UNIVERSITY OF CALGARY

Testing for a moderating effect of laboratory-induced acute stress on gambling-related attentional biases

by

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A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE

DEGREE OF MASTER OF SCIENCE

GRADUATE PROGRAM IN PSYCHOLOGY

CALGARY, ALBERTA

SEPTEMBER, 2023

Abstract

Gambling disorder is often accompanied by elements of disordered attentional processes which result in a bias for gambling-related stimuli. These attentional biases (AB) tend to positively correlate with the degree of disorder that an individual may experience and are therefore present (to a lesser extent) in individuals whose gambling involvement is not considered problematic. Stress is well-known to lower the threshold for the initiation of addictive behaviours and is associated with AB; however, the contextual and temporal relationship between a stressor and gambling-related ABs have not been well investigated. This study examined the moderating effects of acute stress induced in the laboratory with the anticipatory speech task (AST) on the relationship between problem gambling severity and AB for gambling-related imagery. ABs were measured as the fixation time toward gambling-related images vs. neutral images using eye-gaze tacking technology. Stress was assessed with subjective self-reports, using a 10-point visual analog scale, and physiological measures (heart rate, skin conductance, heart rate variability; HRV). Results from linear regression analyses indicated that subjective measures of stress significantly moderated the relationship between problem gambling severity and AB, whereas HRV was a marginally significant moderator. The overall AB observed was avoidance of gambling-related images, and this was most pronounced in at-risk gamblers who were least affected by the AST. In at-risk gamblers who experienced increases in stress from the AST, the avoidance bias was smaller (i.e., they attended to gambling-related images more than at-risk gamblers who did not experience an increase in subjective stress). Overall, these findings suggest that acute stress can quickly lead to an increase in preferential attention for gambling-related images in those who report problematic gambling habits.

Preface

This manuscript-style thesis is an original, unpublished work conducted independently by the author, Daniel R. Cunningham. All procedures were approved under Ethics Certificate number REB22-1388 issued by the University of Calgary Conjoint Research Ethics Board for the project "The moderating effects of laboratory-induced acute stress on attentional biases in gamblers" on February 9th, 2023.

Acknowledgements

I would like to express my gratitude and appreciation to those who have assisted me in the completion of this work and through my graduate studies. Thank you to my supervisors Dr. Chris Sears and Dr. Daniel McGrath who provided exceptional guidance and support through the research process from study conception to the careful editing of this finished manuscript. I am indebted to Chris and Dan as mentors who have shown me the beauty of scientific inquiry, taught me how to pursue my interests, and opened countless doors for me along the way. Chris especially, has mentored me through my undergraduate degree and graduate studies thus far. He's taught me how to improve my writing, my scientific rigor, and has devoted a tremendous amount of time to my academic development. I am eternally grateful and look forward to what we may accomplish in the future. I would also like to thank the examining committee who have provided invaluable feedback and made this accomplishment possible.

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Testing for a moderating effect of laboratory-induced acute stress on gambling-related attentional biases

Disordered gambling is a costly mental health issue with a high public health burden (Blank et al., 2021; Price et al., 2021; Sulkunen et al., 2020). With the unprecedented rise in gambling availability world-wide (Abbott, 2020), disordered gambling is a growing concern for public health professionals. In the most recent version of the Diagnostic and Statistical Manual of mental disorders (the DSM-5- TR), Gambling Disorder (GD) is listed in the 'Substance-Related and Addictive Disorders' section, and most of its diagnostic criteria are analogous to the criteria used to classify substance use disorders (J. E. Grant et al., 2017; Petry et al., 2014). For example, disordered gamblers may have made repeated attempts to stop gambling and may be irritable when trying to stop; they may lie to conceal their gambling involvement, and may have lost a significant relationship, job, or career opportunity because of their gambling (J. E. Grant et al., 2017). Although a majority of the adult population in North America engage in gambling activities at some point in their life (Kessler et al., 2008; Williams et al., 2020), most do not develop GD. For some, however, gambling becomes a debilitating addiction characterized by repeated bouts of disordered behaviour that impairs overall quality of life. The most recent epidemiological evidence indicates that 2.7% of Canadians have been identified as at-risk gamblers and an additional 0.6% are estimated to meet the criteria for gambling disorder (Williams et al., 2020). These individuals experience, or are at risk of, significant harm to themselves or their social relationships.

