of executive functioning and psychophysiological responses has been performed between clinical and non-clinical populations. This makes it difficult to determine whether the deficits in executive functioning were pre-existing individual vulnerabilities, or whether the neurocognitive deficits developed in response to repeated gambling behaviour. The current study aims to investigate whether stake size has a causal effect on executive functioning, and therefore whether gambling at higher stake sizes is a risk factor for losing control when gambling.

In order to establish the requisite experimental control necessary to make conclusions regarding causal effects, a simplified version of virtual roulette was utilised. It is acknowledged that gambling behaviour will not solely be affected by a single structural characteristic in isolation, but rather the collective interaction of a range of environmental and structural characteristics (Parke & Parke, 2013). However, given that there is a minimal amount of knowledge available regarding the specific impact of stake size in EGM gambling, it was necessary to attempt to isolate the specific effect of stake size on executive control as a foundational starting point. Naturally, as the research base develops, the aim will progress to exploring how the impact of stake size is influenced and mediated by other game features and environmental cues.

In the current study we investigated two executive functions, reflection impulsivity and response inhibition, that have been strongly implicated as developmental and maintaining factors in addiction in general, and problem gambling specifically. The study will observed the causal effect of stake size in virtual roulette on players' level of reflection impulsivity and response inhibition performance. The study will also observe the causal effect of stake size on the experience of arousal, and more specifically whether winning and losing at higher and lower stakes produce distinct experiences of arousal for the participant. By determining whether the experience of gambling on virtual roulette at high stakes is physiologically different to low stakes, insight will be provided into the relative importance of arousal in understanding the relationship between stake and deterioration of executive functions, and potentially the loss of control in gambling.

8.1 Research Hypotheses

1. A player's level of reflection impulsivity will be higher after gambling at higher stakes in comparison to either gambling at lower stakes or not gambling (i.e. control condition).
2. A player's level of reflection impulsivity will be higher after losing bets in comparison to either winning bets or not gambling.
3. A player's level of reflection impulsivity will be higher after losing higher stake bets in comparison to either losing lower stake bets or not gambling.
4. A player's level of reflection impulsivity will be higher after winning higher stake bets in comparison to either winning lower stake bets or not gambling.
5. A player's ability to inhibit prepotent responses will be lower after gambling at higher stakes in comparison to either gambling at lower stakes or not gambling (i.e. control condition).
6. A player's ability to inhibit prepotent responses will be lower after losing bets in comparison to either winning bets or not gambling.
7. A player's ability to inhibit prepotent responses will be lower after losing higher stake bets in comparison to either losing lower stake bets or not gambling.
8. A player's ability to inhibit prepotent responses will be lower after winning higher stake bets in comparison to either winning lower stake bets or not gambling.
9. The percentage increase in arousal level will be higher when gambling at higher stakes in comparison to either gambling at lower stakes or not gambling (i.e. control condition).
10. The percentage increase in arousal level will be higher when losing higher stake bets in comparison to either losing lower stake bets or not gambling.
11. The percentage increase in arousal level will be higher when winning higher stake bets in comparison to either winning lower stake bets or not gambling.
12. Players are more likely to produce a somatic response when gambling at higher stakes in comparison to either gambling at lower stakes or not gambling.
13. Players are more likely to produce a somatic response when losing higher stake bets in comparison to either losing lower stake bets or not gambling.
14. Players are more likely to produce a somatic response when winning higher stake bets in comparison to either winning lower stake bets or not gambling.

9 Research Methodology

9.1 Participants

A sample size of N=32 (30 males, 2 females) was recruited for the repeated-measures experiment. Participant ages ranged from 19–36 with a mean age of 25.8 (SD=4.46). The study was advertised through a range of avenues including popular internet sports networking sites used by those in the Lincolnshire area. In addition, local adult sports clubs were contacted directly, where the research was advertised as an investigation into gambling behaviour on category B2 machines. This recruitment strategy was used as an efficient way to target a sample predominantly consisting of young adult males; a cohort that has been consistently shown to make up a large proportion of EGM gamblers (British Gambling Prevalence Survey, 2007; 2010). Local betting shops also advertised the study through their list of registered players from the surrounding Lincolnshire area.

The study inclusion criteria required participants to have experience of participating in gambling activities within the last six months, and to be frequent gamblers in terms of participating in sports betting, casino gambling (online or offline) and/or category B2/B3 gambling at least once every 14 days. The importance of category B2 experience was to ensure that electronic gambling was not a novel concept to participants and that they understood how to operate electronic gambling machines and how they worked. Participants all had normal or corrected-to-normal vision and hearing.

Information about the participants' gambling behaviour, in terms of preferred gambling activities and level of stake they typically gambled with, was obtained via a semi-structured interview conducted by the experimenter prior to participation. In addition to category B2 participation, last six month gambling participation included: sports betting; live and online poker; online slots and casino table games; scratch cards; and national lottery. Information obtained from the brief interview revealed that participants on average took part in 2.1 different gambling activities in addition to category B2 machines. See Appendix 1 for summary of participant gambling activities and their stake size preferences.

An additional purpose of the interview was to ensure that no participant was currently under any gambling self-exclusion programme, or currently seeking help regarding problems with their gambling. Fundamentally, the design of the experiment does not support between group analysis, therefore it would be inappropriate to attempt to extrapolate any differences in performance based on whether participants were problem or non-problem gamblers, and therefore no problem gamblers were included within this study. Furthermore, it would be ethically unsound to provide problem gamblers with a monetary stake and make them risk the provided stake. However, any impact of individual differences would be controlled for within a repeated measures design.

Participants were all informed prior to commencement of the experiment that they would not have to use any of their own money and that any stake remaining and money won during the experiment could be retained. Participants who were recruited from the same sporting club were all tested separately on the same day to minimise communication with other participants.

9.2 Procedure and Apparatus

Figure 1 below is a schematic summarising the experimental procedure.

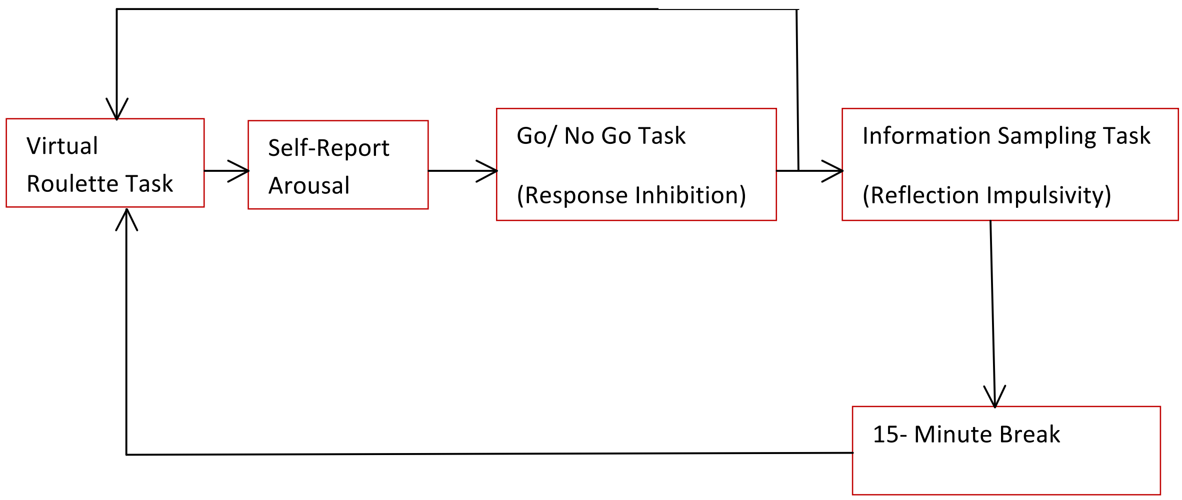


Figure 1 Experimental Overview

In each condition participants made three bets on a virtual roulette task. Following each bet participants were asked to self-report arousal level before completing a Go/No Go task. This process was repeated three times. After the third Go/No Go task participants were reminded of their monetary wins and losses of their last three bets before completing five trials of the IST. Participants' electrodermal activity was being recorded throughout the session to measure arousal. Participants were given a 15-minute rest between each condition.

Upon arrival at the laboratory, participants were given a stack of betting chips that had a total monetary value of £132. They were informed that the chips were now theirs and that any money won or retained at the end of the experiment would be converted into cash and would be theirs to keep. Participants were given six betting chips, each being worth £2, and six betting chips worth £20 each.

An outline of the experimental process, what was required of the participant, and their rights within the study were discussed before signed consent to proceed with the experiment was obtained. The experimenter then read a detailed outline of the experiment to the participant, stopping regularly to check for understanding and allow questions to be asked.

Participants were briefed that the research was looking into the physiological and cognitive effects of gambling at different stake levels on virtual roulette. The experiment comprised of five parts, with each part requiring participants to make three separate bets on a game of virtual roulette. The bets consisted of participants selecting whether the result of the roulette spin would land on red or black. In two of the five parts of the experiment, participants made three £2 bets; in another two parts they made three £20 bets. In one section, to provide a control condition the participants made virtual roulette decisions and observed the roulette wheel revolving similar to the other betting conditions, however no money was staked.

Each part of the experiment represented the five experimental conditions assessing two independent variables: stake size (no bet, £2 and £20) and outcome (win/loss). The conditions comprised: £2 stake losing condition; £2 stake winning condition; £20 stake losing condition; £20 stake winning condition; and a control condition with no opportunity to win or lose money and no feedback as to correct/incorrect selections. Outcome was manipulated by the experimenter to produce three wins in both the high (£20) and low (£2) stake winning conditions and three losses in both the high and low stake losing conditions. This allowed an assessment of the effects of both losing at lower and higher stakes as well as winning at lower and higher stakes; an important distinction given the often asymmetrical impact outcome has on EGM behaviour (Harris & Parke, under review), physiological arousal (Hochman & Yechiam, 2011), as well as affect and decision-making (Leith & Baumeister, 1996). The order in which the different conditions were presented was counterbalanced across all participants. This was to prevent confounding variables, such as the impact of early big wins or extended losing streaks for example, affecting results in the physiological and executive control assessments.

The control condition was designed to represent the act of selecting red or black on a roulette simulation with no result being provided, rather than being a direct replication of the high stake or low stake roulette betting conditions. The objective was to control for the arousal associated with making roulette predictions (i.e. the selection of red or black) and the potentially conditioned arousal response stimulated by a spinning virtual roulette wheel. Each participant had experience of playing B2 machines, and many had experience of casino games both online and offline, therefore it was probable for several participants that roulette cues such as selecting a prediction and the sight and sound of a virtual roulette wheel may stimulate an arousal response, conditioned from previous pairings of virtual roulette and excitement. Put simply, the control condition was designed to control the 'learned stimulation' that may be associated with engaging in associated roulette activities without specifically simulating a zero stake bet.

There was potential to provide control conditions to replicate the experience of both winning and losing zero stake virtual roulette bets; however this would have required a sixth experimental condition to replicate the experience of three sequential wins and three sequential losses. This proposition was considered in detail, but ultimately rejected because the addition of a sixth experimental condition would have extended an already protracted experimental design by at least 30 minutes per participant. There would inevitably be effects on the quality of data collected, as participants during the experimental trials became fatigued (Healy, Kole, Buck-Gengler& Bourne, 2004). Furthermore, given that the proposed zero stake conditions with winning and losing outcomes would need to provide a series of three sequential wins followed by three sequential losses, it would have been more challenging to suspend disbelief in the participants that the results were randomised rather than predetermined. With the aforementioned negative consequences of extending the control condition to include the impact of wins and losses at zero stake in mind, and considering the objective of the control condition was simply to control for conditioned arousal associated with virtual roulette stimuli, it was determined that two control conditions that simulated results of the zero stake bets was not appropriate in this experiment.

9.2.1 Virtual Roulette Simulation

The virtual roulette simulation was created using Superlab ® version 4.5 software. The game was viewed from a wall-mounted 46-inch flat screen television that was connected to a PC that ran the game software. Participants operated the game using a standard QWERTY keypad. Initially, participants were presented with a green screen containing a roulette wheel and text that identified the required stake size, as well as a red and black box that represented their options to choose to gamble on the roulette spin landing on red or black (see Figure 2).

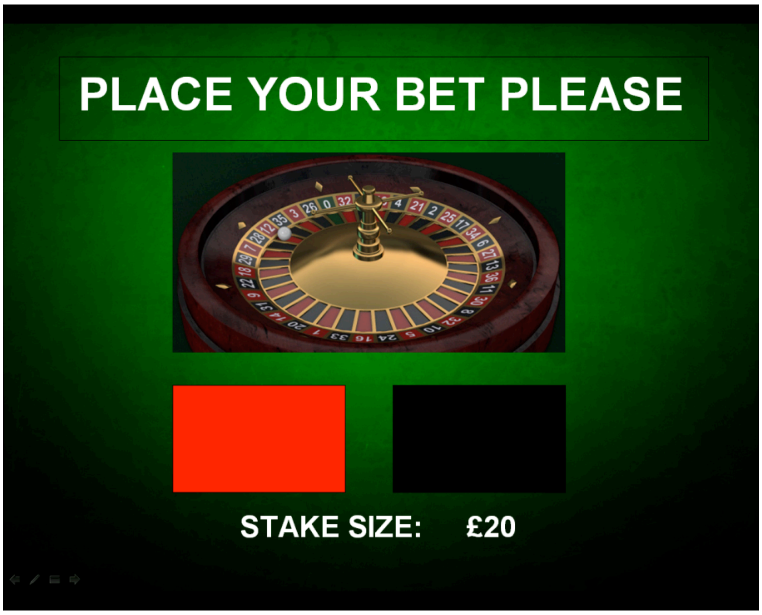


Figure 2. Roulette Wagering Screen. Participants made their selection of red or black by pressing 'R' or 'B' on the keypad respectively. Once the participant made their decision of red or black, the experimenter placed the appropriate value chip from the participant's stack to a wagering area in the middle of the desk in front of the participant. The experimenter moved the chips to limit participant movements to prevent contamination of arousal readings, as the participant's non-keypad operating hand was connected to sensitive EDA electrodes. Upon selection, a screen appeared with a spinning roulette wheel, which spun for 13 seconds.

Once participants made their selection by pressing either 'R' or 'B' on the keypad for red or black, the roulette wheel spun for a duration of 13 seconds, followed by a seven- second graphic informing participants of the result, win or loss (or a seven- second blank screen for the control condition).

Figure 3 below summarises the gambling section of the experiment.

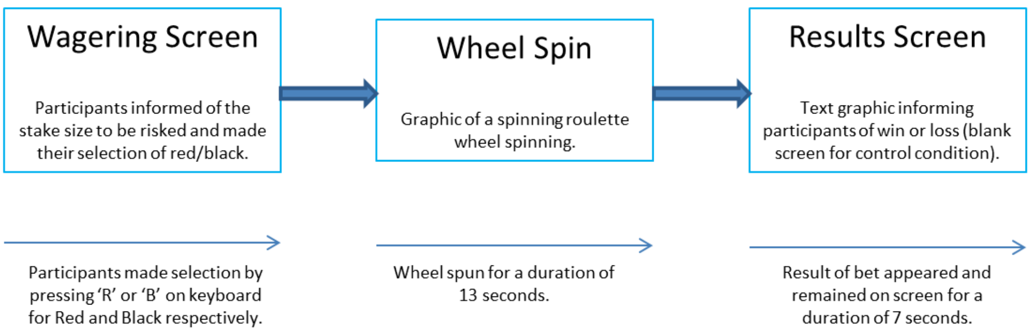
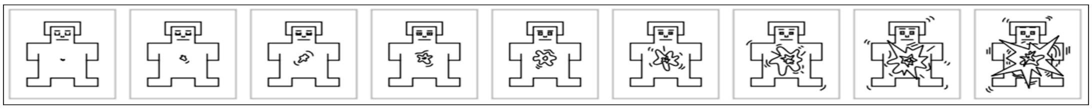


Figure 3. Gambling Section Schematic. Once participants were made aware of the stake size to be gambled, they made their selection of red or black on the roulette wheel. The wheel spun for 13 seconds before participants were informed of their win/loss. Three bets were made in each experimental condition, each bet being partitioned by a self-report rating of arousal, as well as a Go/ No Go task.

9.2.2 Self-Report Arousal

Once outcome was revealed after each betting event, participants were presented with a partial version of the computer-based SAM (SAM; Lang, 1980; Hodes, Cook, & Lang, 1985). Immediately after the result of the bet was revealed, participants were asked to self-report their subjective level of arousal in response to the betting experience. In addition, taking self-report arousal ratings allowed data to be contrasted with direct measures of physiological arousal taken from EDA recordings. The SAM to record arousal experience was presented in a nine-point scale version, as opposed to the five-point alternative, to increase sensitivity in detecting event-by-event changes in subjective experience. Participants were familiarised with the scales during the experimental brief and the experimenter checked that participants understood what the scale intended to measure.

Figure 4 illustrates SAM scales used in the experiment.



1 2 3 4 5 6 7 8 9

Figure 4. SAM Scale. Immediately following results of the previous bet, participants were asked to indicate on a nine-point scale how aroused they felt. Participants were briefed that 9 indicated maximum level of excitement, and 1 completely calm. Participants made their choices using the top row of numbers on a standard keypad, and data was recorded automatically by the Superlab ® 4.5 software.

