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The Relationship between Arousal, Personality, and Perception of Control in a Gambling Task

Guillaume J. Pagnier
University of Massachusetts Amherst

THE RELATIONSHIP BETWEEN AROUSAL, PERSONALITY, AND PERCEPTION OF CONTROL IN A GAMBLING TASK

A Thesis Presented

by

GUILLAUME J. PAGNIER

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Approved as to style and content by:

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Heather N. Richardson, Chair

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Andrew L. Cohen, Member

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David E. Moorman, Member

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Paula R. Pietromonaco, Member

____

Melinda Novak, Program Director

Neuroscience & Behavior

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ABSTRACT

THE RELATIONSHIP BETWEEN AROUSAL, PERSONALITY, AND PERCEPTION OF CONTROL IN A GAMBLING TASK

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GUILLAUME J. PAGNIER, B.S., UNIVERSITY OF MASSACHUSETTS AMHERST

M.S., UNIVERSITY OF MASSACHUSETTS AMHERST

Directed by: Professors Andrew L. Cohen & Heather N. Richardson

The somatic marker hypothesis posits that physiological arousal is partially responsible for decision-making behavior. Arousal, measured by skin conductance responses (SCR), increases before deck choice in the Iowa Gambling Task (IGT). These markers co-vary with performance -- pathological gamblers lack these markers and perform poorly. Personality also modulates IGT behavior – high-novelty-seeking (NS) individuals tend to perform worse. In the IGT, participants decide which deck to select, creating a potential confound between personality, performance, and arousal. For example, high-NS individuals select the bad decks more often, potentially causing habituation and a muted SCR. The first goal of this research was to replicate the finding that personality modulates arousal in a task which removes these confounds. Participants selected a series of cards from two decks. Each card was either a win or loss. Real money was used. To remove the potential confound between choice and outcome, all participants experienced the same outcomes regardless of choice. SCR was measured during the task. Personality characteristics previously shown to modulate gambling behavior, such as sensation seeking (SS), were measured. Arousal may also occur during other phases of gambling, for example, before or after the outcome is revealed. To date, few studies have examined the relationship between arousal in these different phases. The second goal was to determine this relationship. The phases of gambling (pre-choice, anticipation, and outcome) were temporally separated to allow for precise SCR measurement in each phase. The final goal was to determine the relationship between perceived control and physiological arousal. An 'illusion of control', e.g., pulling the lever on a slot machine, promotes gambling, especially in pathological gamblers. Little work has addressed the relationship between personality, control, and arousal. In different sessions, participants either selected the next card or the next card was selected for them. SS decreased arousal during all three gambling phases. The perception of control decreased arousal during the pre-choice phase only. This latter effect was strongest for low-SS individuals. The ramifications of this study are clear: identifying how physiological responses vary with personality opens up avenues for potential treatment of problem gambling.

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CHAPTER 1

INTRODUCTION

Gambling is the process of making a decision where the monetary prospect is uncertain – an everyday occurrence that requires an assessment of risk (Studer & Clark, 2011). Previous research has shown that gambling and physiological arousal have a bidirectional relationship (Bechara, Damasio, Damasio & Anderson, 1994; Mardaga & Hansenne, 2012; Crone, Somsen, Beek, & Van Der Molen, 2004). Both the act of making a gamble and seeing the outcome of a gamble produce a physiological response (Damasio, 1994; Lole, Gonsalvez, Blaszcczynski, & Clarke, 2012). Conversely, a gambling decision is subject to both emotion and its associated autonomic response (Dolan, 2002; Lang & Davis, 2006; Studer & Clark, 2011). Understanding this relationship has both significant practical and theoretical implications, from determining how gambling is cognitively determined to elucidating why certain individuals are vulnerable to pathological gambling. Damasio and colleagues were among the first to find a connection between an individual's emotional arousal and behavioral choices in a gambling task (e.g., Bechara et al.,1994).

To explain the link between gambling and arousal, Damasio developed the Somatic Marker Hypothesis (SMH). The SMH posits that unconscious, physiological markers are largely responsible for guiding decision-making behavior (Bechara et al., 1994; Damasio, Everitt, & Bishop, 1996). Empirical support for the SMH was found using the Iowa Gambling Task (IGT), a task designed to measure decision-making ability. On each trial of the IGT, participants choose between four card decks. The top card of the selected deck is revealed. Each card is associated with a gain and sometimes, unpredictably, a loss. Two of the decks, the *good decks*, have relatively small gains that outweigh even smaller losses. The other two decks, the *bad decks*, have relatively large gains which are overshadowed by even larger losses. Healthy participants eventually learn to stop choosing the bad decks and start picking solely from the good decks. Damasio and colleagues found a relationship between selection of the good decks and the development of anticipatory somatic marker signals, as measurable by skin conductance responses (SCR). SCRs are a measure of the electrical conductance of the skin and are used as an indicator of physiological arousal (Lykken & Venables, 1971). Damasio and colleagues concluded that these somatic markers act as warnings for the disadvantageous decks, influencing choice and accounting for differences in individual decision-making (Bechara et al., 1994). Importantly, patients with ventromedial prefrontal cortex or amygdala lesions lack these somatic markers and do not learn which decks are good and which are bad (Bechara et al., 1994; Anderson, Bechara, Damasio, Tranel & Damasio, 1999).

Goudriaan and colleagues found additional empirical evidence supporting the importance of these anticipatory somatic markers (Goudriaan, Oosterlaan, deBeurs, & van den Brink, 2006). Pathological gamblers both perform significantly worse on the IGT and fail to display the anticipatory somatic markers that were measured in healthy participants (Goudriaan et al., 2006). This finding, combined with Damasio's SMH make it clear that the increase in emotional arousal before making a decision is involved in determining an individual's decision making preferences (Bechara, Tranel, & Damasio, 2000; Goudriaan et al., 2006; Preston, Buchanan, Stansfield & Bechara, 2007).

This previous work suggests that understanding the factors that influence the arousal experienced during a gambling task also speak to task performance. One possible factor is an individual's personality (Franken et al., 2007; Steel & Blaszczynski, 1998). Indeed, there is considerable evidence that personality differences do play a role in predicting IGT performance (Carter and Smith-Pasqualini, 2004; Miu, Heilman, & Houser, 2008; and Werner, Jung, Duschek, & Schandry, 2009). More specifically, personality traits such as sensation seeking, impulsivity, and sensitivity to rewards and punishments are correlated with IGT performance (Franken, VanStrien, Nijs, & Muris, 2008; Kim & Lee, 2011; Suhr & Tsanadis, 2007; Mardaga & Hansenne, 2012; van Honk, Hermans, Putman, Montagne, & Schutter, 2002). These personality traits are believed to modulate arousal to wins and losses (Gray, 1970; Mardaga & Hansenne, 2012), which, in turn, influences IGT performance. For example, high sensation-seeking and novelty-seeking individuals tend to experience lower anticipatory somatic markers before making a choice in the IGT. These individuals also experience lower levels of arousal after large losses, causing the disadvantageous decks to be perceived as less risky (Mardaga & Hansenne, 2012). Other studies support this idea that personality traits that result in higher anticipatory somatic markers before making a decision lead to better IGT performance (Carter, MacInnes, Huettel, & Adcock, 2009; Miu et al., 2008; Werner et al., 2009).