Neurophysiological evidence implicates activity in the mesocorticolimbic dopamine pathway in the rewarding experience accompanying addictive behaviours (Adinoff, 2004; Bühler et al., 2010; Diekhof et al., 2008; Joyner et al., 2019; Linnet, 2020; Meng et al., 2014; Tomasi &

Volkow, 2013). Disordered gamblers often present with dysfunctional activation in this system, also known as the reward pathway (Fauth-Bühler et al., 2017; Petry et al., 2014). Although the brain's reward pathway is known to influence motivations and behaviours related to addictions, the specific contexts that lead to dysfunction in this pathway in gamblers are not entirely clear.

Stress has been widely studied as one factor affecting both the initiation and maintenance of addiction (Koob, 2008), and has been identified as a robust predictor of disordered gambling behaviour, recovery, and relapse (Buchanan et al., 2020; Gomes & Pascual-Leone, 2015). Longitudinal studies show that gambling severity increases in the year following a stressful life event (Russell et al., 2021). Research into the mechanisms involved in the stress-gambling relationship has found that gambling craving is strongly predicted by psychosocial stress (Elman et al., 2010; Tschibelu & Elman, 2010), which suggests that important cognitive processes are influenced by stress and may motivate an individual to pursue gambling activities. Selective attention is one cognitive process implicated in the connection between stress and gambling behaviour.

Selective attention is the process responsible for determining what information receives limited cognitive resources and what information is ignored (Knudsen, 2007). While there is a vast amount of information in the environment, the brain has limited attentional resources and can focus only on a minute subset of this information at any one time. Notably, a large part of the reward circuitry is geared to direct attention preferentially toward environmental cues that have been previously associated with reward (Anderson et al., 2016). By doing so, attentional processes guide behaviour and play a significant role in addiction-related motivation. There is now a large body of literature that identifies attentional biases (AB) toward addiction cues as a

marker for addiction-related motivational states (e.g., Anderson, 2016b; Christiansen et al., 2015; Cox et al., 2014; Field et al., 2014, 2016; Field & Cox, 2008; Marhe et al., 2014).

AB toward gambling-related cues has been identified as a characteristic of disordered gambling (Ciccarelli et al., 2016b, 2016a; Coelho et al., 2023; L. D. Grant & Bowling, 2015; Hønsi et al., 2013; H. S. Kim et al., 2022; McGrath et al., 2021; Takahashi et al., 2022; Vizcaíno et al., 2013). Gambling environments contain many cues that are presented preceding and during rewards (e.g., celebratory sounds and flashing lights on electronic gambling machines). Over time, these cues become objects of attraction and pair with dopaminergic activity in the reward pathway. In studies that use eye-gaze tracking to measure selective attention, high-risk and disordered gamblers have longer fixation times for gambling-related imagery than low-risk gamblers (Anselme & Robinson, 2020) and preferentially attend to images that match their preferred type of gambling (poker, VLT, etc.; McGrath et al., 2018). Conversely, abstinent disordered gamblers exhibit avoidance biases for gambling-related images (Ciccarelli et al., 2016a), which demonstrates that gambling-related attentional biases can manifest as attentional avoidance or attentional engagement, depending upon the motivations of the individual. Disordered gamblers orient their attention toward gambling-related images faster than to neutral images when a pair of such images is presented (Ciccarelli et al., 2016b, 2016a), which suggests that the biases are, to some extent, outside the realm of conscious control (Anselme & Robinson, 2016).

Physiological Responses – Stress, the Reward Pathway, and Attentional Biases

External pressures that evoke physiological responses are often thought of as ‘stressors’ (Lupien et al., 2007). The acute stress response is an adaptive syndrome that allows individuals to better handle stressors (McEwen, 2008). Chronic stress, on the other hand, is thought to be

maladaptive and is associated with dysregulation of the stress response (Lupien et al., 2009). The stress response involves a series of neural and endocrine changes, including changes in the autonomic nervous system (ANS). Specifically, the stress response is associated with activation of the sympathetic branch of the ANS (i.e., the sympathetic nervous system; SNS), which prepares the body for 'fight or flight' and suppression of the parasympathetic branch (i.e., the parasympathetic nervous system; PNS), which is responsible for rest and recovery (Mackersie et al., 2015; McEwen, 2008). Sympathetic and parasympathetic systems often work in concert to create nuanced effects in the body. For example, variations in heart rate during a stressful situation result from the interplay between parasympathetic decreases in vagal tone and sympathetic increases in sinoatrial node excitability and ventricular muscle contractility (H.-G. Kim et al., 2018).