The SAM was chosen to assess self-report arousal as the method has been demonstrated as an easy to administer, non-verbal method for quickly assessing the arousal associated with a person's emotional reaction to an event, and SAM scores regarding experiences of arousal correlate highly with ratings obtained using verbal and more lengthy semantic differential scales (Bradley & Lang, 1994). The SAM hasve been used to effectively measure an individual's emotional responses to a wide range of stimuli, including both pictures (e.g. Lang, Greenwald, Bradley, & Hamm, 1993) and sounds (e.g. Bradley, 1994). The method has also been used successfully with a wide range of clinical populations, as well as children and non-English speaking citizens (Bradley & Lang, 1994).

9.2.3 Go/No Go Task as a Measure of Response Inhibition

Immediately after the participants completed the arousal SAM, they were given a Go/No Go test, which was administered to assess the impact of stake size and gambling outcome on participants' ability to withhold a prepotent response (response inhibition) as well as attention, vigilance, and reaction time. Participants were presented with a series of arrows one at a time, which either pointed to the left or the right. Participants were instructed to respond as quickly and as accurately as possible to the arrows by pressing the left arrow key when presented with left facing arrows and the right arrow key when presented with right facing arrows. Each arrow was presented on screen for a maximum duration of 1500ms, or until a correct or incorrect response was made. Arrow stimuli were partitioned by a fixation point for a duration of 500ms. All responses were made using a standard keypad. Participants were informed that on some trials the arrow would be presented simultaneously with a short sharp audio 'beep'. The start of the beep was delivered at the same time as the arrow, and the beep ran for a duration of 150ms. On such trials, participants were instructed not to respond to the arrow and to not press any key. A practice trial was provided during the experimental brief.

The order of the arrow and auditory stimuli were randomised and the participant was never presented with the same Go/No Go task twice to avoid learning effects.

The Go/No Go task has been used as a consistent measure of impulse control – the ability to inhibit instigated prepotent responses (Fillmore, 2003). Evidence for the suitability of the Go/No Go task comes from empirical data that shows clinical populations such as children and young adults with ADHD, a disorder characterised by poor impulse control, show more commission errors (i.e. an ability to withhold a developed prepotent response), compared with healthy controls (Derefinko et al., 2008).

As well as measuring the participants' ability to withhold a prepotent response on No Go trials, the test also measured the number of omission errors made (i.e. providing the incorrect response on the Go trials), which is an indication of attention and vigilance (Wright et al., 2014). Mean reaction time was also measured, which is the average amount of time participants took to respond to the Go trials, and it is used as an indication of a range of cognitive processes including preparedness and vigilance (Wright et al., 2014).

Figure 5 below illustrates structure of Go/No Go Task.

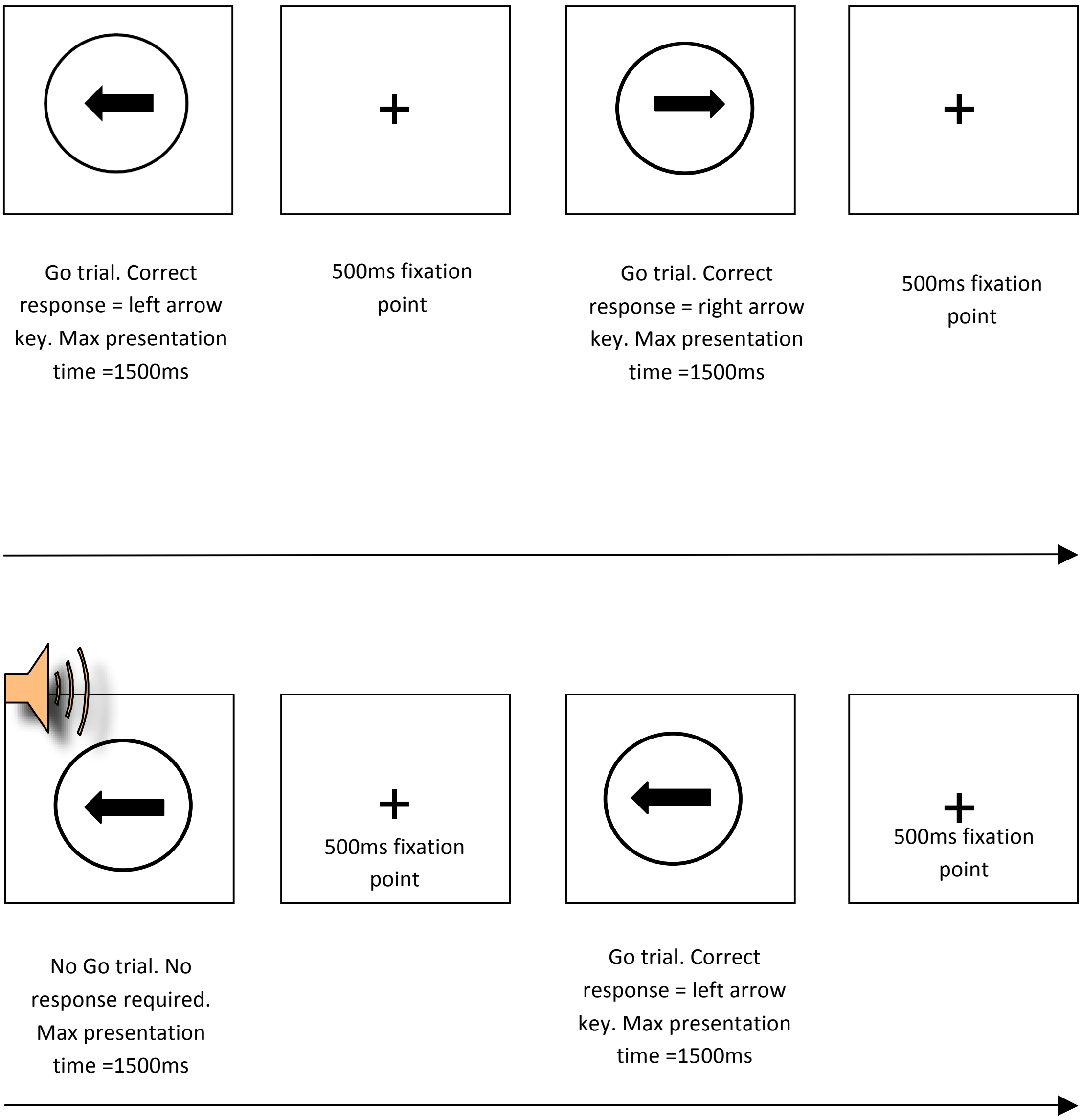


Figure 5. Example Go/No Go Trial. There were 90 trials presented in each Go/No Go task. The first 30 trials all required a Go response from the participant by pressing the corresponding left or right arrow key. The last 60 contained 15 No Go trials (arrows accompanied by an audio beep), which required participants to withhold any response. Duration of the task was approximately two minutes.

9.2.4 Information Sampling Task (IST) as a Measure of Reflection Impulsivity

To measure the impact of stake size and outcome on the participant's reflection impulsivity, an adapted IST was administered. The test design was adapted from that of Clark, Robbins, Ersche and Sahakian (2006), who presented participants with a 5x5 grid of grey boxes. In their study, touching one of the computerised grey boxes revealed one of two colours and remained revealed for the rest of the trial. The aim of the task was to decide the majority box colour on the grid. Participants were rewarded with points for making correct decisions, with the total points awarded being reduced by ten for every box 'opened'. Incorrect decisions resulted in a point deduction.

The IST used in the current study used the same principles as those used by Clark, Robbins, Ersche and Sahakian (2006), but the format was adapted for several key reasons. First, the task had to be integrated with the Superlab ® 4.5 software that was running the roulette simulation and Go/No Go task to allow a smooth transition and data recording from one part of the experiment to another. Also, no feedback regarding correct and incorrect decisions was provided, to ensure that each participant had a standardised experience, rather than decisions being influenced by different patterns of successful and unsuccessful outcomes. This then allowed a *clean* assessment of the impact of stake size and gambling outcome on participants' reflection impulsivity.

The current IST design resembled an *Urn Problem*, which is a widely used paradigm in probability and statistical exercises. More specifically, a hypergeometric distribution design was created, where balls are taken out from the urn and not replaced once extracted. This format is also referred to as 'drawing without replacement', which fits the principle of traditional ISTs.

During the experimental brief, participants were presented with three *walk-through talk-through* examples of the IST. They were instructed that they would complete five urn tasks at the end of every three bets. Points were available during this game and it was made clear that the participant with the most points after the testing phase of the research would win a £100 prize in addition to any money that may or may not have been won during the virtual roulette task. This was to create increased involvement and motivation for performing well in the IST trials.

Participants were presented with a green urn on screen and informed that it contained 19 balls, with each individual ball either being coloured red or black. Participants were told they had to decide if the majority of the 19 balls originally in the urn were red or black. They could remove a ball from the urn to check its colour, i.e. sample information, and inform their decision-making further. A ball could be removed by pressing 'space bar' on the keypad, and once removed, the ball stayed out of the jar and visible for the remainder of the trial. Participants were informed, however, that every time a ball was removed from the urn five points would be deducted from their points total. Each game began with 95 points, so for example, removing ten balls left a remaining 45 points available. Participants were instructed that they could decide to propose a judgement of a majority of red or black balls in the urn by pressing 'R' or 'B' on the keypad respectively (see Figure 6). Making a correct decision would result in the remaining points on the board being added to their overall score, but an incorrect guess would result in all available points for the trial being lost. Participants were instructed that they would not be receiving feedback on correct/incorrect decisions, and that the winner would be contacted after all 32 participants completed the study.

Figure 6. Example IST trial. Participants could select if they thought the majority of the 19 balls in the urn were red or black at any time by pressing 'R' or 'B' on the keypad. Choosing to press the 'space bar' resulted in a ball being removed from the urn. The test had no time limit, and participants were allowed to remove as many balls as they chose, up to the full 19. Five IST trials were administered at the end of each experimental phase with each test being partitioned by a five-second screen instructing participants to prepare for the next trial.

The order in which the balls would appear from each urn was randomly predetermined by the experimenter using a random number generator. Five sequences of balls were created to produce five separate urn trials. The sequence of colours was also inverted, therefore creating five new trials in terms of sequence of colours while retaining the same probability structure as its counterpart. To control for urn favourability, i.e. the sequence of balls that appeared, participants were always presented with the same five urns in each experimental condition. However, to prevent learning effects, the urns could also be presented with the colours inverted, and the combination of original and inverted urns was randomised, as well as their order of presentation (see Table 1 for example).

	Order of Urn Trials Presented				
Participant	Control Condition	£20 Stake Loss Condition	£2 Stake Win Condition	£2 Stake Loss Condition	£20 Stake Win Condition
1	1-3-2R- 4R- 5R.	2R-5-3-1R-4	1-4-3-5-2	4R- 5- 2- 3R- 1	5R-4R-3R- 2R- 1R

Table 1. Example Order of Urn Presentation. The participants were presented with the same five urns in each condition, but the sequence in which the urn was presented, i.e. original or inverted coloured (represented by 'R' in the table below), as well as the order of presentation, was randomised.

The IST measured three dependent variables. First*, Mean Information Sampled*, which refers to the average amount of balls removed from the urn before a decision is made. Second, *Mean Response Latency*, which is the mean amount of time spent making decisions upon extraction of new information and is calculated by total time spent on each urn divided by the number of balls removed.

Finally, *Probability of Making Correct Decisions (P(correct))*, which refers to the odds of a participant's choice of red or black being correct based on the ratio of red to black balls removed from the urn and the amount of balls remaining in the urn. P(correct) is calculated with the following formula:

$$P(\text{Correct}) = \frac{\sum_{k=A}^{Z} \binom{Z}{k}}{2^{Z}}$$

where Z = 19 – (number of balls removed from urn), and A= 10 – (number of balls removed of chosen colour).

9.2.5 Psychophysiological Measurement of Change in Arousal

Arousal measurements were taken using the AcqKnowledge Biopac System, consisting of the MP150 base module in combination with the BioNomadix EDA and PPG amplifier. Five minutes before each phase of the experiment, participants had disposable pre-gelled EL507-10 EDA electrodes attached to the fingertips of their index and middle finger on their non-dominant hand to enable time for the gel to absorb into the skin and provide a strong electrical signal. Non-dominant hands were used to allow participants use of the keypad with their dominant hand. Prior to commencement of each experimental phase, participants were asked to take deep sharp breaths to check for SCRs and that the equipment was working correctly. Participants were instructed to rest the hand with the electrodes on the table at a 90-degree angle. This placed less strain on the hand and arm and enabled stillness, and was therefore suitable for minimising signal interference caused by movement.

The AcqKnowledge software provided with the Biopac System was operated on a laptop separate to the computer operating the EGM and executive control tasks. The software allows set-up of acquisition parameters, real-time observation of the signal measurement, records data to a hard drive, and is used for data filtering and analysis. The software was synchronised with Superlab 4.5 to enable accurate analysis of the skin conductance data in response to specific events. The laptop running the AcqKnowledge software was kept out of sight of participants to ensure that the live bio-feedback data did not cause distraction from the EGM and cognitive tasks.

After each experimental phase, participants were given a 15-minute break to allow arousal levels to return to baseline. During the intervals participants were brought to a quiet seating area outside of the laboratory environment. The intervals were also necessary to afford participants the opportunity to rest and drink water.

9.2.5.1 Skin Conductance Level (SCL) Measurement

When analysing arousal levels and change in response to gambling on virtual roulette, behaviour was separated into three measurement periods, *Pre-Event Baseline*, *Placing Bet,* and *Observing Outcome of Bet*. 'Pre-Event Baseline' refers to a measurement period with a duration of 5000 milliseconds, that occurs when the participant is either waiting for a new experimental condition to commence or is resting after completion of a previous test of executive control. The Pre-Event Baseline is observed with a blank screen with no gambling images or stimuli present onscreen; this measurement of EDA ceased 5000 milliseconds before the participant was invited to place a bet. The 'Placing Bet' measurement period refers to a 8000 millisecond observation occurring after the participant makes a betting selection; recording as the participant observes the roulette wheel spinning on the virtual roulette game and measurement ceases 5000 milliseconds before the result of the bet is revealed. Finally, 'Observing Outcome of Bet' is a measurement of electrodermal activity, with a duration of 7000 milliseconds, which commences 1000 milliseconds after the result of the bet is revealed to the participant (see Figure 7 for summary).

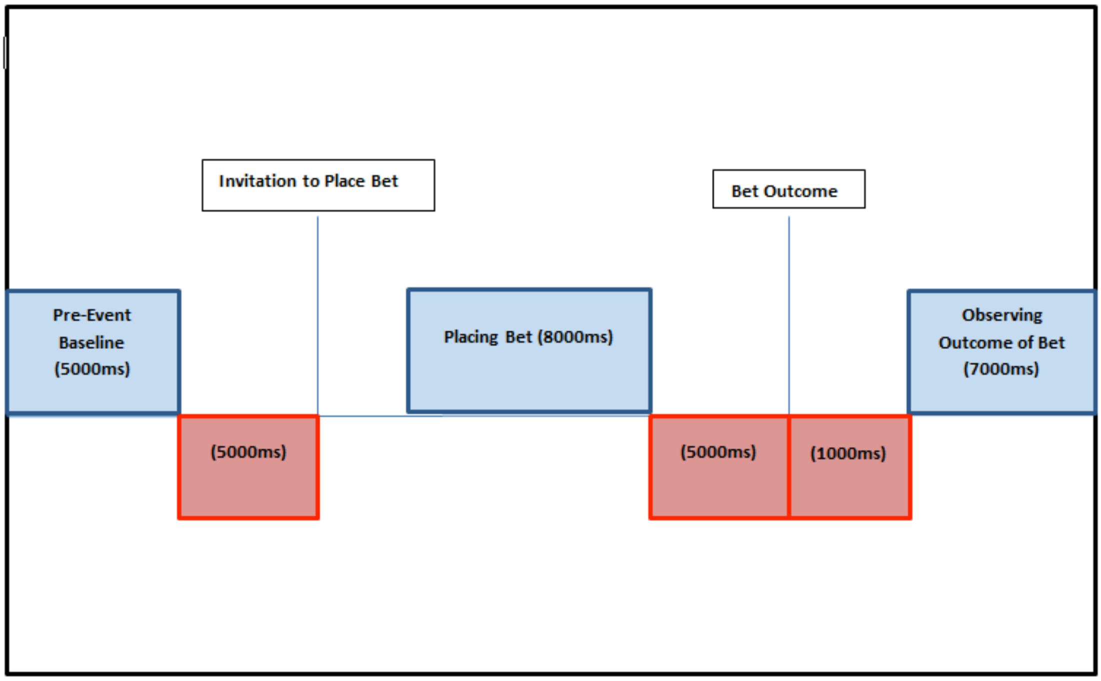


Figure 7. Phases of SCL Measurement. SCL readings taken at baseline 5000ms prior to participants being invited to place a bet. SCL was then recorded for a 8000ms period during the roulette wheel spin initiated by the placing of the bet. Finally, SCL was taken for a 7000ms period 1000ms after the outcome of the bet was revealed to the participant.

9.2.5.2 Observation of Skin Conductance Responses (SCRs) during Gambling Behaviour

In the current study, the two experimental stimuli markers used to create an SCR were the *Placement of Bet* and *Bet Outcome*. Placement of Bet was marked as the time the participant selected red or black as their bet on the roulette gambling simulation, and in accordance with the standardised measurement principles put forward by Boucsein et al. (2012), if an SCR was initiated within a 1-3 second latency period it was recorded as an Event Related Skin Conductance Response (ER-SCR), and if the SCR was initiated outside of this window it was recorded as a Non-Significant Skin Conductance Response (NS-SCR). Bet Outcome was marked as the visual presentation of whether the bet was won or lost and, retaining the same principles as before, if an SCR onset was initiated within the 1-3 second latency period it was recorded as an ER-SCR, otherwise it was discarded as a NS-SCR (see Figure 8 for summary).