Removing Potential Confounds between Personality and Arousal

It is important to note, however, that there is an inherent confound in the traditional IGT when it is used to examine the relationship between arousal, personality, and IGT performance. The IGT was originally designed to assess decision-making deficits in patients with damage to the prefrontal cortex. Participants are free to pick any of the four decks. Individuals who pick the bad decks will typically experience more large gains and losses than those individuals who tend to stick with the good decks. Thus, individuals will potentially experience very different outcomes and so it is impossible to attribute an individual's anticipatory arousal to the true expected value of each deck. Instead, individuals rely on their subjective perception of the decks, which is not always an accurate representation of the expected value.

It is unclear, therefore, if the reason some individuals experience lower levels of arousal before making a disadvantageous choice in the IGT is a result of acknowledging, but ignoring, the higher risk of the bad decks or whether they simply fail to perceive risk the same way as others. Even if these individuals implicitly understand the IGT, they could still be prone to picking these risky decks because they have an inherent preference for large rewards, regardless of the possible loss. The fact that they pick the bad decks more often also leads to the possibility that they are becoming habituated to the large losses these bad decks deliver (Chiu, Lin, Huang, Lin, Lee, & Hsieh, 2008). For example, there is considerable work demonstrating how novel stimuli amplify an individual's arousal, regardless of content (e.g., Lole et al., 2012; Sharpless & Jasper, 1956).

The first goal of the current research was to replicate the finding that personality traits, as measured by sensation seeking, impulsivity, and sensitivity to rewards and punishments, modulate the physiological arousal experienced before making a decision, but in a task that eliminates the potential confound between choice and behavior. To remove this confound, we adopted a modified IGT task based on Dong, Lin, Zhou, & Du (2014). As in the IGT, the participant selects a deck on every trial. To simplify the task, there are only two decks and the participant either wins or loses (with no associated win) on every trial. The important change is that, unknown to the participant, the outcome is controlled by the experimenter. That is, regardless of deck choice, the outcomes and order of outcomes are predetermined, so all participants experience the same outcomes (in potentially different orders, as described below). This design removes any potential relationship between personality and experienced outcomes allowing for a cleaner measurement of the relationship between personality and arousal in a gambling task. Based on the literature discussed previously, we expected personality to modulate the arousal in the modified IGT, even with this confound removed.

SCR was measured during this task. Participants were also measured on impulsivity, sensation seeking, and sensitivity to rewards and punishments. To better motivate the participants (Dixon, Ghezzi, Lyons, & Wilson, 2006), they played for real money. They gained or lost money based on the outcome that is revealed after their deck choice.

Arousal across Gambling Phases

Gambling is a time extended task. A typical gambling task can be separated into 3 distinct phases: the *pre-choice* phase, the time from when the gamble is presented to when the choice is made; the *anticipation* phase, the time between the choice and the outcome; and the *outcome* phase, the time after an outcome is revealed. While the SMH accounts for the differences in individuals' arousal during the pre-choice phase, there is evidence that the other phases also elicit significant amounts of arousal (Lole et al., 2012; Mardaga & Hansenne, 2012). For instance, the anticipation phase in a slot machine paradigm (i.e., when the reels are spinning) has been shown to increase an individual's heart rate (Coventry & Constable, 1999). Similarly, expecting an outcome elicits arousal when measured via skin conductance (Lole et al. 2012). Individuals also tend to experience strong physiological arousal during the outcome phase (Lole et al., 2012). This increase in arousal tends to be maximized after a relatively large win compared to a small win and a loss (Lole, 2013; Wilkes, Gonzalvez, & Blaszczynski, 2009; 2010).

Personality also changes the physiological response across the different gambling phases. For example, wins tend to elicit higher levels of arousal in individuals who are sensitive to rewards (Goudriaan et al., 2006). Some of these results, however, are inconsistent. For instance, while one set of studies showed that pathological gambling and impulsivity decrease reactivity during the gambling process (Goudriaan et al., 2006), another set demonstrated that pathological gamblers exhibit more arousal during the decision-making process (Sharpe et al., 1995). Interestingly, both findings have been used as evidence for Brown's hypo-arousal theory of gambling which states that pathological gamblers experience decreased amounts of arousal during a gambling task -- the former group citing that gamblers are consistently hypo-aroused and the latter group stating that gamblers physiologically compensate resulting in amplified levels of arousal (Anderson & Brown, 1994; Lole & Gonsalvez, 2013; Mardaga & Hansenne, 2012). Other phases are also affected by personality. For example, relative to the rare-loss decks of the IGT, low novelty-seeking individuals tend to show higher pre-choice (anticipative responses in their terminology) responses for the frequent-loss decks (Mardaga & Hansenne, 2012).

In order to appropriately examine potential differences in the effect of personality across gambling phases it is important to account for the response function of the SCR over time. SCR's typically register 1-4 seconds after a stimulus (Dawson, Schell, & Filion, 2007), not unlike the fMRI BOLD response. This delay is potentially problematic when studying arousal across gambling phases. For example, arousal during the pre-choice phase may register during the anticipation phase and so, be misattributed to the anticipation phase. The design and analysis of most gambling studies that incorporate SCR do not typically account for delays this large -- studies typically allow for a latency of between 500 and 2000 ms (e.g. Dawson et al., 2000, but see Clark et al, 2012). If the question of interest is overall arousal during the gambling task, as is the case in much of the literature cited previously, then delay is not a critical factor. Delay *is* critical, however, if arousal across neighboring gambling phases is of interest. For instance, Dong et al (2014) used anticipation and outcomes phases of 1.5 and 2 s, respectively, which creates the possibility that, for example, the SCR response measured during the anticipation phase is due to arousal from the pre-choice phase.

The second research goal was composed of two parts, one methodological and one theoretical. In terms of methodology, this research accounted for the SCR response delay in both the experimental design and data analysis. To be able to clearly distinguish the SCR's of each gambling phase, we used a within-subjects decision-making task composed of three distinct stages (pre-choice, anticipation, and outcome) each of which lasted for at least 3000 ms. The SCR analysis also accounted for this delay, allowing for an overlap in experimental phase and SCR response. Most prior research explores arousal during a single phase (Bechara, 1994; Lole, 2012) or, rarely, two phases (Clark et al, 2012). The current study is the first to look at all three distinct phases. In terms of theory, based on the literature cited previously, we expected a relationship between personality and the SCRs evoked during each of the three gambling phases. In particular, following Mardaga & Hansenne (2012), sensation-seeking was expected to influence SCRs during, at least, the pre-choice and outcome phases. One possible explanation for the difference in SCR responses between low- and high-novelty-seeking individuals discussed previously is that low-novelty-seeking individuals are more reactive to punishments and thus develop a greater anticipatory fear (Mardaga & Hansenne, 2012). Based on this assumption, we predict that individuals who are sensitive to punishments will show greater anticipatory SCR responses.