SNS activity is separate but closely interconnected and coordinated with the activation of the hypothalamic-pituitary-adrenal (HPA) axis (H.-G. Kim et al., 2018). The hypothalamus secretes corticotropin-releasing hormone (CRH), signalling the pituitary gland to release adrenocorticotropin (ACTH), which travels outside of the brain to the adrenal glands and initiates secretion of stress hormones (Lupien et al., 2007). The glucocorticoids (cortisol in humans) and catecholamines (adrenaline and noradrenaline) released have significant effects on the brain and body (Lupien et al., 2007; McEwen, 2008). Catecholamines prepare the body for physical exertion by increasing heart rate, blood pressure, and sweat gland activity (McEwen, 2008; Reinhardt et al., 2012). In the laboratory, these responses can serve as proxy measures of the sympathetic stress response, as will be discussed below. Glucocorticoids have extensive physiological effects, and notably, they can pass through the blood-brain barrier to interact with receptors in the brain's dopaminergic reward system (Baik, 2020; Marinelli & Piazza, 2002; Pani

et al., 2000; Sinha, 2008). Mesolimbic dopamine activity in response to stress occurs as an "inverted U" curve, where mild stress functions to excite dopaminergic release and intense chronic stress creates inhibition (Baik, 2020). Increased dopaminergic release in the reward pathway can attach reward value to environmental cues and spur addictive tendencies (Bloomfield et al., 2019; Sinha, 2008; Volkow et al., 2009). Similarly, inhibited reward pathway activation can reduce an individual's sensitivity to natural rewards and lead to the pursuit of unnatural rewarding experiences in an effort to return dopaminergic activity to homeostatic levels (Volkow et al., 2009). Thus, both acute and chronic stress can influence dopaminergic pathways in the brain to induce addictive behaviour.

The incentive-sensitization theory of addiction (T. E. Robinson & Berridge, 1993) posits that addiction-related cues become more salient through pairing with mesocorticolimbic dopaminergic activity (Berridge & Kringelbach, 2015; Berridge & Robinson, 2003, 2016; File et al., 2022; M. J. F. Robinson et al., 2015; T. E. Robinson & Berridge, 2001, 2008). The dopaminergic system itself does not mediate the pleasurable experiences associated with the addiction cues but is associated with this system. The feeling of pleasure results from activity in hedonic "hotspots" located throughout the limbic and prefrontal brain regions that are not dopamine-responsive (Berridge & Kringelbach, 2015; Castro & Berridge, 2014). These pleasure regions are small and project into other brain areas significantly less than the dopaminergic pathways responsible for motivation (Berridge & Kringelbach, 2015; Berridge & Robinson, 2016; Mahler et al., 2007; Peciña & Berridge, 2005). Addictive substances and behaviours support disproportionately more growth in the dopaminergic motivation systems than in the non-dopaminergic pleasure systems (Anderson, 2016b; Anderson et al., 2016; Berridge & Kringelbach, 2015; Berridge & Robinson, 2016; Castro & Berridge, 2014). This dopaminergic

circuitry is well integrated with attention-orienting psychomotor circuits (Anderson, 2016a) and works to guide attention preferentially to cues previously associated with reward (Anderson, 2015, 2016b; Anderson et al., 2016; Anderson & Kim, 2019; Anderson & Yantis, 2013). Thus, a key indicator of the distinctive brain functioning associated with addictive disorders is an individual's biased attention for addiction-related stimuli.

The Effect of Stress on Attentional Biases

Chronic stress has been shown to impair attentional processes in the prefrontal cortex, which is theorized to lead to a greater bottom-up influence from the mesolimbic reward pathways on attention (Blaine & Sinha, 2017). One finding consistent with this hypothesis is that ABs are larger in heavy drinkers following a stress-induction procedure, but only for those who drink to cope (Field & Powell, 2007; Field & Quigley, 2009). This suggests a greater susceptibility to stress in some individuals that uniquely influences attention. Furthermore, physical exercise – a protective factor against chronic stress and stress sensitivity (Salmon, 2001; Tsatsoulis & Fountoulakis, 2006) – has been found to reduce ABs in 3-day abstinent heavy drinkers (Taylor et al., 2013).