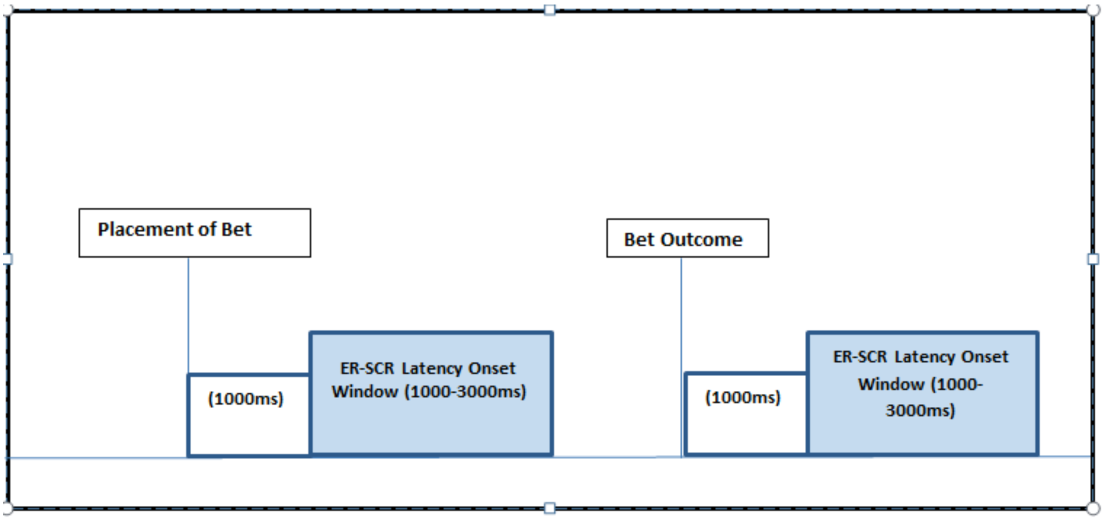


Figure 8. Phases of SCR Measurement. Participant ER-SCR was first measured upon placing their bet, at either high or low stakes. Placement of bet in the control condition consisted of simply selecting red or black with no stake at risk. ER-SCR was also measured when participants observed the result of the bet.

10 Results

10.1 Response Inhibition

10.1.1 Commission Errors Committed in Go/No Go Task after Different Stake Size Gambling Events

'Commission Errors' refers to an inability to withhold a developed prepotent response within the Go/No Go Task. There was relatively little difference in mean percentage of commission errors, however, mean commission error percentage in the high stake condition was higher (M=10.765, SD=8.9) than the low stake condition (M=9.523, SD=6.094) and the control condition (M=9.166, SD=7.483). This difference in mean commission error percentage across stake size was not statistically significant, $F(2,62)=1.48$, $p>0.05$, meaning that gambling at £20 per bet did not affect participants' ability to inhibit prepotent responses in comparison to betting £2 per event or the control condition.

Mean percentage of commission errors was relatively similar after winning bets (M=10.561, SD=8.249), after losing bets (M=9.762, SD=6.669), and after the control condition (M=9.166, SD=7.483). Therefore, as one would expect, there was no main effect for betting outcome on commission error rate, $F(2, 62)=1.189$, $p>0.05$, meaning ability to withhold prepotent response does not differ whether the outcome of one's bet wins or loses.

Exploring the relationship further, there is no statistically significant difference in percentage of commission errors when winning £20 bets (M=11.042, SD=10.167), winning £2 bets (M=10.08, SD=8.095) and the control condition (M=9.166, SD=7.483), $F(2,62)=1.078$, $p>0.05$.

Finally, there is also no statistically significant difference in percentage of commission errors when losing bets of various stake sizes $F(1.583, 49.07)=1.089$, $p>0.05$. Although mean percentage of commission errors was higher after losing £20 bets (M=10.486, SD=8.784) in comparison to losing £2 bets (M=8.967, SD=6.342) and the control condition (M=9.166, SD=7.483).

10.1.2 Omission Errors Committed in Go/No Go Task Different Stake Size Gambling Events

'Omission errors' refers to providing the incorrect response on the Go trials, which is an indication of poor attention and vigilance (Wright et al., 2014). The mean percentage of omission errors after participants were betting in the high stake condition (M=3.236, SD=3.041) was higher than after betting in the low stake (M=2.908, SD=2.692) and the control condition (M=2.902, SD=2.747). However, this difference in means was not statistically significant as there was no main effect for stake size observed $F(2, 62)=0.986$, $p>0.05$.

The mean percentage of omission errors after winning conditions (M=3.262, SD=2.943) was not statistically significantly different in comparison to post-losing conditions (M=2.882, SD=2.725) and the control condition (M=2.902, SD=2.747), $F(2,62)=1.489$, $p>0.05$.

Further analysis also reveals no statistically significant difference in percentage of omission errors after winning £20 bets (M=3.291, SD=3.092), winning £2 bets (M=3.233, SD=3.097) or the control condition (M=2.902, SD=2.747), $F(2,62)=0.830$, $p>0.05$.

Equally, there was also no statistically significant main effect observed for stake size when losing, on percentage of omission errors $F(1.676, 51.943)=1.806$, $p>0.05$ (using Greenhouse-Geisser correction). This means that despite participants committing a higher percentage of omission errors after losing £20 bets (M=3.181, SD=3.276) in comparison to losing £2 bets (M=2.582, SD=2.435) and the control condition (M=2.902, SD=2.747), it is not possible to state that losing at higher stakes causes participants subsequently to make more omission errors in comparison to losing at lower stakes.

10.1.3 Mean Reaction Time in Go/No Go Task after Different Stake Size Gambling Events

Mean response time in the Go/No Go task refers to the average amount of time participants use to respond to the Go trials and it is used as an indication of a range of cognitive processes including preparedness and vigilance (Wright et al., 2014). It is also important to note that a very strong and significant correlation has been observed between mean reaction time and mean reaction time for correct responses ($r=0.987$, $p<0.001$).

The results show that there is no statistically significant difference in mean response time to Go trials after betting in high stake conditions in comparison to post-low stake and the control conditions $F(2, 62)=1.978$, $p>0.05$. A non-statistically significant difference was also observed in mean response time after betting in winning conditions, in comparison to post-losing and post-control conditions, $F(2, 62)=2.225$, $p>0.05$.

Further analysis reveals that no statistically significant main effect was observed for stake size when winning $F(2, 62)=1.977$, $p>0.05$, or stake size when losing $F(2, 62)=1.593$, $p>0.05$. In other words, participants did not on average differ in responding time in completing the Go/No Go task in any comparison of stake size or betting outcome, as demonstrated in Table 2:

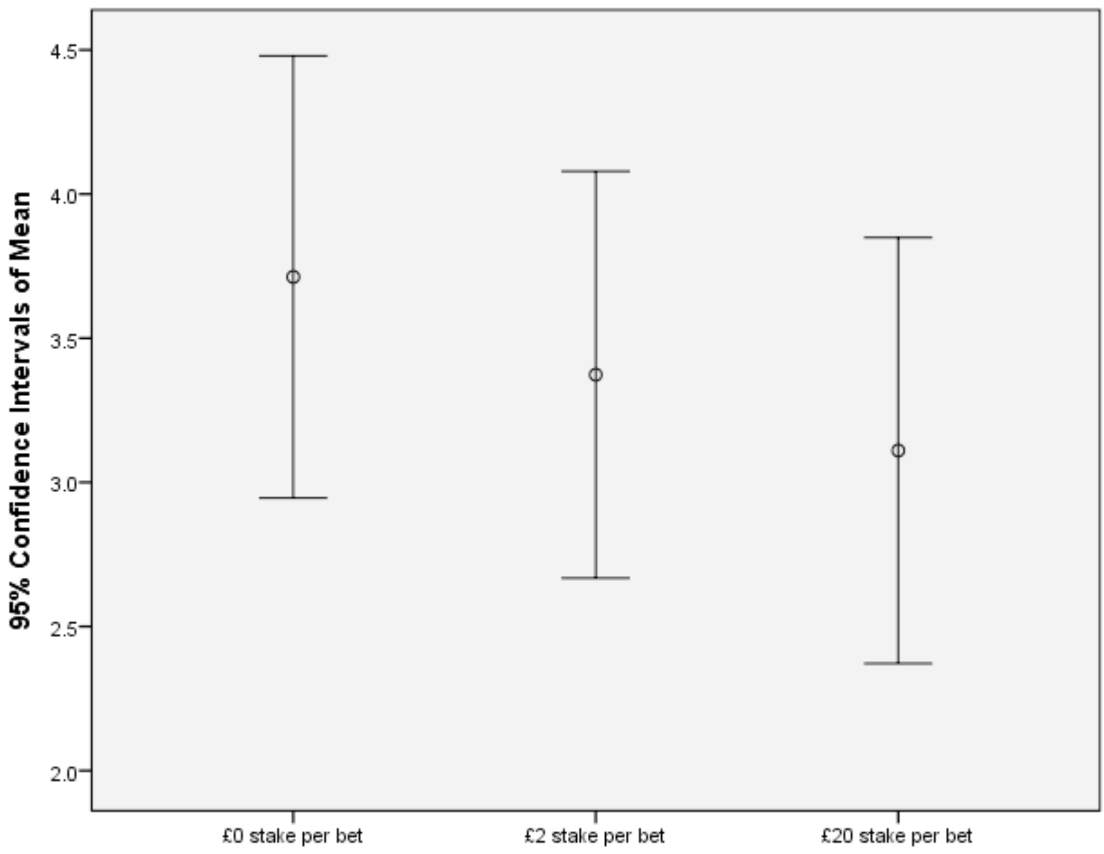
Table 2: Differences in outcome variables of visual Go/No Go Task		
Comparison	*F* ratio	Statistically Significant
Commission Errors (withholding prepotent response)		
£20 stake vs £2 stake and the control condition	1.480	**x**
Winning vs Losing and the control condition	1.189	**x**
Winning £20 bets vs Winning £2 bets and the control condition	1.078	**x**
Losing £20 bets vs Losing £2 bets and the control condition	1.089	**x**
Omission Errors (attention and vigilance)		
£20 stake vs £2 stake and the control condition	0.986	**x**
Winning vs Losing and the control condition	1.489	**x**
Winning £20 bets vs Winning £2 bets and the control condition	0.830	**x**
Losing £20 bets vs Losing £2 bets and the control condition	1.806	**x**
Mean Reaction Time (vigilance and preparedness)		
£20 stake vs £2 stake and the control condition	1.978	**x**
Winning vs Losing and the control condition	2.225	**x**
Winning £20 bets vs Winning £2 bets and the control condition	1.977	**x**
Losing £20 bets vs Losing £2 bets and the control condition	1.593	**x**

10.2 Reflection Impulsivity

10.2.1 Mean Information Sampled

With respect to the amount of information sampled upon which to make predictions of uncertain outcomes, it was evident that participants sampled less information (M=3.111, SD=2.05) in the high stake condition, i.e. removed fewer balls from the urn, than in comparison to the low stake condition (M=3.373, SD=1.957) and the control condition (M=3.713, SD=2.127). This difference was statistically significant, *F*(1.64, 50.854)=3.882, p<0.05, partial η^2 = 0.111 (using Greenhouse-Geisser correction). When exploring the relationship with post hoc tests, it is evident that the only significant difference between the three levels of stake is between the control and the £20 stake conditions (p=0.012), meaning that there was no significant difference in information sampled between the £2 stake and the control condition.

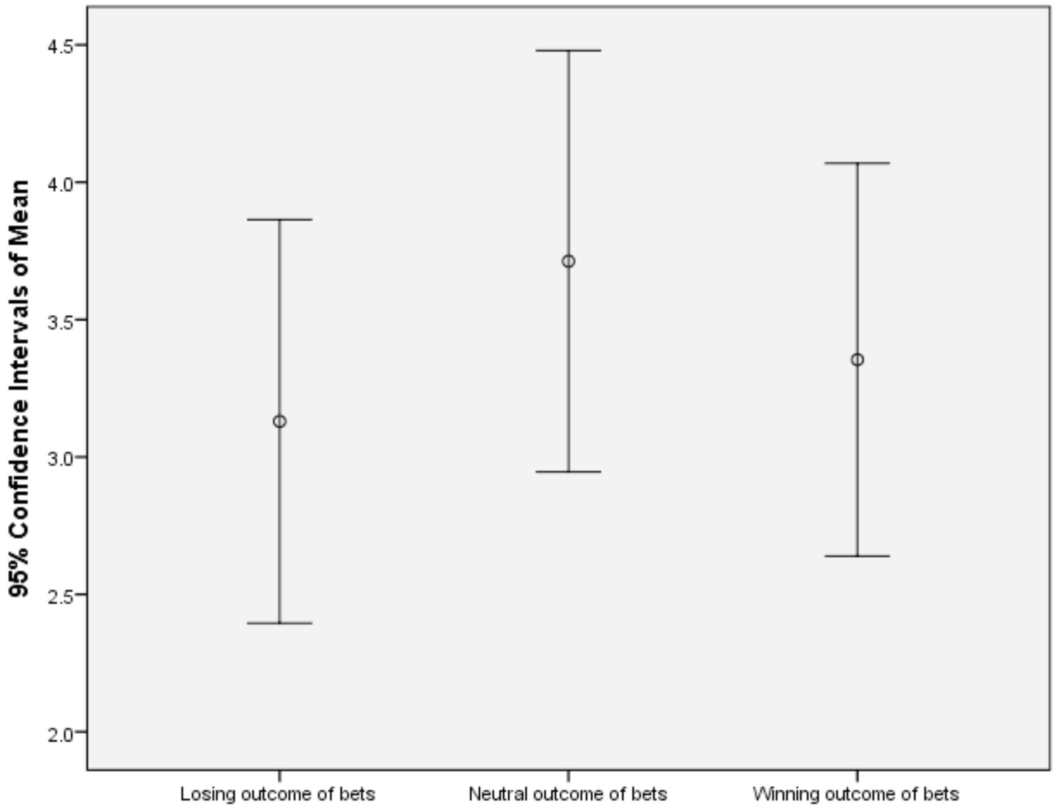
Figure 9: Mean Amount of Information Sampled across Different Stake Size



A statistically significant difference in amount of information sampled has also been observed between the losing condition (M=3.13, SD=2.037), the control condition (M=3.713, SD=2.127) and the winning condition (M=3.354, SD=1.983), *F*(2, 62)=3.565, p<0.05, partial η^2 =0.103.

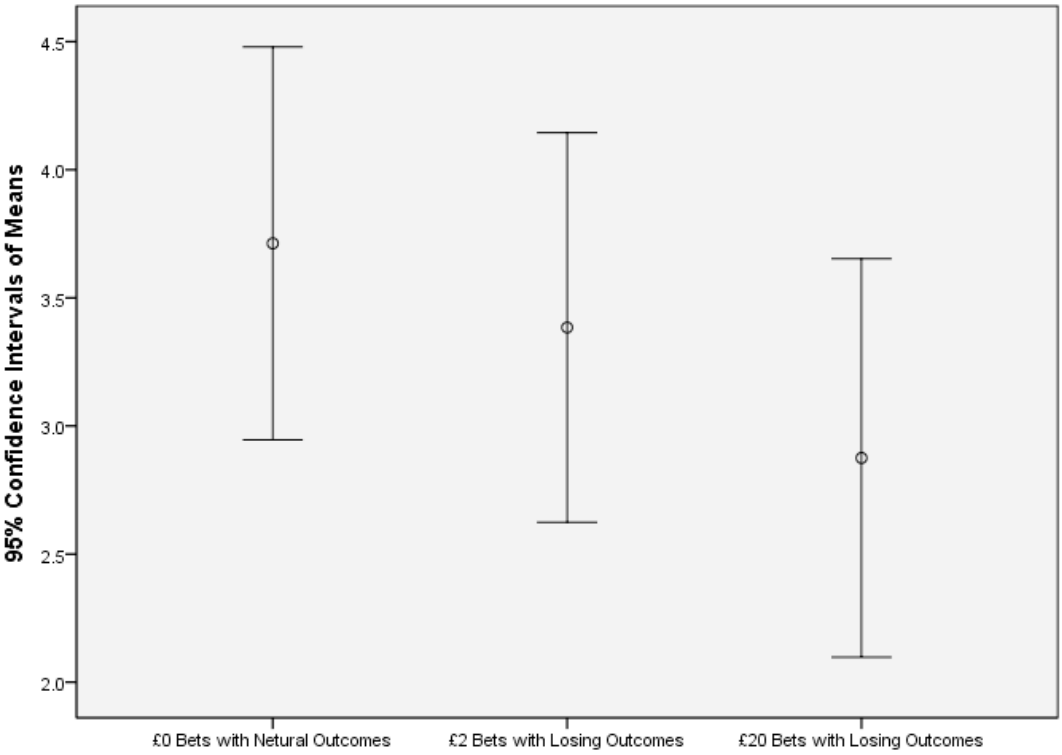
Furthermore, as demonstrated in Figure 10, the trend is quadratic ($F(1,31)=4.726$, $p<0.05$) rather than linear ($F(1, 31)=2.517$, $p>0.05$), showing that both winning and losing bets relate to lower mean amount of information sampled in comparison to the control condition where there was no opportunity to win or lose money. Results of Fisher LSD post hoc tests suggest that the significant difference in mean amount of information sampled was between the losing and the control conditions ($p=0.021$), and the other comparisons were not statistically significant.