Perception of Control

Perception of control also affects arousal while gambling (Langer, 1975; Coventry & Norman, 1998). For instance, roulette players place higher bets if they are allowed to throw the ball onto the wheel, instead of the croupier (Ladouceur, Mayrand, & Tourigny, 1987). In a slot machine paradigm, participants were more likely to keep on playing if they were able to choose the 'play' option as opposed to the machine choosing for them (Clark et al., 2012). Furthermore, experiencing a near-miss, a non-win outcome which strongly resembles a winning configuration, fosters the illusion of control and encourages gambling activity (Clark et al., 2012; Langer, 1975; Lole et al., 2012; Thompson, Armstrong, & Thomas, 1998).

Personality also interacts with the effect of the perception of control. For instance, pathological gamblers are more vulnerable to the perception of control, believing that they have more power in controlling casino outcomes than non-pathological gamblers (Moore & Ohtsuka, 1999). Targeting and reducing this erroneous cognitive distortion can decrease the rate of relapse in Gamblers Anonymous participants, highlighting the importance of understanding such thought processes (Clark et al., 2012; Oei & Gordon, 2008). Furthermore, high-sensation-seeking (SS) individuals are more susceptible to the illusion of control than low-SS individuals. In particular, high-SS individuals show a higher propensity to gamble when they feel in control of the choice (Clark et al., 2012).

The illusion of control also alters an individual's arousal while gambling (Clark et al., 2012, Lole et al., 2012). After a win was revealed on a slot machine, there was a trend for participants to show higher levels of arousal when they themselves chose the 'spin' button (Clark et al., 2012).

The research looking at the relationship between personality and perception of control has not looked at the effects of arousal. Because personality plays a role in determining how vulnerable an individual is to the illusion of control, it is likely that personality also affects an individual's arousal when that individual is faced with the illusion of choice. Because personality affects both the arousal experienced during the IGT and the perception of control, as described previously, it is interesting to consider whether individuals who measure high on impulsivity, sensation seeking, and sensitivity to rewards would experience amplified levels of arousal when they perceive that they control the outcomes of a gambling task. The third and final goal of this research was to address this question. The relationship between perception of control and arousal was addressed by exposing each participant to two different control conditions. In the first, *active*, condition, as discussed above regarding the IGT, participants controlled deck selection. In the second, *passive,* condition, the deck was selected by the computer.

Since the gambling task is time extended, with three distinct phases, each phase was analyzed separately, to determine whether or not the perception of control affects arousal during the pre-choice, anticipation, or outcome phase. Because gambling phases have been shown to elicit varying levels of arousal (Bechara et al., 1994; Damasio et al., 1996; Goudriaan et al., 2006, Lole et al., 2012; Clark et al., 2012), we expected to see the effect of personality on physiological arousal to differ between phases. Because choice is most salient during the pre-choice phase, we expected the effect of control to be most clear in the pre-choice phase. Combined with the findings discussed previously showing that the effect of choice is influenced by SS, we predicted that SS will modulate the effect of control during the pre-choice phase. To the best of our knowledge, this study is the first to look at the relationship between personality, choice, and arousal.

Summary of Goals

In summary, participants engaged in a two deck choice task, similar to the IGT. They won or lost real money on each choice. Participants were given a battery of measures for personality traits (i.e., sensation seeking, impulsivity, and sensitivity to rewards and punishments) thought to influence both gambling behavior and arousal. To eliminate any potential confound between deck choice and arousal, outcomes were independent of choice. This design allowed us to more precisely determine how personality modulates arousal during a gambling task. To test the hypothesis that personality modulates the effect of perception of control on arousal during a gambling task, each participant experienced the task twice – both while making an active choice and while passively viewing choices made by the computer. Allowing for a delay in the

SCR in both the experimental design and data analysis permitted a more refined measure of arousal during the pre-choice, anticipation, and outcomes phases of gambling.

CHAPTER 2

METHODS

Participants

All 23 participants were undergraduate students from the University of Massachusetts Amherst (12 Women, 11 men: age range: 18-23 years old) who were recruited by flyers placed on the Amherst campus. Participants were told they would bring home the amount that they won in each session, with a minimum of $5. Unknown to the participants, due to the fixed nature of the gamble outcomes, all participants were paid $11 per session.

Stimuli

There were 51 gambling trials. On each gambling trials, participants either won $1 (9 trials), $2 (9), $9 (3), $12 (2), or $15 (2) or lost $1 (9), $2 (9), $9 (4), $12 (2), or $15 (2). These frequencies and values were selected to mimic the frequency of low and high magnitude losses and wins in games of chance (Lole et al., 2012). The absolute monetary amounts also coincide with high magnitude outcomes that have been shown to elicit high levels of arousal (Clark et al., 2012). These values sum to -$9.

Procedure

Each participant was first connected to the galvanometer which measures SCR (see below for details). They were then given verbal instructions regarding the task and did a practice trial. They were then given $20 seed money ($20 initial – $9 lost = $11 total) and began the experimental trials. The experiment was run in E-Prime (Psychology Software Tools).

The flow of a gambling trial is shown in Figure 1. Each trial started with of a 1 s 'Get ready' prompt. During the 3 s pre-choice phase, the two card decks were shown locked, i.e., they participant could not yet select a deck. In the active session, once the locks were removed, the participant was free to select one of the two decks by pressing a keyboard button. In the passive session, the computer selected a deck after a 1 s delay. After the choice was made, the deck that was not selected was grayed out and there was a 5 s delay. During this anticipation phase, a countdown timer was shown. The outcome was then displayed on the top card of the deck that was selected. During this outcome phase, win and loss amounts were shown in green and red, respectively. After approximately 5 s, there was a brief interval during which the researcher counted out the money and added or subtracted it from the participant's stack of money. Then the next trial began.

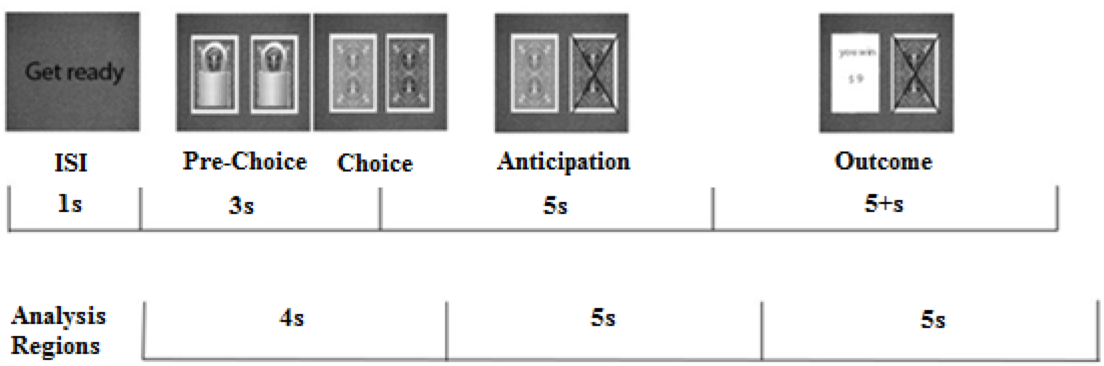

Figure 1. The structure of a gambling trial and associated analysis regions for each phase.