Surprisingly, only one study has investigated the effect of stress on gambling-related AB. McGrath et al. (2021) examined how daily psychosocial stress influenced the relationship between gambling habit severity and ABs for gambling-related images. The authors used eye-gaze tracking to measure each participant's fixations to pairs of gambling-related and neutral images over an 8 s presentation. They defined AB as the difference in fixation times between gambling-related and neutral images (with larger ABs reflecting greater attention to gambling-related images) and examined the association between AB and self-reported problem gambling (assessed via the Problem Gambling Severity Index; PGSI; Ferris & Wynne, 2001). Daily stress

was assessed via the daily stress inventory (DSI; Brantley et al., 1987) and was included as a potential moderator in their analyses. McGrath et al. found that higher levels of daily psychosocial stress were associated with larger ABs for low-risk gamblers but not for high-risk gamblers. One limitation of the study was that the levels of daily stress reported by participants were relatively low, which could have had two consequences. First, McGrath et al. speculated that because high-risk gamblers may already have strong ABs for gambling-related stimuli, the levels of daily stress reported by high-risk gamblers may not have been high enough to increase their ABs significantly. Second, for the low-risk gamblers the association between daily stress and AB likely reflected the escalating effects of stress on AB for these individuals. That is, for individuals who participate in gambling, but are at low risk of developing GD, chronic stress due to regularly occurring events may increase gambling-related ABs and urges. Consistent with this possibility, ABs in non-disordered gamblers are associated with positive beliefs about gambling and may signal a transition to disordered gambling (L. D. Grant & Bowling, 2015).

Given the very limited research on stress and gambling-related ABs, it is currently unclear to what extent acute stress contributes to gambling craving or AB. As discussed above, both craving and AB are related to daily stress, as measured with the DSI. However, a limitation of the DSI as a measure of acute stress is that it assesses daily stress through self-reporting of the stress experienced by 58 different typical stressors (e.g., “argued with another person”; “exposed to feared situation or object”; “concerned over personal appearance”), and therefore the summed DSI score is a non-specific measure of the cumulative amount of daily stress experienced. A direct acute stress induction would permit stronger causal inferences to be made and would increase the external validity of any findings. This was the methodological approach taken in the present study.

The Present Study

The purpose of this study was to investigate the effect of acute stress on the relationship between problematic gambling involvement (assessed via the PGSI) and ABs for gambling-related imagery, which were measured using a free-viewing eye-gaze tracking paradigm. That is, the primary objective was to ascertain to what extent the relationship between problematic gambling involvement and AB may depend on the relative amount of stress experienced in the moment. Acute stress was induced in the laboratory using an anticipatory speech task (AST; e.g., see Schlatter et al., 2021). The AST is derived from the Trier Social Stress Task (TSST; Kirschbaum et al., 1993), which has participants prepare and present a speech to a panel of judges. The TSST is among the most validated stress-induction laboratory procedures (Allen et al., 2014; Het et al., 2009; Man et al., 2022; Seddon et al., 2020), and is effective in inducing stress because of its use of socially evaluative threat and perceived uncontrollability (Dickerson & Kemeny, 2004). The anticipation period of the TSST has been identified as a significant contributor to the total stress induced (Pulopulos et al., 2018, 2020; Starcke et al., 2008; Wong & Moulds, 2011), and some studies have used only this component of the procedure to successfully induce stress (Preston et al., 2007; Schlatter et al., 2021).

For this study, both subjective and objective measures of anticipatory stress were collected during the AST procedure. The subjective stress measure was a 10-point visual analog scale (VAS-stressed), which has been shown to be a valid clinical measure of stress (Lesage et al., 2012). The objective stress measures were obtained by monitoring heart rate, heart rate variability, and skin conductance during the AST procedure. Heart rate and heart rate variability (HRV) are commonly used to monitor anticipatory stress and are correlated with elevated cortisol levels in response to stressors (H.-G. Kim et al., 2018; Kudielka et al., 2004; Pulopulos

et al., 2018, 2020). Imaging studies reveal a relationship between HRV and brain areas implicated in the evaluation of stressful situations (H.-G. Kim et al., 2018). Skin conductance has been used to measure anticipatory stress in laboratory settings (Wong & Moulds, 2011), and has been shown to increase along with cortisol and heart rate following stressful events (Reinhardt et al., 2012). Skin conductance is also useful for predicting stressful emotions (Christopoulos et al., 2019) and emotional arousal in imaging studies (Critchley et al., 2000).