Figure 10: Mean amount of Information Sampled across different Bet Outcomes



The difference in mean amount of information sampled after winning £20 bets (M=3.346, SD=2.19) and winning £2 bets (M=3.363, SD=1.974) and the control condition (M=3.713, SD=2.127) was not statistically significantly different $F(2,62)=1.432$, $p>0.05$. However, there was a significant difference in mean amount of information sampled after losing £20 bets (M=2.875, SD=2.157), losing £2 bets (M=3.384, SD=2.108), and the control condition (M=3.713, SD=2.127), $F(2,62)=5.652$, $p<0.05$, partial $\eta^2=0.154$. Post hoc analyses using Bonferroni corrections revealed that the significant difference lay between mean amount of information sampled after losing £20 bets and amount sampled after the control condition ($p=0.004$).

Figure 11: Mean amount of Information Sampled after Losing Bets at Various Stake Size



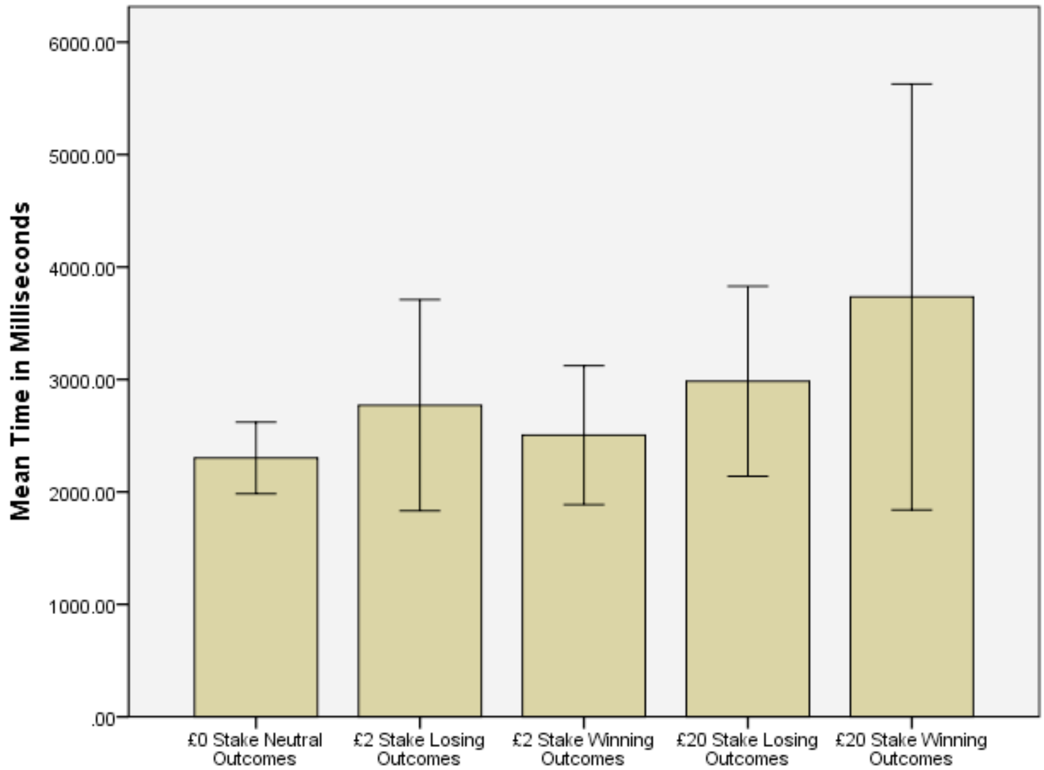
10.2.2 Latency of Response

Average ball removal latency, measured in seconds, did not significantly differ statistically across high stake (M=3.359, SD=3.27), low stake (M=2.639, SD=1.947) and control conditions (M=2.302, SD=0.821), $F(1.472, 39.735)=2.274$, $p>0.05$ using Greenhouse-Geisser correction. Furthermore, there was also no significant difference observed in average ball removal latency after winning outcomes (M=3.120, SD=3.022), losing outcomes (M=2.877, SD=1.860) and the control condition (M=2.303, SD=0.821), $F(1.127, 30.429)=1.866$, $p>0.05$ using Greenhouse-Geisser correction.

Exploring the relationship between stake size, betting outcomes and average ball removal latency further, it was observed that there was also no statistically significant difference between participants' average latency per ball removed after winning £20 bets (M=3.717, SD=4.798), winning £2 bets (M=2.589, SD=1.627) and the control condition (M=2.302, SD=0.821), $F(1.151, 32.236)=2.29$, $p>0.05$ using Greenhouse-Geisser correction. This trend was continued when looking at mean ball removal latency after losing £20 bets (M=3.559, SD=3.765), losing £2 bets (M=3.010, SD=2.705) and the control condition (M=2.302, SD=0.821), which also demonstrated no statistically significant difference $F(2,56)=1.996$, $p>0.05$.

In other words, as demonstrated in Figure 12, there was too much variance observed across stake size and bet outcome conditions, regarding the duration of time participants spent evaluating the information they sampled before making predictions about uncertain outcomes, meaning that a clear significant trend did not emerge.

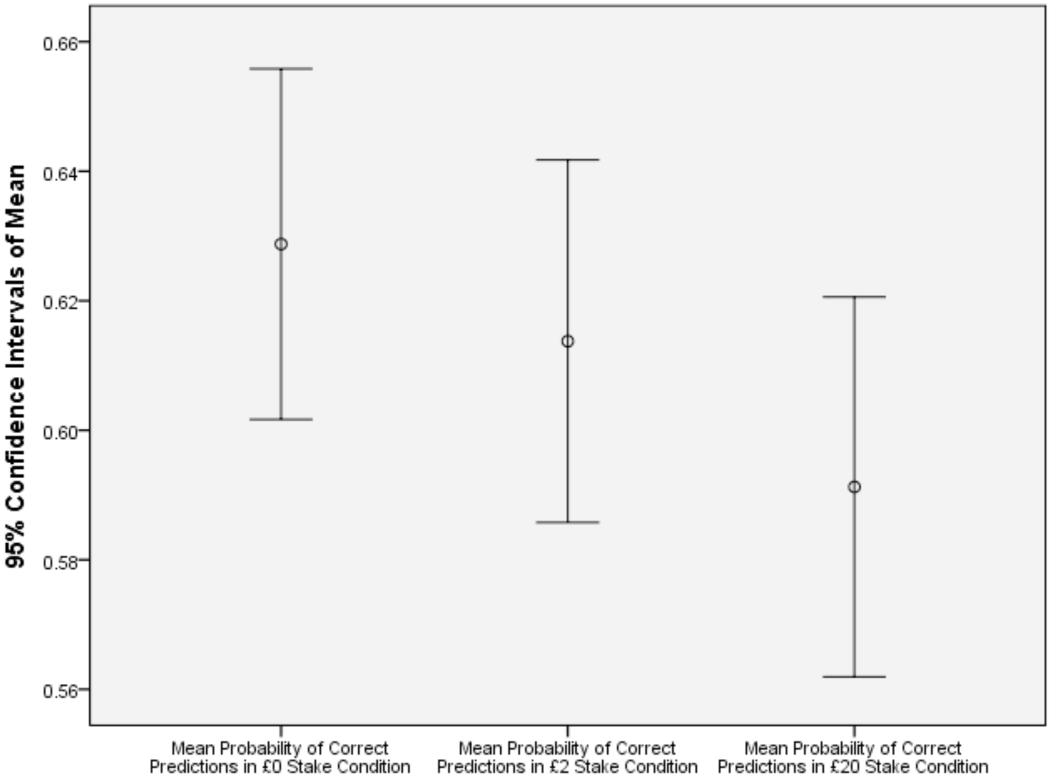
Figure 12: Mean Ball Removal Latency post various Betting Event Outcomes



10.2.3 Probability of Making Correct Predictions

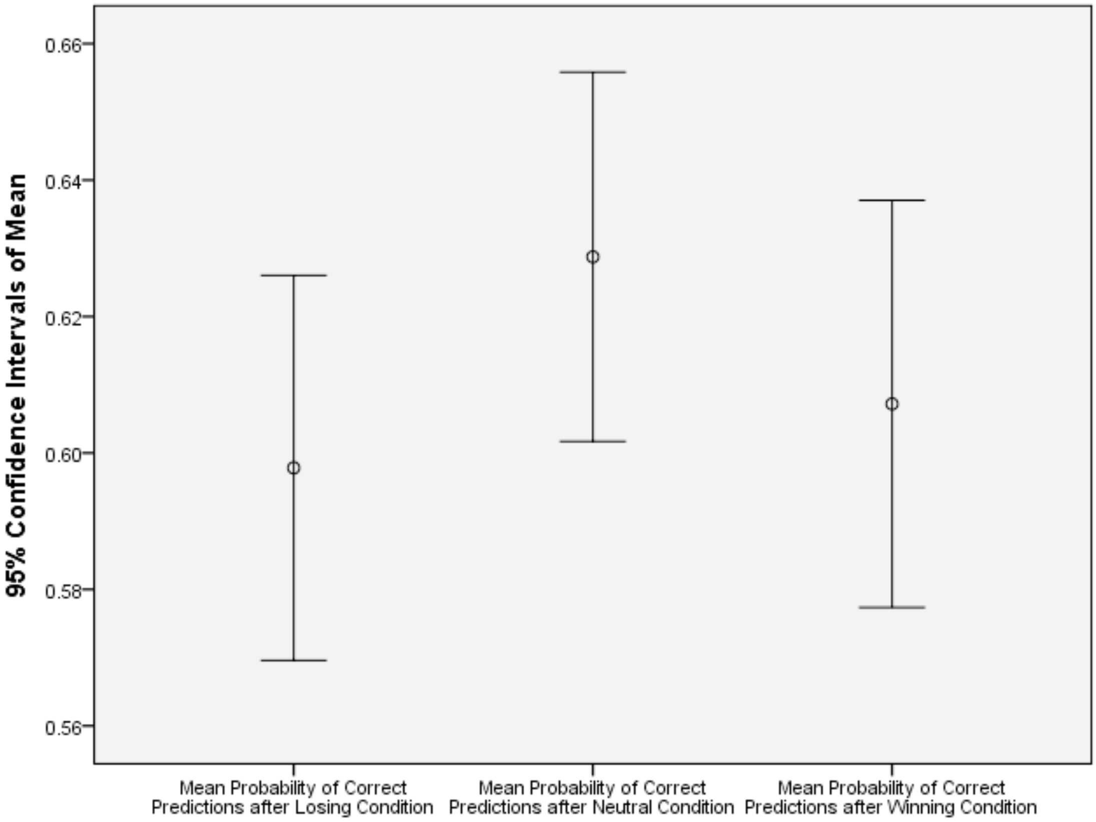
Participants were more likely to make less accurate predictions, i.e. predictions with a lower probability of being correct, after betting in the high stake condition (M=0.591, SD=0.081) than in the low stake condition (M=0.614, SD=0.078) and the control condition (M=0.629, SD=0.075). This difference in probability of making accurate predictions was observed to be statistically significant $F(2, 62)=11.246$, $p<0.001$, partial $\eta^2 = 0.266$. Post hoc tests using Bonferroni corrections identified significant differences in probability of making accurate predictions between gambling at £20 per bet and the control condition (p=0.001) and also between gambling at £20 per bet and £2 per bet (p=0.012).

Figure 13: Probability of Making Accurate Predictions after Gambling at Different Stake Levels



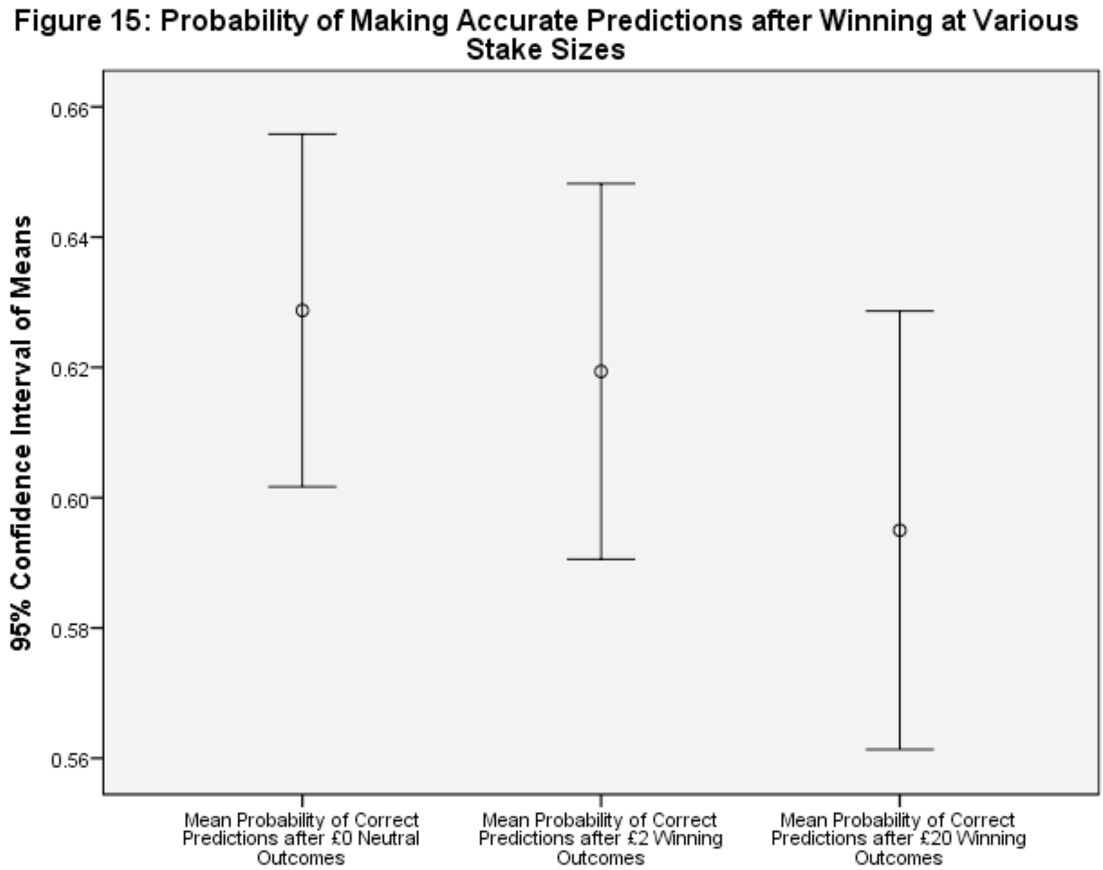
There was also a statistically significant main effect for betting outcome on probability of making accurate predictions $F(2, 62)=6.836$, $p<0.05$, partial $\eta^2 = 0.329$. Essentially, on average, participants were more likely to make predictions with lower probability of being correct after losing bets (M=0.598, SD=0.078), than after winning bets (M=0.607, SD=0.083) or after the control condition (M=0.629, SD=0.075). Post hoc tests using Bonferroni Corrections have demonstrated the significant difference in probability of making accurate predictions lay between predictions made after the control condition and losing condition (p=0.002). As demonstrated in Figure 14, the trend is quadratic ($F(1,31)=12.325$, $p<0.01$, partial $\eta^2 = 0.284$) rather than linear ($F(1, 31)=1.209$, $p>0.05$), suggesting that both losing and winning bets leads to making less probable predictions than after the control condition, where there was no opportunity to win or lose money.

Figure 14: Probability of Making Accurate Predictions after Winning, Losing and Neutral Betting Outcomes



Participants were more likely to make less probable predictions about uncertain outcomes after winning high stake bets (M=0.595, SD=0.093) than after winning lower stake bets (M=0.619, SD=0.08) and the control condition (M=0.629, SD=0.075). This difference in means was observed to be statistically significant $F(2, 62)=6.047$, $p<0.01$ partial $\eta^2 = 0.163$.

Post hoc analyses using Bonferroni corrections revealed that significant differences were observed between £20 winning condition and the control condition (p=0.023) and also between £20 winning condition and £2 winning condition (p=0.042). No significant difference was observed between £2 winning condition and the control condition.



There was a statistically significant difference observed between participants making lower probability predictions of uncertain outcomes after losing £20 bets (M=0.588, SD=0.083), after losing £2 bets (M=0.608, SD=0.085) and after the control condition (M=0.629, SD=0.075), $F(6, 62)=8.533$, $p<0.01$, partial $\eta^2 = 0.216$.

Post hoc analyses using Bonferroni corrections revealed that significant difference was observed between losing £20 bets and the control condition (p=0.001), with no other statistically significant differences observed.