There were also 5 anti-habituation trials. The goal of these trials was to break up the gambling trials to prevent or reduce SCR habituation (Lader, 1967). On each anti-habituation trial, the participant completed a simple counting exercise (e.g., count up to

80 starting from 62). There was a habituation trial after the 11th trial and then after every 10th trial.

At the end of the second session, participants filled out a survey on a computer while the researcher was not in the room (due to the sensitive nature of some of the questions). This survey consisted of the Arnett Sensation Seeking Scale (Arnett, 1996), which measures sensation seeking, the Baratt Impulsivity Scale (Patton, Stanford & Barratt, 1995), which measures impulsivity, the South Oaks Gambling Screen (SOGS, Lesieur & Blume, 1987), which screens for compulsive gambling, and the STRSTP (Torrubia, Avila, Molt & Caseras, 2001), which measures sensitivity to rewards (STR) and punishments (STP). Participants were also asked about drug and alcohol use. These latter data were not analyzed.

Design

Each individual participated in two sessions, one active and one passive. The order of these two sessions was counterbalanced across participants. There was between a 10 and 16 day delay between sessions (based on scheduling constraints).

To best compare across conditions, the order of outcomes was the same during the active and passive sessions (no participant mentioned noticing that the order was the same). The outcome order was pseudo-randomly generated. That is, from a set of random orders, we hand selected 5 different sequences that contained no obvious pattern and always ended with a loss of $9. The ordering of sessions was counterbalanced across participants.

To ensure that the choices made by the computer during the passive session were similar to those that would be made by a human, 2 people were run through the task before data collection began and were asked to select decks as if they were a participant. The latter deck selection order was used during the passive session.

Physiological Measurements

SCR was measured using two silver chloride electrodes applied to the hypothenar eminence of the left hand. These electrodes were connected to a BIOPAC 150 GSR100C stand-alone skin conductance amplifier (BIOPAC Systems, Inc., Goleta, CA). AcqKnowledge (BIOPAC Systems, Inc., Goleta, CA) was used to synchronize phases with SCR's by recording both the skin conductance measure and the trial phase markers. The gambling task was run on a separate Windows PC and was connected to the BIOPAC150 via serial cable.

CHAPTER 3

RESULTS

Only data from the gambling trials are analyzed. 6 participants (3 men, 3 women) failed to complete both sessions and were removed from analysis. Analyses were conducted in R (R Development Core Team, 2007). The distributions of sensation seeking (SS), impulsivity (Imp), sensitivity to punishments (STP), and sensitivity to rewards (STR) measures are provided in Figure 2. The SS, Imp, STP, and STR measures can theoretically range from 20 to 80, 30 to 120, 0 to 24, and 0 to 24, respectively. Each measure shows good variability across the possible values. Because these measures are often correlated (e.g., Carver & White, 1994), the figure also provides scatterplots showing all pairwise relationships between these measures. Although many of these correlations are in the right direction (e.g., a negative relationship between SS and STP and a positive relationship between SS and STR), none reached significance[1] (with a Bonferroni corrected α=.05/6=.008).

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[1] SS v. Imp, r=.04, p=.88; SS v. STP, r=-.42, p=.09; SS v. STR, r=.24, p=.35; Imp v. STP, r=.11, p=.66; Imp v. STR, r=-.07, p=.80; STP v. STR, r=.05, p=.86.

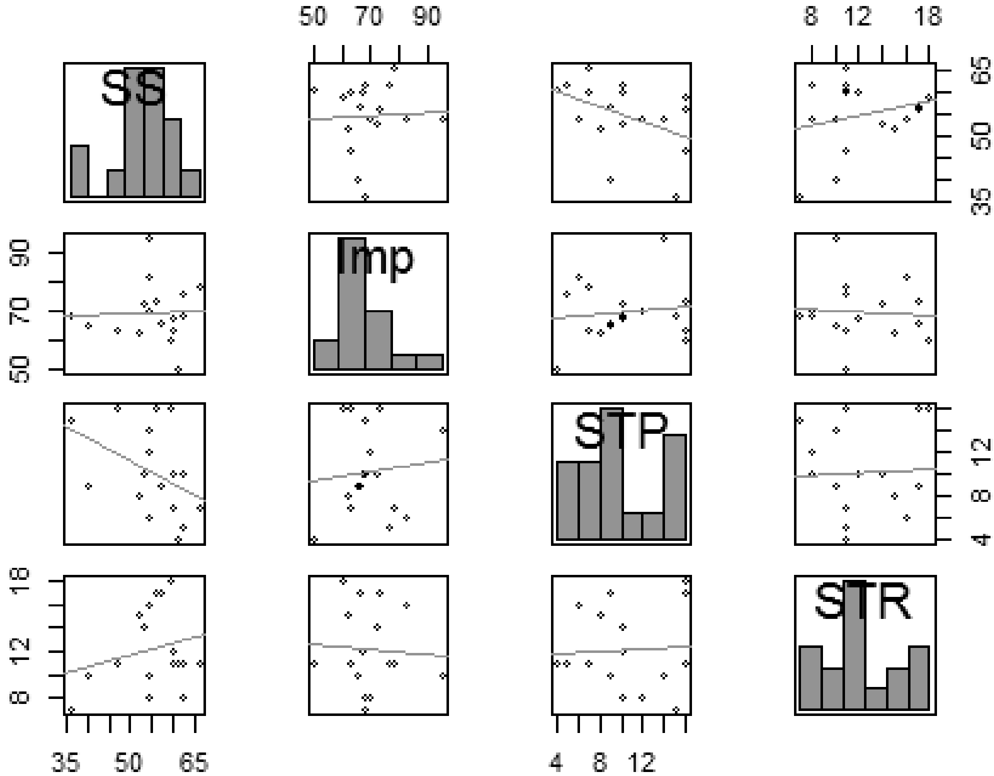

Figure 2. Distributions of the four personality measures (SS=sensation seeking, Imp=impulsivity, STP=sensitivity to punishments, STR=sensitivity to rewards) and all pairwise relationships.