Participant's attention to gambling-related (vs. neutral) images was measured using eye-gaze tracking. Unlike other measures of attention used to compute AB (e.g., the dot-probe task), eye-tracking data provide a direct and continuous measure of the focus of attention as the participant views an image presentation. The free-viewing eye-tracking paradigm is considered the gold standard in attentional bias research and has excellent psychometric properties (Coelho et al., 2023). The free-viewing paradigm allows researchers to assess the natural viewing behavior of participants, unencumbered with the requirement to engage in a timed task. The primary dependent variable of interest was total dwell time, which is the total amount of time that an image is fixated during a specific interval. Longer total dwell times reflect a greater interest in an image (Fitzpatrick et al., 2022; H. S. Kim et al., 2022; McGrath et al., 2021). Using total dwell times to calculate ABs has been validated as a measure of attentional bias (Clauss et al., 2022; Sears et al., 2019; Skinner et al., 2018), and specifically of bias for gambling-related imagery (Coelho et al., 2023; Takahashi et al., 2022).

It was hypothesized that (1) stress measures (both objective and subjective) assessed following the AST would reflect statistically significant activation of the stress response (an increase in subjective stress scores, heart rate, and skin conductance, and a decrease in HRV), (2) gambling craving (as measured by the Gambling Craving Scale; GACS; Young & Wohl, 2009)

would significantly increase following the stress induction, but only for those with indication of problematic gambling, (3) participants who report more problematic gambling behaviour (as reflected by their scores on the Problem Gambling Severity Index; PGSI; Ferris & Wynne, 2001) would exhibit larger ABs for gambling-related images than participants who report fewer indications of problematic gambling, and (4) that the level of induced stress would moderate the association between problem gambling severity and ABs, such that participants with higher PGSI scores and higher levels of induced stress would have the largest ABs for gambling-related stimuli.

Methods

Participants

The study received ethics approval from the institutional research ethics review board prior to data collection (REB22-1388). The participants were undergraduate students recruited through a research participation website administered by the Department of Psychology and by advertisements posted on campus. Prospective participants were invited to complete an online questionnaire assessing demographic information, medication use (anti-depressants, anxiolytics, and oral contraceptives), substance use, gambling motives, and problem gambling severity (the Problem Gambling Severity Index; PGSI; Ferris & Wynne, 2001). Prospective participants were invited to take part in a single laboratory session. Those with PGSI scores of zero and who reported not gambling in the previous 12 months (with the exception of lottery and raffle tickets) were recruited as controls (the no-risk/non-gambler group). Those who had gambled in the previous 12 months and had PGSI scores greater than zero were recruited as at-risk gamblers. Participants were selectively recruited into each group, with efforts made to balance the group sizes and to invite individuals with PGSI scores across the full range of observed scores.

Students recruited through the research participation website received a bonus credit for a psychology course for completing the online survey (1% added to their final course grade) and were offered their choice of another 1% bonus credit or a $25 Amazon gift card for attending the lab visit. Participants recruited through the campus advertisements completed a short qualifier survey online (consisting of demographic questions and the PGSI) to determine eligibility. Those eligible were then invited to complete the full online survey and the subsequent laboratory session, for which they received a $25 Amazon gift card.

Exclusion Criteria

Participants were excluded if they were under the legal age to gamble (18) or if they did not have normal or corrected-to-normal vision.

Measures

The online survey consisted of the Problem Gambling Severity Index (PGSI; Ferris & Wynne, 2001), the Gambling Motives Questionnaire - Financial (GMQ-F; Dechant, 2014), the Generalized Anxiety Disorder 7-item questionnaire (GAD7; Spitzer et al., 2006), the World Health Organization-Alcohol, Smoking and Substance Involvement Screening Test (WHO-ASSIST; World Health Organization Working Group, 2002), and a binary response question for each medication type of interest (e.g., “Have you in the past two weeks or are you currently taking prescription anti-depression medication (e.g., Fluoxetine (Prozac), Sertraline (Zoloft), Bupropion (Wellbutrin, Zyban)?”). During the lab visit, participants completed the Daily Stress Inventory (DSI; Brantley et al., 1987), three Gambling Craving Scales (GACS; Young & Wohl, 2009), and three identical visual analog scales measuring subjective stress (VAS-stress) at different time-points during the procedure.