Figure 16: Probability of Making Accurate Predictions after Losing at Various Stake Sizes

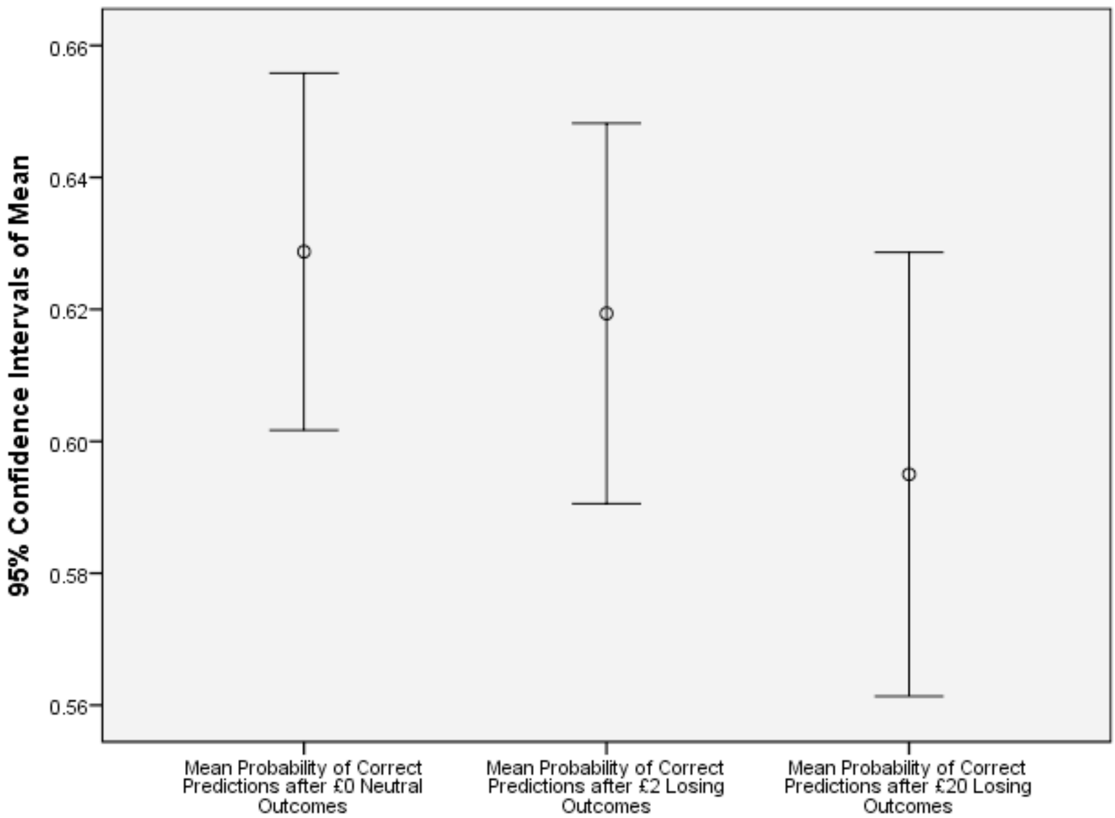


Table 3 is a summary of statistically significant differences across the various outcome variables of the adapted IST observed in differing stake size and betting outcome conditions.

Table 3: Differences in Information Sampling Task Outcome Variables		
Comparison	*F* ratio	Statistically Significant
Mean Information Sampled before making Prediction		
£20 stake vs £2 stake and the control condition	3.882	✓
Winning vs Losing and the control condition	3.565	✓
Winning £20 bets vs Winning £2 bets and the control condition	1.432	x
Losing £20 bets vs Losing £2 bets and the control condition	5.652	✓
Mean Latency of Ball Removal (Reflection)		
£20 stake vs £2 stake and the control condition	2.274	x
Winning vs Losing and the control condition	1.866	x
Winning £20 bets vs Winning £2 bets and the control condition	2.290	x
Losing £20 bets vs Losing £2 bets and the control condition	1.996	x
Mean Probability of Making Correct Predictions		
£20 stake vs £2 stake and the control condition	11.246	✓
Winning vs Losing and the control condition	6.836	✓
Winning £20 bets vs Winning £2 bets and the control condition	6.047	✓
Losing £20 bets vs Losing £2 bets and the control condition	8.533	✓

10.3 Psychophysiological Measurements of Arousal Change

It is important to note that SCL (also known as tonic skin conductance) is constantly changing within the individual; furthermore, there is wide variation between individuals regarding normal skin conductance levels and range of variation of SCL (Braithwaite, Watson, Jones & Rowe, 2013). Therefore, the comparison and reporting of raw SCL between individuals and within individuals in different experimental conditions would not yield meaningful information. As a result, changes in SCL within participants over various gambling conditions were reported as a *percentage change* from Pre-Event Baseline SCL to both Placing Bet SCL and Observing Outcome of Bet SCL. Ultimately, given intra- and inter-individual variation there is little value in reporting the descriptive statistics in relation to SCL.

Moreover, in an attempt to further correct for inter-individual variance, skin conductance measurements were transformed into standardised scores, first computing Z scores and subsequently transforming Z scores into T-scores (Braithwaite et al., 2013).

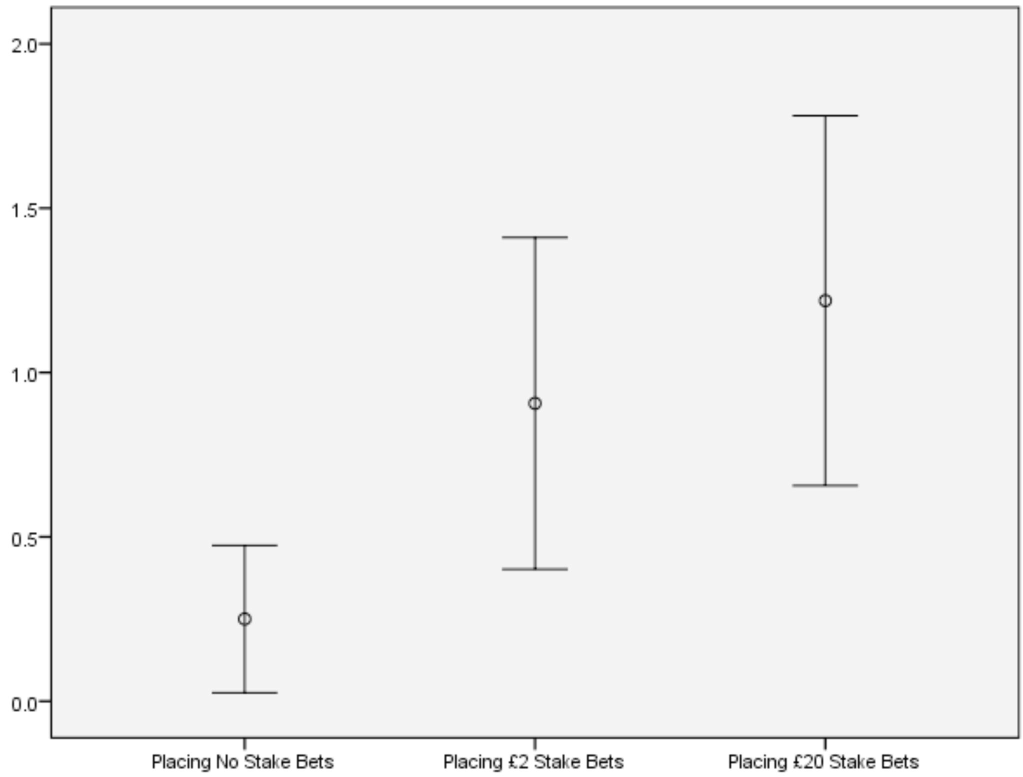
10.3.1. Change in SCL when Placing Bets

It was observed that there were no significant differences in percentage change in SCL from the Pre-Event Baseline to Placing Bet specified epochs when placing bets at different stake sizes $F(2,62)=0.424$, $p>0.05$. Put simply, there were no significant differences in percentage changes of tonic arousal level from baseline to placing £2 stake bets, £20 stake bets or the control condition.

10.3.2 Observation of ER-SCRs after Placement of Bets

The mean amount of ER-SCRs observed in the control condition was 0.25 (SD =0.662). The mean amount of ER-SCRs observed in conditions where participants were placing £20 bets (M=1.218, SD = 1.56) was higher than in the control condition and the £2 stake condition (M=0.906, SD =1.4). There was a significant main effect of size of stake on whether the participant would experience an ER-SCR when placing bets on virtual roulette $F(2,62)=7.384$, $p<0.05$, partial $\eta^2 = 0.192$. Post hoc analyses using Bonferroni corrections identified that the significant difference in mean ER-SCR frequency was observed between high stake betting and low stake betting ($p=0.028$), with no other significant differences observed. In simple terms, a participant was more likely to experience a significant change in phasic arousal when placing £20 bets than £2 bets.

Figure 17: Significant differences in mean amount of ER-SCRs across Stake Size Conditions



10.3.3 Change in SCL when Observing Outcome of Bet

Mean levels of SCL were not significantly different between the control condition (M=4.121, SD=4.574), and when observing outcomes of £2 stake bets (M=4.666) and £20 stake bets (M=4.399, SD=4.832) with the main effect not reaching statistical significance $F(2,62)=0.354$, $p>0.05$.

It is also of note that independent of stake size there was no significant difference in percentage change in Pre-Event Baseline to Observing Outcome of Bet SCL, when observing winning outcomes (M=0.641, SD=4.289), losing outcomes (M=0.231, SD=4.583) and the control condition (M=0.173, SD=3.326), $F(2, 62)=0.141$, $p>0.05$.

Extending the analysis further, it was also observed that there was no significant difference in percentage change in SCL between Pre-Event Baseline to Observing Outcome of Bet when participants lost £20 bets (M=0.134, SD=4.266), £2 bets (M=0.328, SD=5.901) or the control condition where no money could be won or lost $F(1.499, 46.475)=0.024$, $p>0.05$ (using Greenhouse-Geisser correction).

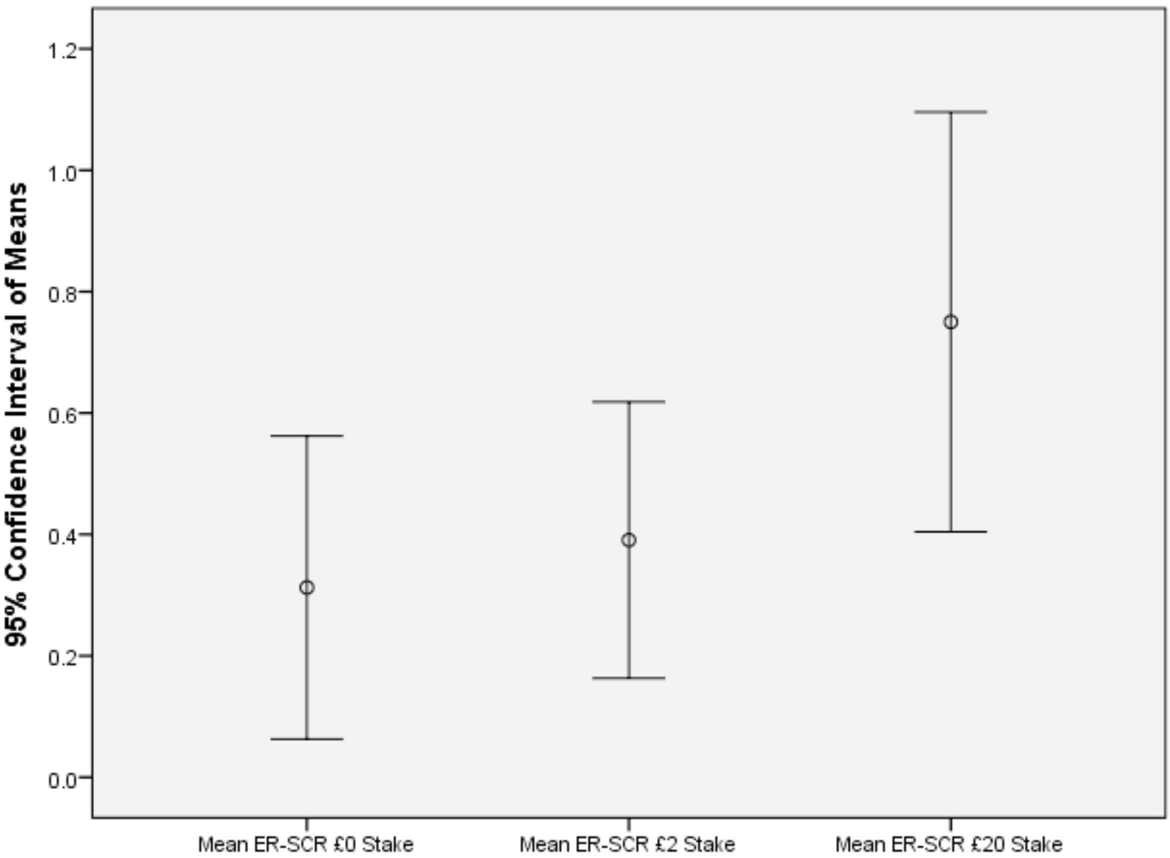
When comparing percentage change in SCL between Pre-Event Baseline to Observing Outcome of Bet when participants won £20 bets (M=0.799, SD=6.111), won £2 bets (M=0.482, SD=5.205) and the control condition, it was observed there were no significant differences $F(2,62)=0.134$, $p>0.05$.

Table 4: Change in SCL from Pre-Event Baseline across Gambling Events and Conditions		
Placing Bets	***F* ratio**	**Statistically Significant?**
Difference in % change in SCL across £20 and £2 stake conditions and the control condition	0.424	X
Observing Outcome of Bets	***F* ratio**	**Statistically Significant?**
Difference in % change in SCL across winning and losing £20 bets	0.354	X
Difference in % change in SCL across winning and losing £2 bets	0.037	X
Difference in % change in SCL across winning £20 bets and £2 bets	0.134	X
Difference in % change in SCL across losing £20 bets and £2 bets	0.024	X

10.3.4 Observation of ER-SCRs after Observing Outcome of Bets

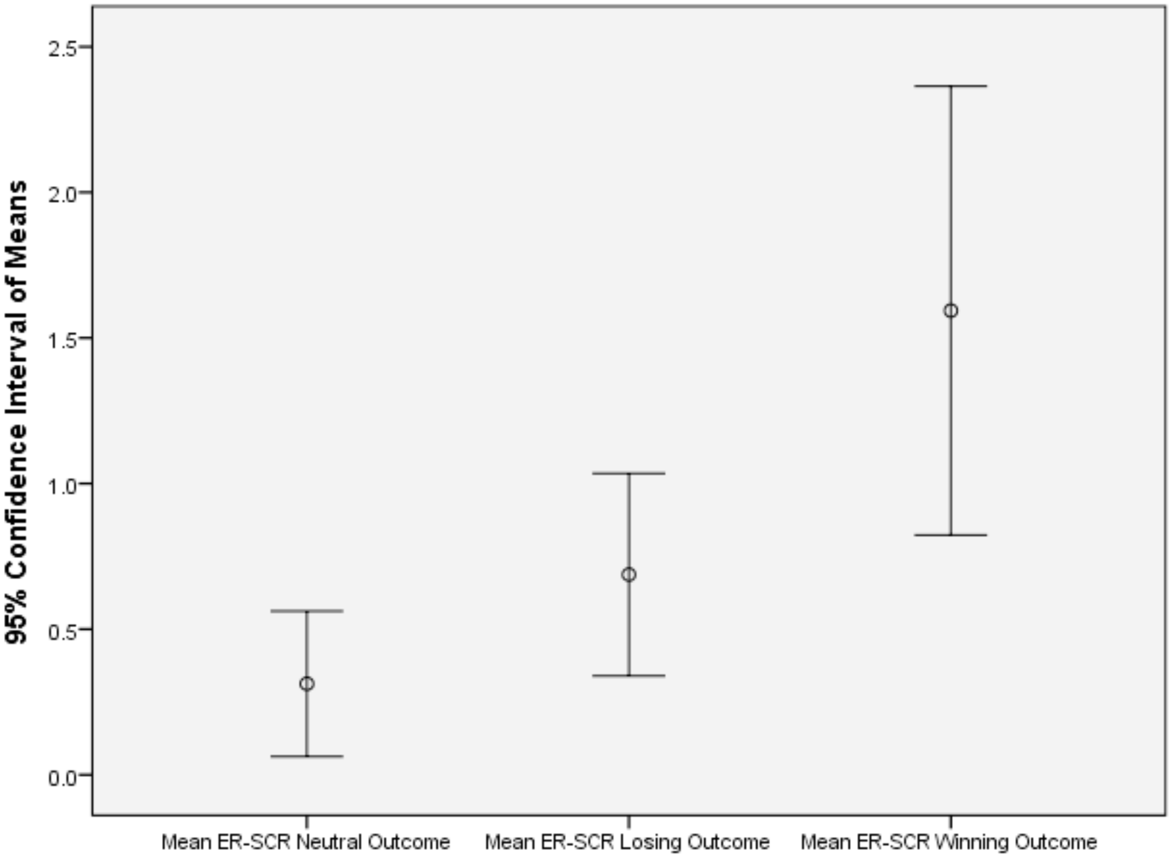
The mean amount of ER-SCRs observed in response to the control condition was 0.312 (SD =0.693). The mean amount of ER-SCRs observed in conditions where participants were observing outcomes of bets at £20 stakes (M=0.75, SD = 0.959) was higher than in both the control condition and the £2 stake condition (M=0.391, SD =0.632). This main effect of size of stake on whether the participant would experience an ER-SCR when observing outcomes of bets on virtual roulette was statistically significant $F(1.667, 51.668)=4.982$, $p<0.05$, partial η^2 = 0.138 (using Greenhouse-Geisser correction). The trend was linear, with post hoc tests using Bonferroni corrections revealing that it was significantly more likely to experience an ER-SCR when observing outcomes of £20 bets versus £2 bets (p=0.028); however the difference between observing outcomes of £20 stake bets and the control condition did not quite meet statistical significance (p=0.059). Furthermore, the difference of mean ER-SCR frequency when betting at £2 stakes versus the control condition was not statistically significant.