The main measures of interest are the SCRs during each gambling phase. An SCR is an increase in skin conductance (measured in micro-siemens, μs) in response to an event. To account for SCR latency, as discussed previously, an SCR analysis region was defined as being part of its respective phase if it occurred during the phase or up to 1 s after the end of the phase (see Figure 1). To ensure that each phase captured its respective SCR, each analysis region lasted for at least 4000 ms. The analysis regions are shown in Figure 1. To keep the duration in line with previous work (e.g., Mardaga & Hansenne, 2012), the pre-choice phase was kept at 3 s. Keeping the pre-choice phase short also reduced the chance that participants made an early decision and then waited a considerable time to make the choice. Within each phase, the SCR response was defined as the mean SCR response across a region ±100 ms from the peak SCR in that region. Averaging across a temporal region around the peak SCR reduces noise and artifacts due to measurement error. To account for individual differences in skin conductance and SCR drift across the experiment, each SCR was measured relative to a baseline SCR for each trial. The baseline SCR was defined as the average skin-conductance during the 1 s ‘get ready’ prompt. To exclude outliers due to, for example, excessive movement, any SCR more the 3 SD from the mean SCR of that participant and phase was removed from analysis (5 total SCRs were removed). Every SCR was also screened visually to remove trials that included extreme and obvious artifacts (4 total SCRs were removed). Visual inspection of the SCRs also indicated that there were no non-responders (Lader, 1967), i.e., individuals who fail to elicit SCRs, and that, on most trials, there were distinct SCRs in each phase.

It is common for the SCR to decrease over the course of an experiment (e.g., Figner & Murphy, 2010). This decrease is often attributed to habituation and would serve to decrease power. To determine the effect of habituation, we separately regressed the mean SCR for each phase, averaged across participants, on trial number. None of these three regressions reached significance[2], indicating relatively consistent SCRs throughout the experiment.

To identify how an individual’s SCR varies across phases, we conducted Bonferroni-corrected Pearson product-moment correlation tests between each pair of

[2] Pre-choice, β=0.001, *S.E.*=0.16, t=1.03, p=.31; anticipation, β=-0.001, *S.E.*=0.22, t=-.63, p=.53; outcome, β=0.001, *S.E.*=0.23, t=0.42, p=.67.

phases. All three of these correlations reached significance (pre-choice vs. anticipation: r=.71, p=.001; pre-choice vs. outcome: r=.70, p=.001; anticipation vs. outcome: r=.80, p=.0001) indicating that an individual's SCR responses in one phase was related to the SCR responses in the other phases.

To determine a global relationship between SCR and personality, we regressed the mean SCR, averaged across participants, phases, and trials, on each of the four personality measures. The results are provided in Figure 3. There was a significant negative relationship between SS and SCR, β=-0.023, *S.E.*=0.23, t=-3.63, p=.002. That is, participants with high SS scores tended to show lower arousal than participants with low SS scores. This result coincides with past findings that sensation seeking influences the degree of arousal an individual experiences during a gambling task. Individuals who were more sensitive to punishments (STP) tended to have higher levels of arousal, STP, β=0.039, *S.E.*=0.27, t=2.24, p=.04. Imp and STR did not show an overall relation to arousal[3].

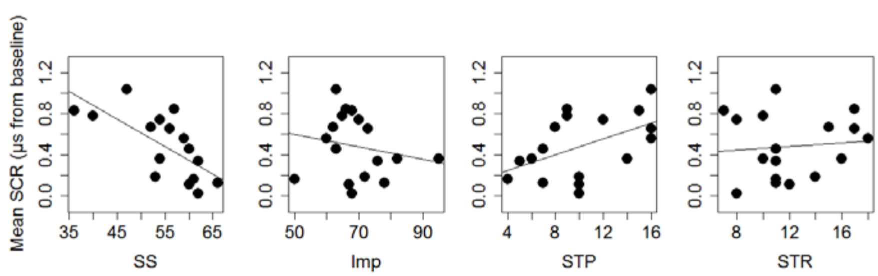

Figure 3. Mean SCR as a function of personality (SS=sensation seeking, Imp=impulsivity, STP=sensitivity to punishments, STR=sensitivity to rewards).

[3] Imp, β=-0.005, *S.E.*=0.31, t=1.65, p=.46; STR, β=0.008, *S.E.*=0.31, t=.36, p=.72.

The main questions of interest concern the relationship between SCR in each gambling phase, personality, and the perception of control. The SCRs are shown in Figure 4 as a function of phase, personality, and choice condition. Each row of the figure is a different personality measure and each column is a different gambling phase. Results from the active and passive conditions are shown with black and white dots, respectively. The regression lines were produced by bivariate regressions for the appropriate subset of data.

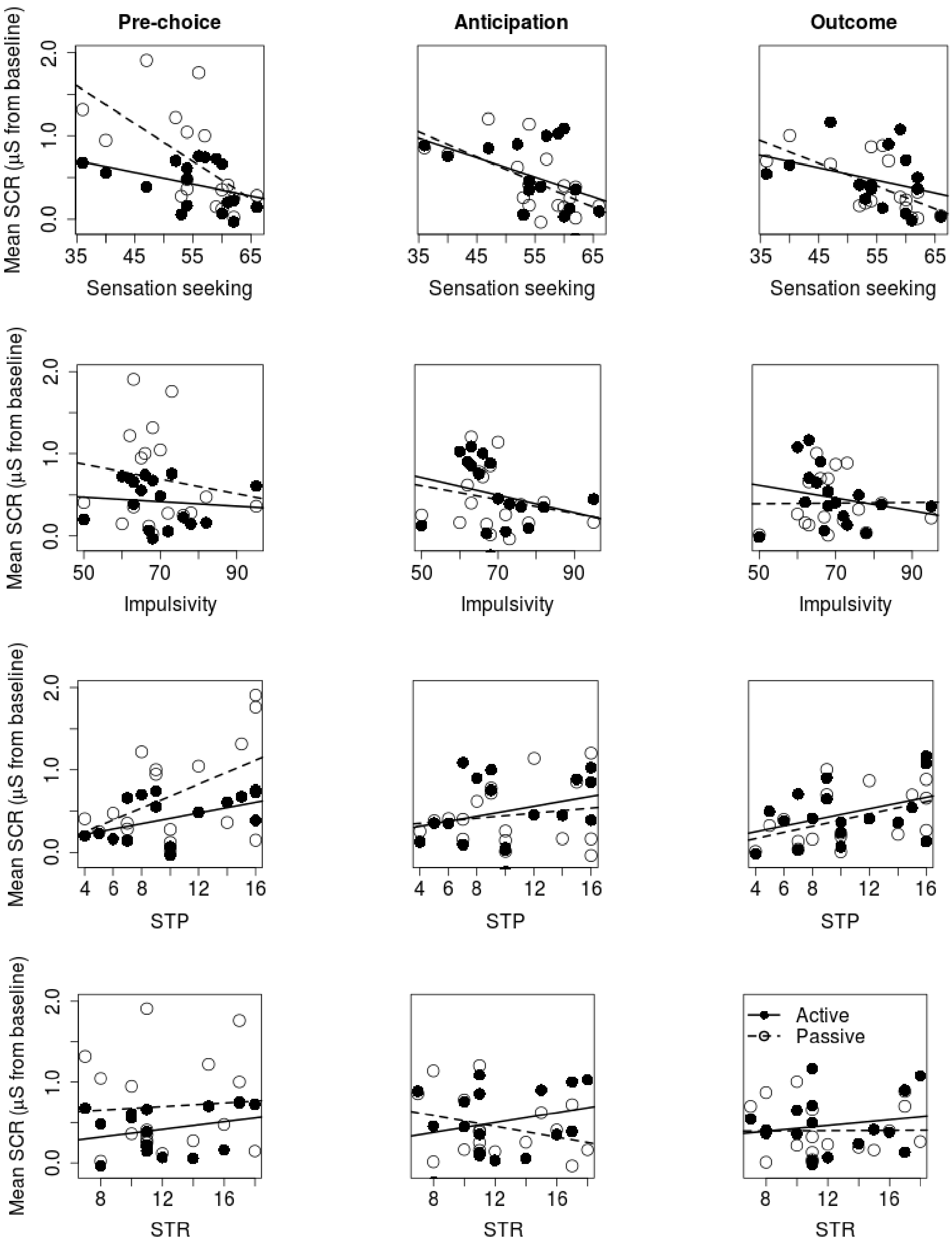

Figure 4. SCR as a function of personality measure and perception of control in each gambling phase.

A linear mixed-effects model (Bates, 2005; Bates, Maechler, Bolker & Walker, 2014) was used as an overall test of the effects of personality and choice on arousal. This model allows us to readily account for differences in SCR across participants. Three tests were performed, one for the SCR in each gambling phase. To normalize and centralize scores, personality measures were included as *z*-scores, and choice (i.e., active/passive) was coded as -0.5 and 0.5 for active and passive, respectively. A random intercept for each subject and a random effect of choice were included. Choice was always included as a fixed-effect. In the outcome phase, the participant is shown the trial outcome which may influence SCR. To account for possible effect of the outcome, two additional fixed-effect factors were included in the model for outcome phase -- amount, i.e., the raw outcome value, and magnitude, i.e., the square of the raw amount. Amount differentiates wins and losses. Magnitude accounts for variability due to the absolute amount won or lost. Because the outcome value was not available to participants in the pre-choice and anticipation phases, amount and magnitude were not included in those models.

To reduce both collinearity between factors and the possibility of a Type I error, the fixed-effect personality factors were determined via model selection. In particular, we first compared a baseline model that included the factors previously described, to a model with the same factors plus the main effect of and all interactions with a single personality measure. Sensation seeking was the only personality measure that significantly improved the fit of the model over the baseline in all three phases -- choice: $\chi^2(2)=8.03$, $p=.02$, anticipation: $\chi^2(2)=9.32$, $p=.009$, and outcome: $\chi^2(8)=20.09$, $p=.01$[4]. We then checked to

[4] Adding STP during choice, $\chi^2(2)=6.17$, $p=.05$, STR to anticipation, $\chi^2(2)=7.49$, $p=.02$, and STR to outcome, $\chi^2(8)=16.60$, $p=.03$, also significantly improved the baseline model.

see if adding an additional personality measure, beyond sensation seeking, improved the model fit. With one exception they did not. Adding STR during anticipation improved the model, $\chi^2(2)=7.54$, $p=.02$. To keep the model simple and consistent across phases, STR was not included. Regardless, except for a main effect of STR during anticipation, the addition of STR did not change any other qualitative aspect of the model fit. Based on these results, the final model only included sensation seeking as a personality measure.

The results of the linear mixed-effects models on pre-choice, anticipation, and outcome SCR are shown in Table 1. Following Bates (2005), effects with *t*-values greater than 2 were apriori considered significant. Three important results emerge from this analysis. First, as expected, the effect of SS is significant in all three phases. That is, SCR in all phases decreases as SS increases. This result extends the results of the previous global analysis. Second, as predicted, the effect of choice is significant, but only in the pre-choice phase. Third, and perhaps most interesting, this effect of choice during pre-choice is modulated by a significant choice by SS interaction. Inspection of Figure 4 shows the cause of this interaction -- relative to high-SS individuals, low-SS individuals show a highly elevated SCR during passive trials. As far as we know, this is the first finding of its kind to suggest that sensation seeking modulates the degree to which an individual experiences the perception of control.

Table 1. Results for the fixed effects of the linear mixed-effects models on pre-choice, anticipation, and outcome. Bold rows are significant.

Effect	Estimate	S.E.	*t*-value
Pre-choice			
(intercept)	**0.559**	**0.078**	**7.177**
choice	**-0.289**	**0.106**	**-2.719**
SS	**-0.231**	**0.078**	**-2.949**
choice×SS	**-0.236**	**0.107**	**2.211**

Anticipation			
(intercept)	**0.475**	**0.067**	**7.083**
choice	0.047	0.092	0.505
SS	**-0.210**	**0.067**	**-3.107**
choice×SS	0.046	0.092	0.493
Outcome			
(intercept)	**0.431**	**0.056**	**7.755**
choice	0.055	0.093	0.592
SS	**-0.166**	**0.056**	**-2.978**
amount	-0.012	0.059	-0.197
magnitude	**0.056**	**0.030**	**1.990**
choice×SS	0.091	0.093	0.975
choice×amount	0.002	0.118	0.015
choice×magnitude	0.023	0.060	0.391
SS×amount	0.004	0.059	0.070
SS×magnitude	0.039	0.030	1.297
amount×magnitude	0.170	0.310	0.550
choice×SS×amount	-0.125	0.118	-1.058
choice×SS×magnitude	**0.155**	**0.060**	**2.583**
choice×amount×magnitude	-0.021	0.062	-0.340
SS×amount×magnitude	0.008	0.031	0.259
choice×SS×amount×magnitude	0.061	0.062	0.989

Previous results suggest a relationship between SCR and either a win or loss and the magnitude of the win or loss (Clark et al, 2012; Lole et al., 2012). SCR response as a function of amount and magnitude is shown in Figure 5. Perhaps surprisingly, we find no effect of win/loss (i.e., amount during outcome) on arousal. In these previous studies, however, wins were relatively rare events. For example, Clark et al. (2012) used a slot machine task in which wins occurred on only 1/6 of the trials. In the current task, participants won or lost on approximately half of the trials. It may be that in previous studies, participants were responding to rare events, i.e., wins, not the event itself. We do, however, find a significant (albeit barely marginal) effect of magnitude. Arousal was higher for the high magnitude outcomes. There was also a three-way choice×SS×magnitude interaction that we do not interpret.