Figure 18: Observed Differences in Occurences of ER-SCR when Observing Outcome of High, Low and No Stake Bets



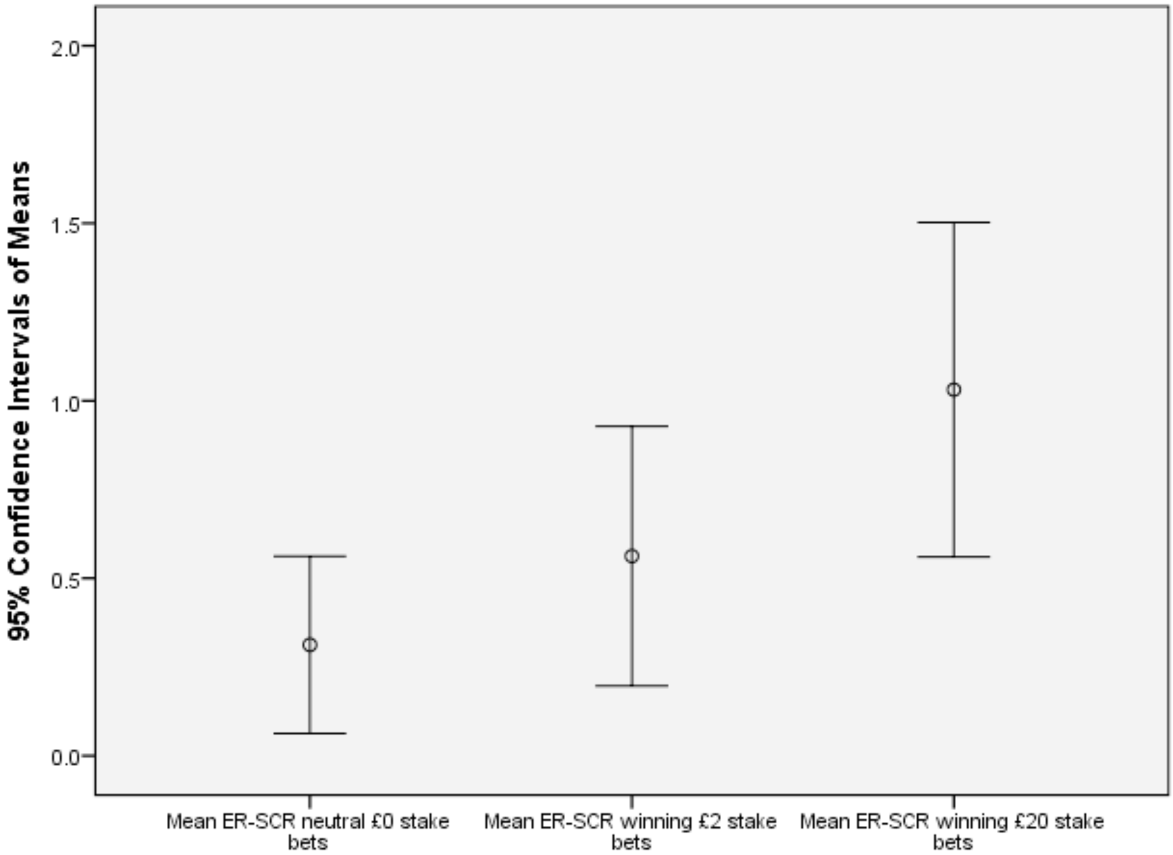
Furthermore, there was a significant linear main effect on whether participants would experience an ER-SCR when observing winning bets (M=1.594, SD=2.138) or losing bets (M=0.688, SD=0.965), F(1.33, 41.221)=10.912, $p<0.05$, partial η^2 = 0.260 (using Greenhouse-Geisser correction). Post hoc tests using Bonferroni corrections demonstrated that there was a significant difference observed between winning bets and losing bets (p=0.01), and between winning outcomes and the control condition (p<0.01); however, there was no significance difference in ER-SCRs observed between losing outcomes and the control condition (p=0.112).

Figure 19: Observed Differences in Occurences of ER-SCR when Observing Outcome of Winning, Losing and Neutral Bets



There was a significant linear main effect on whether participants would experience an ER-SCR when observing outcomes of winning £20 bets (M=1.031, SD=1.307), winning £2 bets (M=0.563, SD=1.014) and the control condition, F(1.658, 51.390)=7.048, $p<0.05$, partial η^2 = 0.185 (using Greenhouse-Geisser correction). Post hoc tests using Bonferroni corrections demonstrated that there was a significant difference observed between winning £20 bets and winning £2 bets (p=0.027), winning £20 and neutral £0 stake bets (p=0.013), but the difference between the control condition and £2 winning bets did not reach statistical significance. Figure 20 demonstrates the relative differences across conditions:

Figure 20: Mean Differences in Occurences of ER-SCR when Observing Outcome of Winning High, Low and No Stake Bets



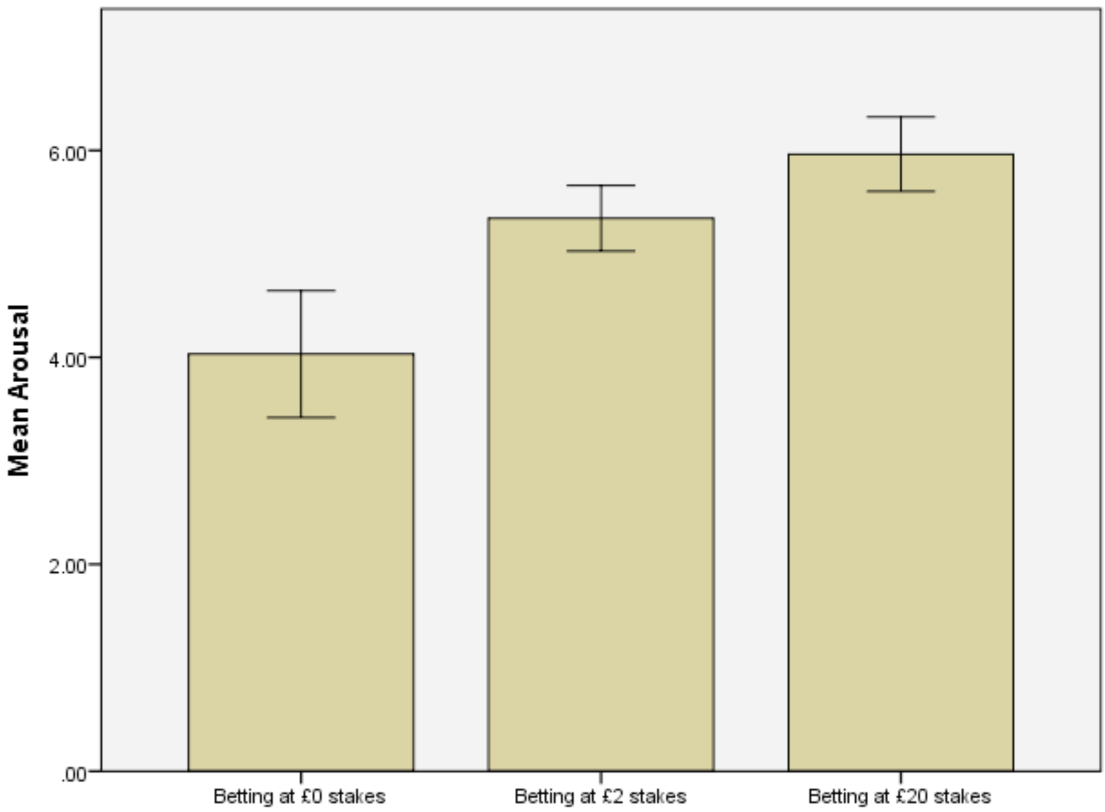
With respect to losing bets, there was no significant difference found in observed mean ER-SCR occurrences in £20 stake conditions (M=0.469, SD=0.761), £2 stake conditions (M=0.219, SD=0.42) and the control condition (M=0.313, SD=0.693), $F(2,62)=1.667$, $p>0.05$.

10.3.1.5 Self-Reported Levels of Arousal for Gambling at Different Stake Sizes

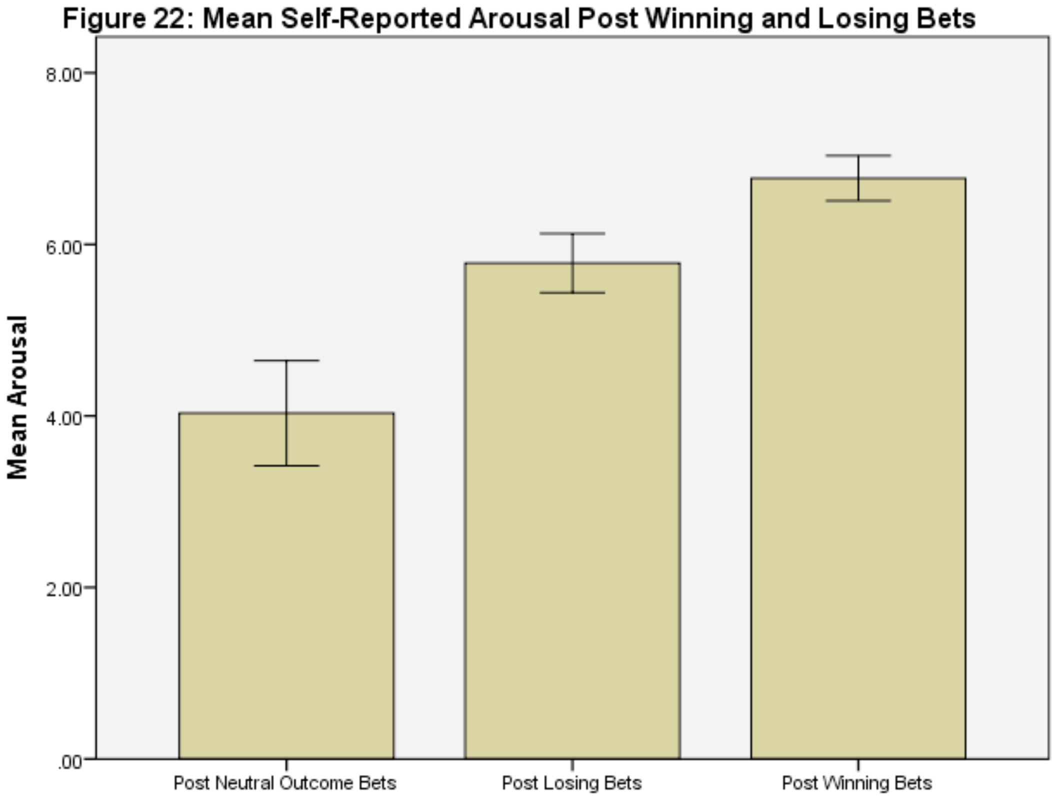
Unlike non-reactive measures of arousal such as SCL and SCR, the possibility of determining change in arousal through self-report has diminished internal validity. In simple terms, asking participants to consciously evaluate their level of arousal at baseline is likely to create either an anchoring effect on future evaluations of arousal or make participants conscious of their body's psychophysiological response to gambling stimuli. Because of this limitation in self-report it was decided that self-report measures of arousal would only be taken post-bet outcome, and were intended to measure perceived arousal level after the betting experience.

Mean levels of self-report arousal after observing outcomes of £20 bets were higher (M=5.964, SD=0.996) than self-reported arousal levels post-£2 betting (M=5.343, SD=0.88) and post-control condition (M=4.031, SD=1.7). Furthermore, this difference was statistically significant *F*(1.441, 44.656)=36.076, p<0.05, partial η^2 = 0.538 (using Greenhouse-Geisser correction). Post hoc tests using the Bonferroni correction revealed significant differences with self-reported arousal between betting at £20 and £2 stakes (p=0.001), between £20 stakes and the control condition (p=0.0001) and between betting at £2 stakes and the control condition (p=0.0001).

Figure 21: Mean Self-Reported Arousal Post Betting for High and Low Stakes



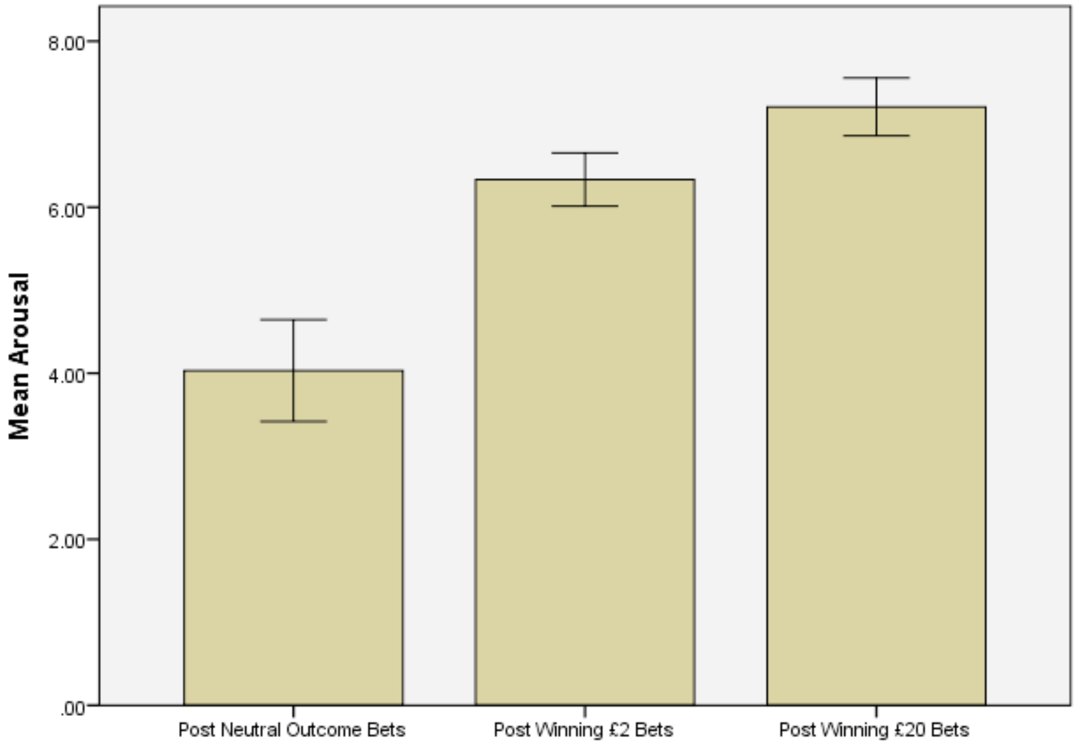
Mean levels of self-report arousal after observing outcomes of winning bets were higher (M=6.771, SD=0.729) than after observing losing bets (M=5.781, SD=0.958) and after the control condition (M=4.031, SD=1.7). This difference in self-report arousal was statistically significant *F*(1.432, 44.384)=73.431, p<0.05, partial η^2 = 0.703 (using Greenhouse-Geisser correction). Post hoc tests using the Bonferroni correction revealed self-report arousal was significantly higher when winning bets versus the control condition (p=0.0001) or losing bets (p=0.0001). Finally, it was observed that there was statistically significantly higher self-reported arousal after losing bets the control condition where no money could be won or lost (p=0.0001).



Participants reported statistically significant higher levels of arousal when winning £20 bets (M=7.208, SD=0.968) than winning £2 bets (M=6.333, SD=0.892) and the control condition, $F(2, 62)=76.812$, $p<0.05$, partial η^2 = 0.712.

Post hoc tests using Bonferroni corrections revealed self-report arousal was significantly higher when winning £20 bets in comparison to winning £2 bets (p=0.001) or the control condition (p=0.0001), and higher in winning £2 bets in comparison to the control condition (p=0.0001).

Figure 23: Mean Difference in Self-Reported Arousal Post Winning High and Low Stake Bets



When looking at losing at various stake sizes, it was observed there was no statistically significant difference in self-reported arousal between losing £20 bets (M=4.719, SD=1.579), losing £2 bets (M=4.354, SD=1.424) and the control condition $F(1.573, 48.750)=2.929$, $p>0.05$ (using Greenhouse-Geisser correction).

Table 5: Self Report Levels of Arousal across various Stake Sizes and Betting Outcomes		
Comparison	*F* ratio	Statistically Significant
£20 stake vs £2 stake and the control condition	36.076	✓
Winning vs Losing and the control condition	73.431	✓
Winning £20 bets vs Winning £2 bets and the control condition	76.812	✓
Losing £20 bets vs Losing £2 bets and the control condition	2.929	**x**

11 Discussion, Conclusion and Implications

Before discussing the experimental findings in relation to the impact of stake size on reflection impulsivity, response inhibition and arousal individually, it is important to address some of the global limitations of the experimental design, to assist with interpreting and evaluating the validity and reliability of the findings presented within each section. In addition, the limitations of the design outlined below will also be discussed with reference to the potential impact on the specific relationship between stake size and reflection impulsivity, response inhibition and arousal.

Throughout the report, it is repeatedly acknowledged by the authors that the virtual roulette simulation used in the experiment has limitations. First, within the experimental simulation there is less choice available in terms of bet type, frequency of bet and the size of bet placed than a gambler would have when playing a commercial form of virtual roulette. Effectively, in commercial roulette there is scope for the player to adjust the volatility of bets in terms of potential payoffs and probability of winning. However, in the current experimental design participants were not afforded the opportunity to adjust the probability and potential reward levels, and instead were required to make a simple 50/50 bet with an 'even money' return. It is acknowledged that this limits the generalisability of the findings with regards to commercial forms of virtual roulette; however, this was a necessary step in order to standardise the experimental task across all conditions and participants, which in turn enables causal conclusions to be drawn regarding the specific effect of stake size.

Second, the money risked had been provided by the experimenters, and therefore the monetary loss experienced by the participants during the gambling task may be phenomenologically different to the experience of monetary loss when gambling with their own funds. However, the research team argue that the virtual roulette simulation in the experimental task is still representative of commercial gambling because participants must first make a betting selection, and based on an unknown result they will either be able retain the monetary funds provided in addition to being provided with more money when their bet is successful, or will lose money when the bet is unsuccessful. Although the physiological and psychological impact of winning and losing may be somewhat muted within the parameters of experimental task, the monetary wins and losses within the experiment remain significant, and this limitation was accepted in order to establish the requisite experimental control that would enable causal conclusions to be drawn.