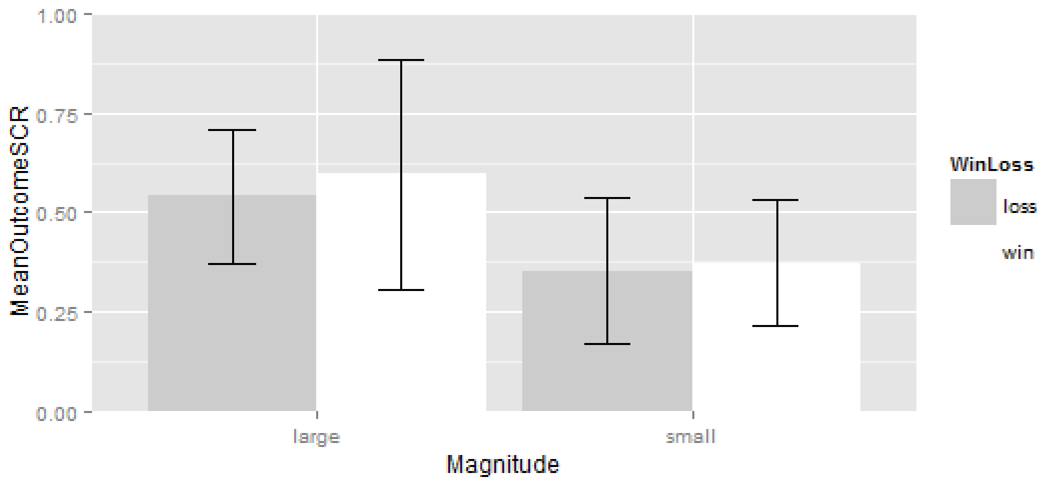

Figure 5. Outcome SCR as a function of win/loss and large/small magnitude outcome. Error bars are within subject confidence intervals (Cousineau, 2005; Morey, 2008).

CHAPTER 4

DISCUSSION

The overarching aim of this research is to examine physiological arousal during a gambling task and how that arousal is modulated by personality. Participants performed a simplified version of the IGT while their skin conductance, an indicator of sympathetic activity (Dixon et al., 2010; Goudriaan, 2004; Sharpe et al., 1995; Wilkes et al., 2010), was measured. Each participant was also measured on four personality scales: sensation-seeking, impulsivity, sensitivity to rewards, and sensitivity to punishments. There were three main goals.

The first goal was methodological. Deck choice and outcome are confounded in the IGT. It is typically assumed that deck choice is a function of arousal, e.g., people who experience higher arousal at the possibility of a loss are less likely to select the bad decks (e.g., Mardaga & Hansenne, 2012). Because the choices that participants make directly influence the outcomes experienced, however, this relationship may work both ways. For example, a participant who selects a deck with a low probability of loss may experience higher arousal when a loss occurs because, in part, it is a rare event. The first goal was to remove this confound. Participants performed a simplified and modified version of the IGT. On each trial, participants selected from two decks. Unknown to the participants, outcome was independent of choice. Indeed, all participants experienced the same set of outcomes. This design provides participants with the perception of choice, while removing outcome differences.

Because there is evidence that personality is correlated with SCRs across the gambling phases (e.g., Lole et al, 2012; Mardaga & Hansenne, 2012), the second goal involved separately measuring the effect of personality on the physiological response in each of three gambling phases. An experimental trial was broken into a pre-choice phase, the time preceding a choice, an anticipation phase, the time between choice and outcome, and an outcome phase, the time immediately after the outcome is revealed. Similar to the BOLD response in fMRI, the SCR, takes time to develop and decay. It is important to account for this delay when analyzing temporally adjacent events, such as these gambling phases. For example, an SCR measured during the beginning of the anticipation phase may actually reflect residual physiological arousal experienced during the pre-choice phase. This delay was accounted for both methodologically, by temporally separating the gambling phases, and statistically, by overlapping the gambling phases and temporal regions of statistical analysis.

Consider the main results that do not involve personality. Consistent with previous results (Clarke et al., 2012; Lole et al., 2012), participants experienced higher arousal after a large win or loss relative to a small win or loss. Perhaps surprisingly, however, losses and wins produced nearly equivalent SCRs (Lole et al., 2012; Mardaga & Hansenne, 2012). Further research is needed to determine if this lack of effect is spurious, due to a lack of power, or whether the typical effect, higher SCR for wins (Dixon, Harrigan, Sandhu, Collins, Fugelsang, 2010), is the result of the potential confounds discussed previously. It is worth nothing that, perhaps due to the addition of habituation trials and time-extended phases during each trial, SCR remained relatively constant throughout the experiment.

Personality affected SCR in a number of ways. Because impulsivity and sensitivity to rewards did not show consistent effects, the discussion will focus on the effect of sensation-seeking. Relative to high-SS individuals, low-SS individuals produced elevated SCRs in all three gambling phases. Combined with the methodological advances discussed previously, this result provides converging evidence that personality is inherently linked to arousal in a gambling task and is consistent with Bechara's SMH (Bechara et al., 1994). That is, these results lend evidence to the suggestion that low-SS individuals are more likely to select the good decks because they are more influenced by risk. Put another way, the low arousal experienced by high-SS individuals may translate into less compunction about taking the risk of selecting a bad deck. This provides further physiological evidence of the finding that high-SS individuals tend to appraise risks to a lesser extent, even on tasks that they have not encountered before (Zuckerman, 2007).

Whereas the pre-choice, anticipation, and outcome phases have all been shown to elicit SCRs independently of one another (Lole et al., 2012; Clark et al., 2012; Dawson et al., 2011), this study was the first of its kind to compare the SCRs of each of these phases within a participant. Each of the three phases elicited a similar SCR (between 0.25 to 1.5 μS). Because the current design allowed ample time for the SCR in each phase to build and dissipate, we are confident that the reported SCRs target the appropriate phase. Because most studies combine the pre-choice, anticipation, and outcome phases, i.e., measure SCR across the entire trial, these studies may be picking up on an interaction between all three phases. Although individuals tended to respond similarly across phases, there were also some critical differences as will be discussed below. We recommend that future research consider differences across gambling phases and that the research take SCR delay into account.

It was surprising that impulsivity and sensitivity to rewards did not consistently affect arousal to the same extent as sensation-seeking. It is important to note, however, that each of these personality traits measure different aspects of personality (Magid, 2007). Indeed, in the current data set, these personality traits were not significantly correlated, although they often are (e.g., Aluja & Garcia, 2004). The finding that SS modulates arousal, however, is consistent with previous research (e.g., Mardaga & Hansenne, 2012) including fMRI research showing that high-SS individuals produce stronger responses in the right insula and posterior medial orbito-frontal cortex to arousing stimuli (Joseph, Liu, Jiang, Lynam & Kelly, 2009). These brain regions are associated with arousal and reinforcement. We should note that it is also possible SS may modulate the extent to which novel stimuli are registered, regardless of the content (Smith, Perlstein, Davidson, & Michael, 1986). Further research is needed to disentangle these possible explanations.

The final goal concerned the relationship between personality, arousal, and the perception of choice in a gambling task. Subjects participated in two sessions. In the active session, the participant selected a deck on every trial, eliciting the perception of control. In the passive session, the computer selected the deck, producing a lack of control. Perhaps because the choice has already been made, control did not affect arousal during the anticipation and outcome phases. During the pre-choice phase, however, control did modulate arousal. In particular, participants tended to experience more arousal during the pre-choice phase in the passive condition. This result shows that participants were engaged during the passive condition, which is a potential worry when participants are not actively making choices. As hypothesized, however, this difference in arousal is modulated by personality, and, more specifically, sensation seeking. Previous research looking at the effect of control on arousal (Clark et al., 2012) found no significant effects[5]. Using this lack of effect as a baseline, the current results suggest that, relative to low-SS individuals, high-SS individuals are less affected by the perception of control. That is, high-SS individuals showed similar arousal in the active and passive conditions. Indeed, this view is consistent with the finding that pathological gamblers (who tend to be high-SS), typically gamble equally whether or not they have control over the situation (e.g., Moore & Ohtsuka, 1999). Regardless, this result confirms that high-SS individuals are less physiologically affected by both the act of choosing and the perception of choice and these effects carry through to potentially more risky behavior (e.g., Zuckerman, 2007).

Conversely, because they show higher arousal when they lack control, the data suggest that low-SS individuals are, in some sense, protected from the distortion caused by the perception of control. Perhaps it is this heightened level of arousal that inhibits low-SS individuals from choosing to gamble to the same extent as high-SS individuals. This result suggests that pathological gamblers tend to gamble excessively, in part, because they are more physiologically vulnerable to cognitive distortions such as the illusion of control and that low SS individuals are somehow protected from this

[5] Although there was a non-significant trend towards higher arousal during the active condition for wins during outcome.

vulnerability by exhibiting high levels of arousal when they are aware they are not in control (Clark et al., 2012; Goudriaan et al., 2006).

Although the discussion thus far has focused on SS, STP also modulated SCR, albeit to a smaller extent. In particular, high-STP individuals produced larger SCRs than their low-STP counterparts. Although this result did not replicate across all gambling phases, as discussed previously, it was significant when collapsed across phases. This finding is in line with the idea that STP influences anticipatory autonomic responses and suggests that these high-STP individuals strongly weight potential losses (Mardaga & Hansenne, 2012).

Although this research was not designed to investigate gender differences, gender has been shown to modulate both skin conductance (Venables & Mitchell, 1996) and gambling behavior (Hraba & Lee, 1996). Here we run a preliminary analysis to determine if there were gender differences in this task. Figure A1 in the appendix shows the relationship between each of the personality measures and mean SCR broken down by gender. In the current study, females tended to have a higher SCR response than males, $t(14.53)=2.30$, $p=.036$. It should be noted that these prior findings were primarily based on viewing emotional stimuli, not a gambling task as in the current study. Next, we considered gender differences in the personality measures. None were significant, although the difference in SS, $t(12.62)=1.67$, $p=.12$, and STP, $t(14.18)=2.13$, $p = .051$, were marginal. Finally, we looked at the relationship between mean SCR (averaged across phases) and gender. We ran a linear mixed-effects model with random intercepts per subject. Gender was included as a fixed effect. There were 4 regressions each with one of the personality measures as an additional fixed effect. For the personality measures, only SS was significant[6]. There were no significant interactions between gender and any of the personality traits[7].

There are some limitations and open questions that should be noted. One downside of using predetermined outcomes, is that it is not possible to directly gauge gambling behavior in the typical manner. Although similar tasks have been used to gauge gambling behavior (e.g., the Iowa Gambling Task; Dong et al., 2014), a natural next step would be to determine whether this result extends to a traditional casino-style gambling task. Similarly, the participants in the current study were young adults with limited gambling experience. As a result, it is unclear how well the results generalize to more experienced or pathological gamblers. Indeed, our gambling measure showed no pathological gamblers in our sample. We carefully designed and analyzed these data to account for the delay in SCR response. SCRs also decay over time. Although we did visually inspect the data to make sure that SCRs decayed across phases and temporally separated the phases to allow for decay, the rate of decay is variable across participants and may have led to misattributed SCRs. While this study was one of the first to account for delay, future research may also wish to consider SCR decay. Finally, although we find compelling evidence that personality and arousal are related, we stress that this study cannot make direct causal relations between personality and arousal. It may be possible to study this causal relation using, for example, studies that prime particular personality traits (e.g., Erb, Bioy, Hilton, 2002). Further study is needed to address these questions.

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[6] SS: β = -0.164, *S.E.* = 0.069, t=-2.38

[7] Gender was significant for Imp, β = -0.29, *S.E.* = 0.14, t=-2.14, and STR, β = -0.40, *S.E.* = 0.14, t=-2.84.

This study reinforces previous findings (e.g., Mardaga & Hansenne, 2012) demonstrating that personality, i.e., sensation seeking, can modulate arousal while gambling task even when the choice and outcome have been decoupled and further suggests that the sympathetic nervous system is part of the mechanism responsible for interpreting risk (Bechara et al., 1994; Dixon, Harrigan, Jarick, MacLaren, & Fugelsang, 2011). This study was the first to examine all the different phases of gambling (pre-choice, anticipation, and outcome) within a subject and to look at the relationship between personality and arousal within each of these phases. The correlation between arousal during gambling phases suggests that the stages of gambling should be studied as complimentary. Future research looking at the gambling phases should clearly delineate each phase to avoid any carry-over effects. Finally, personality plays an additional role in moderating the arousal experienced when participants are subject to the perception of control and provides a possible physiological explanation for why some individuals tend to make riskier decisions and are more likely to become pathological gamblers. The ramifications of this study are clear: identifying how physiological responses vary with personality opens up avenues for potential treatment of problem gambling.

APPENDIX: GENDER

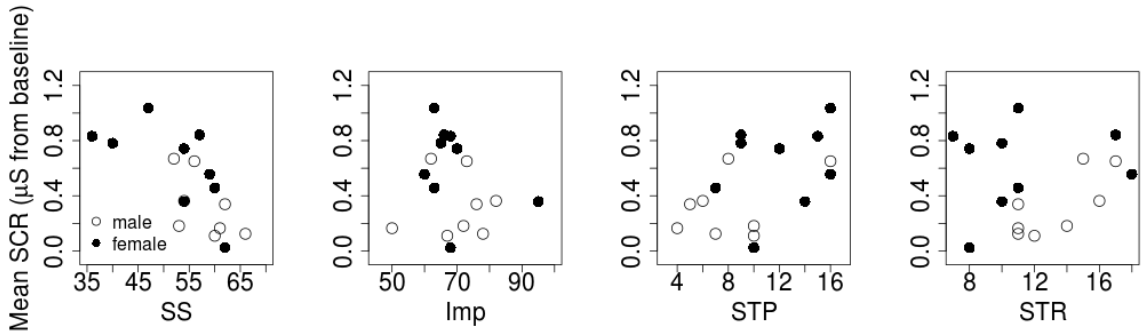

Figure A1. The relationship between personality and mean SCR as a function of gender.

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