Furthermore, in order to draw causal conclusions from the research it was necessary to standardise gambling outcomes in four of the experimental conditions, i.e. participants would receive either three wins or three losses in a sequence. It is possible that some participants may have interpreted the repeated sequences of wins and losses as an indication that the results received were not based on chance, but rather predetermined. However, participants were enabled to choose freely to bet on red or black, and this personal involvement and choice appeared to have been effective in maintaining the illusion of randomness within the experimental trials. In the intervals between experimental conditions, the experimenter would informally engage the participant in conversation regarding the outcomes of their bets, and monitor for any verbal indications of the participant's questioning the randomness of the virtual roulette simulation. There were no instances of participants questioning the randomness of the betting outcomes; however, there were multiple instances of participants internalising the blame for making the wrong prediction in terms of incorrectly guessing whether the result would be red or black.

As discussed in section 9.1, this study made no attempt to compare the differential effects of stake size and gambling outcome on reflection impulsivity, response inhibition and arousal across non-problem, problem and pathological gamblers. The objective of the research was solely to investigate impact of stake size on potential indicators of control in within-session gambling across 'normal' populations. Evidence has demonstrated that individuals with a gambling disorder are more likely to have decision-making and inhibition deficiencies and a different arousal response when gambling, in comparison to non-problem gambling populations (Goudriaan et al., 2004). Therefore, one would anticipate a different performance on the measures of executive control and arousal from problem gamblers; however, if problem gamblers were included within the current study it would be difficult to determine whether any deficiencies observed in high or low stake conditions were caused by the independent variables or pre-existing neurocognitive vulnerabilities.

It is probable that there would be an interaction effect between problem gambling status and stake size on reflection impulsivity, response inhibition and arousal, and this may help develop understanding of potential maintenance factors in problem gambling with reference to stake size. However, this is outside of the remit of the current study, which focused on the potential for stake size to affect executive control in within-session gambling across non-problem gamblers.

11.1 Effect of Stake Size on Reflection Impulsivity

11.1.1 Discussion of Reflection Impulsivity Findings

The construct of reflection impulsivity is a measure of the individual's approach to decision-making, and the quality of approach is constructed of three specific domains; namely, time taken to deliberate and evaluate, amount of information used to make the decision and finally, the quality of decision being made in terms of the probable accuracy of being correct. Research clearly shows that individuals with addiction disorders, including pathological gambling, demonstrate poor performance in tests of reflection impulsivity (Clark et al., 2009; Lawrence et al., 2009), thus implicating it as a potential causal or maintenance factor in addiction disorders. The current study indicates that size of stake has a causal effect on an individual's quality of decision-making, in terms of the probability of making correct decisions.

It was demonstrated in this experiment that gambling at higher stake sizes did not have an effect on latency of decisions being made in the IST. Essentially, there was no trend to make more rapid decisions at higher stakes, regardless of whether the participant was winning or losing.

There was however a general trend where, as the size of betting stakes increased, participants used less of the information available upon which to base their decisions. In other words, participants had a higher tolerance for uncertainty when they were asked to make probability judgements after they had been gambling at a higher level of stake. Looking at the findings with more detail, it was observed that this difference in amount of information used to make decisions was only found after betting at £20 per spin in comparison to the control condition. There was no difference in amount of information used after betting at £2 per spin and the control condition, suggesting that this is a phenomenon that only occurs when betting at a threshold above £2 per spin. Moreover, after losing higher stake bets participants were also more likely to use more of the information possibly available to base their decisions on, in comparison to the control condition where money could not be won or lost.

In the adapted IST in this experiment there was motivation to tolerate uncertainty because as information was sampled the potential amount that could be won in that trial also reduced. Fundamentally, the less information sampled to help make a decision the higher the potential reward; therefore, the choice to make riskier predictions is not entirely maladaptive or a sign of poor decision-making. However, when observing the effect of stake size on the quality of decisions being made after betting, in terms of probability of being correct it is evident that as stakes increase the quality of decisions are reduced.

Potentially the most important finding of the current study was: it was observed that after an individual has been gambling at higher stakes they are more likely to make poorer probability judgements than after gambling at lower stakes and after the control condition. There was not only a reduction in quality of decision-making between the £20 per spin and the £2 per spin condition, but also a significant reduction was observed between gambling at lower stakes (£2 per spin) in comparison to the control condition, where no money could be won or risked. Exploring the findings more closely, it was also shown that when both winning and losing at higher stakes, there was a reduction in probability of making correct judgements in contrast to winning and losing lower stake bets.

Ultimately, while controlling for alternative causal factors, it was observed that after betting at either the £20 or £2 per spin level, the participant made more unsound and impaired judgements in a reflection impulsivity task. Poor reflection impulsivity, in terms of poor judgement and evaluation, is proposed as an explanatory factor in addiction disorders and problem gambling: therefore, it is an important finding that an isolated structural characteristic, size of stake risked, is shown to cause impairments in this domain.

It has been observed that this deficit in decision-making is not a result of making rapid decisions, as amount of time spent making decisions did not differ across stake sizes. Furthermore, although less information was used after higher stake betting than no stake betting, this was not the case when comparing information used after £20 versus £2 bets, or indeed after £2 bets versus the control condition. This indicates that the impairment in decision-making is not simply a result of participants making poor decisions because they were not using enough information to make accurate judgements.

In the research literature, reflection impulsivity in addiction populations is often considered to be a result of individual differences, where those with addiction disorders have specific neurological vulnerabilities, either pre-existing or caused by repeated exposure to the substance (Ersche et al., 2006; Whitlow et al., 2004). In this experiment, it is unlikely that the change in reflection impulsivity was caused by individual differences as the effect was shown within individuals across a single day. It is much more probable that the impact on reflection impulsivity is explained by short-term changes in internal state such as arousal, valence and emotion.

With respect to oscillations in internal state, although participants made poorer decisions when losing in comparison to winning bets or the control condition, the impairment in decision-making was still observed at the £20 stake level when the participant was winning and being successful. This suggests that the increase in reflection impulsivity is not related to a negative valence component such as frustration or annoyance, which may mean that intensity of emotion, i.e. arousal rather than positivity, may be an explanatory factor to consider in future research designs.

As outlined in the results section, participants did not experience a statistically significant change in skin conductance level between baseline and either placing the bet or observing the outcome of bet in any experimental condition, therefore suggesting that the deficiency in decision-making is not a result of elevated arousal from gambling at higher stakes. However, prior to the IST commencing, participants were provided with a reminder of the total monetary outcome of the condition, i.e. the total amount won or lost during the last 15-minute session (see section 9). Therefore, it is possible that although participants did not experience a significant change in arousal after a singular high stake bet, they may have experienced a significant change in arousal in response to seeing the larger cumulative sums won and lost in the reminder. The change in arousal experienced in response to the cumulative total may account for the increase in reflection impulsivity; however, further investigation is required to support this explanation.

11.1.2 Limitations and Caveats Specific to Reflection Impulsivity Findings

Given the aforementioned lack of existing literature, this experimental study was initiated as an explorative piece, solely observing whether gambling with higher stakes reduced quality of decision-making, reducing one's ability to withhold urges and affecting the physiological experience of gambling. As a direct result of the explorative nature, the work was conceived not to produce a definitive assessment of the impact of stake size on these three factors, but rather to identify the most dominant effects and outline key concerns regarding category B2 machine gambling and research priorities. Therefore, priority was placed on establishing experimental control in terms of controlling all possible alternative causal factors in the design, to enable confident conclusions to be made regarding whether stake size has an impact on these factors. Because of this, it was important to ensure that each participant experienced gambling at higher stakes, lower stakes and a control condition where no money was won or lost; and experienced both winning and losing at high and low stakes in case the impact differs across different gambling outcomes. Furthermore, it was also essential for each participant to have repeated trials of the five conditions in order to observe the effect more reliably, rather than using a 'one-shot' measurement.

The consequence of such a controlled experiment means that there is an inevitable trade-off with respect to available resources; specifically that the more time-consuming the data collection process for each participant, the less scope there is to test participants in higher numbers. Prioritising the observing of a robust causal link between stake size and different decision-making and behavioural outcomes through a counter-balanced repeated measures design, meant that it was not possible in the current study to engage in statistical analysis regarding the possible mediating role of arousal in the observed deficits in reflection impulsivity.

Another limitation of the reflection impulsivity findings is the latency of the IST measure in relation to the independent variable, i.e. betting outcomes. In summary, the participants completed the measure of reflection impulsivity at the end of each of the five gambling conditions, rather than immediately after the result of the bets. Given that the only variable to be manipulated in each condition was the stake size and outcome (i.e. £20 win, £20 loss, £2 win, £2 loss and the control condition) it is still possible to conclude with confidence that the difference in reflection impulsivity performance is attributable to stake size. However, the target of future research should seek to simplify the complexity of the research design, and measure the impact on reflection impulsivity of gambling at various stake sizes in a variety of latencies post gambling. For example, it would be valuable to determine the change, if any, on the strength of the effect if participants were tested immediately after the betting trials, and also to determine how long the increase in reflection impulsivity persists after gambling. Investigating the precise nature of the relationship between size of stake, betting outcome and reflection impulsivity would be highly informative regarding considerations given to potential harm minimisation strategies such as altering structural characteristics, or the design of existing or new responsible gambling features.

11.1.3 Conclusions and Recommendations Specific to Reflection Impulsivity Findings

Conclusions

- While controlling all other factors, gambling on a simulated virtual roulette activity at higher stakes impairs judgement and quality of decision-making in comparison to gambling at £2 levels or not betting on virtual roulette.
- The reduction in quality of decision-making was not a result of making more rapid decisions, as there was no significant difference in the length of time that decisions were being made across different experimental conditions.
- In the test of reflection impulsivity, when gambling at the £20 per spin level participants were less willing to retrieve more information to make more informed decisions than in the control condition. As retrieving more information led to a reduction in the amount that could be won, this finding could be interpreted as a willingness to make less informed bets with a higher potential win. There was no significant difference in the level of information used on which to base probability judgements between gambling at £2 per spin levels and the control condition, indicating that the increase in willingness to make less informed decisions, for higher potential wins, is created when gambling at stakes higher than the £2 level.

Recommendations

- It cannot be stressed strongly enough that the findings of the experimental work must be applied with caution, given that this is the first study to demonstrate that stake size can affect level of reflection impulsivity in the short term. Before policy decisions regarding stake size on EGMs can be fully informed, it is essential that these findings are not only replicated consistently but also expanded upon, to develop understanding regarding the precise nature of this effect.
- Furthermore, as stated previously, it is unrealistic to consider that singular structural characteristics of EGMs, such as size of stake playable, will have an effect on gambling behaviour without influence from other structural features of the game such as event frequency or game volatility (Parke & Parke, 2013). Therefore, in order to inform policy regarding stake size limits it is important to look at the effect of stake size when integrated with other structural and environmental characteristics of EGMs in gambling environments.
- The next step should be to conduct *in vivo* experimental research into the impact of stake size on reflection impulsivity, with all structural characteristics of different categories of EGMs and the characteristics of gambling environments present, including responsible gambling features. As well as potentially supporting current findings through replication, there will be an opportunity to develop and expand understanding by observing the impact outside of the limitations and rigidity of the laboratory. This *in vivo* research will require considerably more time to conduct as there will no longer be the experimental control assured within a repeated measures design. However, the substantial funding and duration required to complete such experimental work in a natural setting is certainly easier to justify after the clear findings presented in this explorative study.

11.2 Effect of Stake Size on Response Inhibition

11.2.1 Discussion of Response Inhibition Findings

Despite evidence showing a clear link between response inhibition deficits and addictive disorders (Fillmore & Rush, 2002; Lawrence et al., 2009; Solowij et al., 2012; Wright et al., 2014) including problem gambling (Carlton & Manowitz, 1992; Goudriaan et al., 2006; Vitaro, Arsenault & Tremblay, 1999) it was shown that gambling at higher stake sizes in a virtual roulette simulation does not reduce participants' ability to withhold prepotent responses (i.e. *behavioural urges*). This lack of causal effect could be interpreted as an indication that size of stake when gambling on EGMs does not reduce an individual's ability to withhold responses that are inappropriate. However, given the exploratory nature of this research study it is fundamental to replicate this finding before asserting this conclusion with any confidence. It could be tentatively inferred that deficits in response inhibition within problem gambling populations may be a result of pre-existing neuropsychological vulnerabilities.

In contrast, it is equally important to consider whether the observed lack of effect of stake size on response inhibition was a result of limitations within the experimental design discussed below.

11.2.2 Limitations and Caveats Specific to Response Inhibition Findings

The importance of considering the impact on cognitive and behavioural outcomes of stake size in EGM gambling alongside other structural characteristics of the activity has been discussed previously (Parke & Parke, 2013). In this experiment, to ensure a high level of experimental control to determine the direct effect of stake size on response inhibition, the virtual roulette gambling task was simulated in a laboratory setting and multiple important structural characteristics such as event frequency (i.e. the ability to re-bet rapidly) were altered. Put simply, in the experiment participants could only bet on virtual roulette approximately once every 240-300 seconds, and therefore this reduced the external validity of the virtual roulette simulation. As a result, although it is possible to infer that response inhibition is not negatively affected by size of stake in isolation, before size of stake can be readily discounted as an explanatory factor in response inhibition deficits in problem gambling, it is fundamental to replicate the findings of this experiment using live EGMs. By replicating this research using a live EGM rather than a simulation it will be possible to determine whether stake size, when interacting with other structural characteristics of EGMs such as being able to bet rapidly and continuously, can have an effect on a player's ability to withhold prepotent responses and urges.

Another limitation of the research design, driven by ethical principles and the need not to cause harm to research participants, is that the money the participants risked, and were ultimately forced to lose through deception, was provided by the experimenters. The participants were given the sum of £132 after they consented to the experiment. They were clearly instructed that although they were required to make forced betting choices in terms of the number and size of bets to be made, ultimately the money was theirs, and they were allowed to retain all of the money remaining at the end of the experiment, including any winnings that they had acquired during the test. Therefore, any bet that they lost was in real terms a personal monetary loss, similar to real EGM gambling. However, it could be argued that although there were negative consequences to losing bets in terms of reducing the amount of money they would have after the experiment finished, the money lost did not represent money that was earned, saved or allocated for essential costs such as subsistence, transport or utility bills for example. Strictly speaking, the monetary loss in this experiment represents loss of potential profit rather than loss of money that the individual has personally acquired and perhaps is dependent upon. This means that the reaction towards losses and potential losses in terms of money risked, whether stake size is small or large, may be different because of the different consequences associated with losing in this experiment versus live EGM gambling.

Persistent gambling, or losing control and chasing losses, is driven by the motivation to remove negative affect created by the loss such as anxiety and frustration, and to make financial reparations and recoup losses (Campbell-Meiklejohn et al., 2008). If the loss of money in this experiment represents a loss of 'house money' rather than losing money that was difficult to obtain or required for subsistence, this is likely to dull the negative affect associated with losing and the urge to return to how things were before the session commenced. As a result, the difference in meaning of monetary losses in the experiment in comparison to live EGM gambling may account for the lack of effect of stake size on the individual's capacity to inhibit inappropriate responses.

A further limitation of ecological validity to consider as a possible reason for observing no effect of stake size on response inhibition is the absence of multiple gambling related cues in the gambling environment. As experimental control was prioritised in isolating the causal effect of stake size, apart from the virtual roulette simulation itself and monetary stake there were no other gambling situational characteristics in the laboratory. Dickerson (1979) identified that betting shop gamblers, after a brief latency period, gradually began to find other characteristics beyond betting money as rewarding and stimulating, through a process of classical conditioning. Repeated exposure to environmental cues, such as horse racing commentary or interacting with peer gamblers, and continuously pairing these cues with the excitement and arousal of gambling, means that over time the environmental cues within the betting shop can elicit an excitation response independent of betting. It is possible that the lack of classically conditioned gambling related cues in the laboratory environment that elicit aroused states for gamblers may also dull physiological and emotional reactions to monetary losses. In turn, this may account for a lack of effect of stake size on response inhibition observed in the current study.

This reiterates the need to attempt to replicate these explorative findings with *in vivo* experimental work within licensed betting offices (LBOs) and other machine gambling environments in order to provide further confidence that gambling at stake size in isolation does not create temporary response inhibition deficits in gamblers, and also whether other structural or environmental characteristics affect the impact of stake size on response inhibition.

11.2.3 Conclusions and Recommendations Specific to Response Inhibition Findings

Conclusions

- In this experimental design, stake size, independent of other structural or environmental characteristics related to EGM gambling, did not cause a temporary deficit in participants' response inhibition.
- This suggests that if loss of control in gambling behaviour is indeed caused by poor response inhibition then it is a result of a) pre-existing neuropsychological vulnerabilities, b) different structural characteristics other than stake size, or c) an interaction of multiple structural and situational characteristics alongside stake size.

Recommendations

- As with all original experimental findings, it is fundamental to replicate the findings with different samples before concluding with any confidence.
- It is recommended that the potential relationship between stake size and response inhibition is explored in more detail, specifically to examine if the null effect of stake remains when gamblers are:
    - able to re-bet every few seconds;
    - losing their own money that they have personally acquired rather than 'house money'; and
    - exposed to gambling related cues in the gambling environment that may be conditioned in the individual to elicit aroused internal states.

11.3 Effect of Stake Size on Arousal Experience

11.3.1 Discussion of SCL Change Findings

In terms of SCL, representing the participants' general arousal and activation level, it was observed that there was no significant difference in arousal changes from baseline levels when placing and observing the result of higher stake bets, whether winning or losing, in comparison to either lower stake or no stake bets. The lack of observed effect is not surprising given that SCL is a relatively slow and non-specific physiological reaction. In simple terms, changes in tonic arousal are primarily over the longer term and are therefore likely to be in response to a multitude of interacting factors that are accumulating over time rather than solely driven by one factor, i.e. size of stake.

The lack of effect of stake size on change in SCL remains an important finding, as it emphasises that focus on a singular variable to account for loss of behavioural control may be myopic. Again, this does not mean that size of stake will not create a change in excitement or stress level for players, but rather that the role of stake must be considered in relation to other structural and situational characteristics related to EGM gambling. Similar to recommendations related to lack of effect of stake on response inhibition, it may be important to consider stake size as it interacts with event frequency, represented as *gambling intensity* (Parke & Parke, 2013). It could be argued that tonic arousal level should be framed as being determined by monetary amounts either won or lost accumulated over an extended period of time that have significant implications for the individual (either positive or negative). Put simply, rather than focusing on maximum stake limits in isolation impacting on player arousal, stake size should be combined with speed of play to observe the effect of potential rate of loss on player arousal.

11.3.2 Limitations and Caveats of SCL Findings

The limitations of the design discussed in sections 11.1.2 and 11.2.2 are of course also applicable to interpreting the findings relating to SCL change. To summarise, although losing bets created monetary loss for participants in the study, the monetary losses were not likely to have created significant harm, and this may have influenced the change in arousal the participants experienced in response to winning and losing larger sums of money. Moreover, the lack of other structural and situational characteristics, which may be conditioned as cues to stimulate arousal responses in the individual (Dickerson, 1979), could have limited the stimulation available and experienced within the experiment. In addition, the emphasis on experimental control meant that it was not possible to enable the participant to re-bet consecutively and therefore possibly accumulate substantial wins or losses, as is possible in live EGM gambling.

11.3.3 Conclusions and Recommendations to SCL Findings

Conclusions

- Gambling at larger stakes on a virtual roulette simulation, independent of other variables, does not significantly increase arousal change between pre-betting and post-betting levels.
- It is probable that any significant increases in arousal experienced when gambling on EGMs is a consequence of multiple interacting environmental and structural factors rather than dependent on stake size alone.

Recommendations

- With respect to understanding the experience of arousal as a contributing factor in loss of control when gambling, it is recommended in future research designs to explore the impact of stake size in relation to other structural and environmental features rather than in isolation.

11.3.4 Discussion of Self-Report Arousal Findings

When dealing with self-report data one must be conscious of the participant's ability to be introspective enough to gauge and report how they feel during the experiment. In the current study participants were asked to rate their level of arousal at the end of each individual betting event. The findings demonstrate that participants found the experience of betting at higher stakes significantly more arousing than betting at low stakes or the control condition where no money could be won or lost. Furthermore, participants found the winning experience significantly more arousing than both losing and the control condition. In addition, losing was demonstrated to be significantly more arousing than not risking money in the control condition. This supports the argument that betting can be primarily motivated by arousal experiences, independent of whether the participant is winning or losing (Anderson & Brown, 1984).

Exploring the effect of winning and losing at specific levels of stake, it was also observed that participants find winning at £20 stakes significantly more arousing than winning at £2 stakes. This suggests the pleasurable arousal of winning is enhanced at higher stakes. When applying this to the argument that gamblers are motivated to commence and persist in gambling to experience heightened states of arousal (Anderson & Brown, 1984), it could be argued that being able to risk more money to enhance the experience of arousal may increase motivation to continue gambling, in spite of the potential risks involved.

Conversely, it was observed that there was no significant difference in arousal experienced when losing £20 bets in comparison to losing £2 bets. This indicates that the experience of loss for the participants in both conditions was relatively similar in terms of stimulation and intensity. One must be cautious in inferring extensively from self-report data; however observing both that magnitude of loss does not affect experience of arousal, and that losing is not as stimulating as winning, it could be argued that gamblers are more sensitive to the winning experience in comparison to losing. Put simply, participants are more affected by winning than losing, and the pleasurable experience of winning increases as monetary sums increase. In general, it could be argued that if losing creates a more limited arousal experience in contrast to winning, when determining whether to begin or persist in gambling decisions may be therefore biased towards potential rewards versus potential negative outcomes.

When contrasting the lack of short-term change in arousal between baseline and betting outcomes with the large significant effect of stake size and betting outcome on self-report arousal, this may initially seem contradictory. However, it is important to note that the assessment of tonic arousal focused on short-term change within each betting event, whereas self-report arousal was compared across significant time periods (i.e. separate experimental conditions). This supports the argument that change in experience of arousal is a relatively unhurried response to an accumulation of events rather than a rapid response to singular events. The implication of this proposition is that rather than focusing on maximum stake size permitted as a risk factor for loss of control when gambling on EGMs, attention should be directed to potential average monetary sums that can be won and lost over longer-term timeframes. This interpretation highlights the danger of considering individual structural characteristics without further consideration of how such features interact with other variables within the game or the gambling environment. The risk of changing a singular characteristic, such as size of stake, without considering how it interacts with other features of the activity, is that it will not be possible to make informed predictions about the probable effect.

11.3.5 Limitations and Caveats of Self-Report Arousal Findings

In addition to the limitations of the design discussed in preceding sections, it is crucial to emphasise the risks of over-interpreting from self-report data. It is probable that when participants were trying to gauge their level of arousal that it was challenging for them to distinguish between emotion and arousal in isolation. Of course, arousal is a key dimension of emotion; however, it is probable that any self-evaluation was influenced by the other dimension of emotion, i.e. valence. In summary, it is difficult to determine with confidence the participants' capacity to immediately evaluate and report their internal state in terms of arousal, meaning any conclusions must be made cautiously

11.3.5 Conclusions and Recommendations to Self-Report Arousal Findings

Conclusions

- Gambling at higher stakes on a virtual roulette simulation creates an experience to the individual that is significantly more arousing than gambling at lower stakes.
- Winning at higher stakes when gambling on a virtual roulette simulation creates a heightened arousal experience in comparison to winning at lower stakes.

- From analysis of these findings it is concluded that the experience of arousal does not increase when losing at higher stakes in comparison to lower stakes when gambling on virtual roulette.
- It can tentatively be inferred from these findings that participants are more sensitive, in terms of arousal created, to the effects of winning and the magnitude of sums when winning, in contrast to the effects of losing and size of loss. This may cause individuals to bias decision-making towards previous and potential wins when determining whether to continue or cease gambling.

Recommendations

- Given the observed arousal experience, individuals may disproportionately value winning monetary sums in contrast to potentially losing, and this may help account for loss of control and persistent gambling that leads to gambling related harm. Before accepting this finding with any confidence it is important to replicate this finding in EGM gambling environments to determine whether structural and situational characteristics other than stake size affect the losing experience in EGM gambling.
- Self-reported arousal levels appear to change significantly when winning and losing, and also when winning at different stakes. As arousal is one of two component dimensions of emotion, it is probable emotional experience may also change significantly when winning at different stake sizes. Therefore, it is recommended that further research is conducted to explore the impact of stake size and gambling outcome on valence, the second dimension of emotion. Developing a more global understanding of affective changes with the machine betting environment to specific outcomes in EGM gambling, may help account for within-session loss of control.

11.4 Effect of Stake Size on Arousal as a Somatic Marker

11.4.1 Discussion of Arousal as Somatic Marker Findings

It was observed that participants were more likely to have a skin conductance response (SCR: a somatic marker) after observing outcomes of bets at higher stakes in comparison to lower stakes. Moreover, winning at higher stakes produced significantly more SCRs than winning at lower stakes. Although at face value it may appear that a sharp deviation in arousal is likely to have a detrimental impact on decision-making, this spike in arousal dissipates within a few seconds. Rather, it is argued that this sharp deflection in arousal acts a physiological marker. This marker enables one to encode the event as being either positive or negative, and if the event and marker are paired frequently enough the marker will eventually automatically be evoked when faced with the event in future situations (Damasio, 1999). It is argued that the production of a somatic response in anticipation of an event assists the individual in their cognitive processing and decision-making, by providing affective context (Tranel, 2000).

Fundamentally, gambling at higher stakes in this experiment had the consequence of producing larger monetary wins and larger monetary losses. Because of this, the observed increase in SCRs produced when gambling at higher stakes may potentially be considered to be adaptive. In other words, it is adaptive and beneficial for the individual to encode this association, because it will enable the individual to learn from past experiences, with decision-making in gambling being appropriately biased based on whether the experience of high stake gambling was positive or negative.

When looking at the impact of stake size on the production of somatic markers more closely, it was observed that participants had more SCRs in response to winning bets than losing bets. Furthermore, participants did not produce significantly more SCRs when losing higher amounts of money in comparison to losing lower amounts of money. Collectively, this suggests that the participants in this experiment were more effective in creating somatic markers in relation to potential reward, but they demonstrated deficits in response to trying to mark negative outcomes. This is supportive of the emergent findings from the self-report data, which also demonstrated an increased sensitivity towards potential rewards. This may be maladaptive in terms of decision-making in gambling, as the absence of somatic markers indicating potential threat means that the *affective nudge* evoked to assist rational decision-making will be biased towards potential rewards. In simple terms, when playing a simulation of virtual roulette, participant arousal and physiological responses were weighted towards the positive rewards of gambling, and participants were less effective in responding adaptively to negative gambling outcomes.

11.4.2 Limitations and Caveats Specific to Arousal as Somatic Marker Findings

As previously discussed in section 11.2.2, although there was a real monetary loss for participants when they lost bets, the effect of the loss may have been limited by the fact that the money lost was provided by the experimenter during the session; whereas in real gambling environments, the money risked and lost is money that has been personally acquired by the individual and thus may hold more significance for the individual in comparison to money provided to them. Therefore, given that the participants lost money that they were not dependent on, this may have reduced the *threat* of the loss, which in turn may explain the lack of somatic markers recording during loss conditions in the experiment.

It is important to understand the conclusions made in section 11.4 as being the most tentative. Fundamentally, this is because despite demonstrating substantial promise, the somatic marker hypothesis and its role in decision-making performance is the least developed area of research discussed in the report (Colombetti, 2008; Dunn et al., 2006). The somatic marker hypothesis requires substantial development before the role of somatic markers in adaptively assisting decision-making and judgement can be universally accepted. Essentially, the somatic marker hypothesis in its current format is too general, and the model requires refinement by more specifically identifying what components of decision-making are influenced by somatic markers (i.e. attention, working memory, etc.) (Colombetti, 2008). In addition, it is also important to note that, given that there are multiple forms of somatic markers available to the individual, an absence of an SCR in response to losing does not definitively state that no somatic marker was present. Ultimately, although the somatic marker hypothesis is under-developed, the current study does demonstrate that betting outcomes and magnitude of win do impact somatic response, and therefore indicates that this is likely to be a productive direction for future research.

11.4.3 Conclusions and Recommendations to Arousal as Somatic Marker Findings

Conclusions

- In general, participants seemed to show deficits in somatic responding to negative gambling outcomes when gambling on a virtual roulette simulation, and this may have a negative effect on future gambling decision-making.

- When winning, participants produced more somatic markers when gambling at higher stakes. This is interpreted to be an adaptive response as it is of benefit to the individual to signal larger rewards in comparison to smaller rewards. However, this strong somatic response to rewards in combination with a more muted response to punishment may bias decision-making and create a preference for risk.

Recommendations

- The potential maladaptive physiological response to losing in a virtual roulette gambling simulation as observed here is reflective of the findings from the self-report arousal data previously discussed. Therefore, there is a strong rationale for studying the differential physiological and somatic responses of individuals in EGM gambling when losing and winning at higher and lower stakes. This lack of sensitivity to monetary loss when gambling may assist in understanding decision-making deficits and loss of control in within-session EGM gambling.
- When replicating and developing this research area further, it is important to acknowledge that SCRs are only one variation of somatic marker, therefore other somatic markers such as blood pressure and heart must also be observed in future designs (Colombetti, 2008).

12 Concluding Statement

12.1 Key Finding: Gambling at Higher Stakes Can Reduce Quality of Decision-Making

As identified previously by Parke and Parke (2013), higher stakes, along with the variables of Return to Player and Game Speed, can contribute to a higher rate of loss; and rate of loss is a key component of gambling related harm. However, this study finds initial support for a new stake-related risk factor for gambling related harm, as it was demonstrated that gambling on a virtual roulette simulation at higher stakes impairs decision-making quality, which in turn may reduce self-control when gambling.

One of the key questions that remains to be addressed is how the impact of event frequency (i.e. opportunity to re-bet) affects players' reflection impulsivity, response inhibition and arousal experience when gambling. More specifically, there is a need to understand how the observed impacts of stake size on player reflection impulsivity, response inhibition and arousal experience are affected by differing event frequency levels. It is already understood that higher event frequency will lead to an increased rate of loss (Parke & Parke, 2013); however, the direct and indirect effect of event frequency on executive control is an important new research objective on which to focus. Ultimately, by introducing the structural characteristic of event frequency, the observed reduction in reflection impulsivity at higher stakes in the current study may change (either positively or negatively). Furthermore, it is also reasonable to argue that a faster game may affect response inhibition performance when gambling, as stake size in isolation had no impact on a player's ability to withhold urges.

Of all the structural characteristics of EGMs, it is most important to understand the interaction of stake size and event frequency on gambling cognition and behaviour, because in Great Britain gambling machines are categorised to an extent across these two dimensions. For example, category B2 game content has a maximum stake size of £100 with each event lasting around 20 seconds, whereas B3 game content has a much lower maximum stake size of £2 but a much higher event frequency, with each spin lasting approximately three seconds. Although B2 content has a higher theoretical loss per hour in comparison with B3 content (Parke & Parke, 2013), it is possible that the faster rate of play on B3 content may also have a significant effect on executive control in machine gambling beyond rate of loss. Fundamentally, it is important to consider how maximum stake size interacts with speed of play to affect a player's ability to gamble in a controlled, responsible manner, in terms of impairing quality of decision-making and ability to suppress urges to continue gambling.

The gambling task used in this experimental design was developed to represent a simplified version of virtual roulette, where participants were asked to make a simple 'outside bet' (a bet with a probability of approximately 0.5). It is also important to determine how stake size may interact specifically with other electronic gambling formats such as blackjack and slot content also available on EGMs. It is possible that differences in game structure of content other than virtual roulette, or even a fully expanded version of virtual roulette, may also affect a player's executive control, either directly or indirectly.

12.2 Replication of Findings in Natural Setting

Given the need to repeat the experiment in real gambling environments such as betting shops and casinos in order to understand the effects of other structural and environmental characteristics in combination with stake size, one must consider why the research team did not choose to do this initially rather than conduct the study in a laboratory. The importance of conducting this explorative study in a laboratory setting was that it enabled the research team to standardise the gambling experience in terms of type and size of bet, and also the outcome of such bets in terms of wins and losses, and the sequence of such outcomes. Such a high level of experimental control is fundamental to ensure that the researchers can conclude confidently that observed change in the dependent variables (in this case executive functions and arousal response) are caused by the independent variable (stake size). Comparing an individual's reflection impulsivity, response inhibition and arousal response across five experimental conditions within a repeated measures design in a laboratory setting is an effective method to control for the impact of individual differences on the dependent variables. By controlling for the effect of individual differences on arousal response and executive control, the experiment could be conducted with a relatively small sample size while maintaining a high level of experimental rigour.

Put simply, if the data was collected with a live EGM, each participant would experience a different outcome in each condition, and therefore it would not be possible to isolate the effect of stake size without observing hundreds of participants over a substantially longer period of time than the current study. Experimental designs should not be determined by expected length, and therefore budget size; however, it is important and reasonable to precede more extensive studies with explorative work to determine feasibility, design and probable utility of such research.

Beyond being able to measure how stake size interacts with other variables in the gambling activity and environment, conducting research in a natural setting will also minimise a prominent limitation of the current study. Essentially, in the real gambling environment players will be risking money that they have personally acquired and may depend on, which is likely to enhance the experience of monetary loss in comparison to monetary loss in the current study. As discussed previously, monetary loss in the current study had negative consequences for the participants; however, because the money lost was provided by the experimenter, the negative implications of losing that money are likely to be muted in contrast to real gambling. It is important in future, more expansive research to determine whether the experience of losing previously acquired personal money is qualitatively different than observed in the current study, and whether this affects physiological response and performance in executive functioning in gamblers.

12.3 Further Understanding of Relationship between Stake Size and Reflection Impulsivity

In the current study, for practical and ethical reasons, it was only possible to observe the effect of stake size on reflection impulsivity at three levels: £20 per spin, £2 per spin and a control condition where no money could be won or lost. Although it is possible to determine whether higher stake gambling increases the level of reflection impulsivity in participants in contrast to lower stake gambling, it is not possible to fully understand and explain the precise relationship between stake size and reflection impulsivity deficits. It is important for future research to employ a design to measure the impact on reflection impulsivity when participants are winning and losing at a wide variety of stake sizes, ranging across the full spectrum from micro-limits to £100. The relationship between stake size and reflection impulsivity may not be entirely linear and it is possible that the deterioration of decision making-performance may plateau at a specific threshold. In other words, it is not currently possible to state categorically that quality of decision-making reduces proportionally as stake size increases.

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