Problem Gambling Severity Index

The PGSI inventory is designed to measure gambling severity. The measure consists of 9 items (e.g., “Have you ever felt that you might have a problem with gambling?”), each rated on a 4-point scale from 0 (“never”) to 3 (“almost always”). Scores are summed and categorized into “Non-problem gambling” (a score of 0), “Low level of problems with few or no identified negative consequences” (1-4), “Moderate level of problems leading to some negative consequences” (5-7), or “Problem gambling with negative consequences and a possible loss of control” (score of 8+), using the modified scoring criteria devised by Currie et al. (2013) that increases discriminant validity between low- and moderate-risk gamblers. The PGSI is considered the gold standard for problem gambling symptom assessment and has excellent psychometric properties (Miller et al., 2013). For the current sample, the internal consistency of the PGSI, as measured by Cronbach’s alpha, was .78.

Gambling Motive Questionnaire-Financial

The GMQ-F is a 16-item inventory widely used to assess gambling motives. Each item (e.g., “Please indicate how often you gamble for each of the following reasons: ‘because it was exciting?’, ‘because it made social gatherings more enjoyable?’”) is rated on a 4-point scale from 0 (“never/almost never”) to 3 (“always/almost always”). The GMQ-F was developed from the GMQ (Stewart & Zack, 2008), with the addition of a financial factor, to categorize gamblers into four motivational categories: coping (gambling to reduce negative affect), enhancement (gambling to increase positive affect), social (gambling to enhance social contact), and financial (gambling to improve a financial situation). Items are summed to create four scores representing the four motive categories. Higher scores represent a more frequent influence on gambling behaviour. The GMQ-F has a well-supported factor structure and is a reliable predictor of other

problem gambling measures (e.g., severity and frequency; Schellenberg et al., 2016). For the current sample Cronbach's alpha was .93 for the enhancement score, .73 for the social score, .85 for the coping score, and .88 for the financial score.

Generalized Anxiety Disorder 7-item Questionnaire

The GAD-7 is used to measure general symptoms of anxiety. The GAD-7 inquires about common anxiety symptoms experienced during the previous two weeks (e.g., "feeling nervous, anxious or on edge"), with each of the seven items rated on a four-point scale from 0 ("not at all") to 3 ("nearly every day"). Higher scores represent greater severity of anxiety, with a maximum score of 21. Scores of 5, 10, and 15 represent cut-off points for mild, moderate, and severe anxiety, respectively (Spitzer et al., 2006). The GAD-7 has excellent psychometric properties (Dear et al., 2011; S. U. Johnson et al., 2019). For the current sample, Cronbach's alpha was .91.

World Health Organization – Alcohol, Smoking and Substance Involvement Screening Test

The WHO-ASSIST was used to identify alcohol and substance use patterns and dependency. The WHO-ASSIST is an 8-item questionnaire created by a group of international substance use researchers for the World Health Organization. The first item assesses general substance use ("In your life, which of the following substances have you ever used? (*NON-MEDICAL USE ONLY*)") with a yes/no response to 10 substance categories (e.g., "Tobacco products (cigarettes, chewing tobacco, cigars, etc.)". Follow-up items assess specific adverse consequences of substance use for each of the substances the respondent indicates they have used (e.g., "During the past three months, how often has your use of *(FIRST DRUG, SECOND DRUG, ETC.*) led to health, social, legal, or financial problems?"). Responses are scored for each question and summed to provide a total score for each substance used. Scores range from 0-31

for tobacco and 0-39 for alcohol, cannabis, cocaine, amphetamines, inhalants, sedatives, hallucinogens, and opioids. The score for tobacco use excludes the question "During the past three months, how often have you failed to do what was normally expected of you because of your use". The final substance involvement score indicates either a low (scores from 0-3), moderate (4-26) or high (27+) risk. The test-retest reliabilities of the items in this measure range from good to excellent (World Health Organization Working Group, 2002).

Daily Stress Inventory

The DSI consists of 58 items designed to measure the subjective effect of daily stressors. Each item (e.g., "Hurried to meet a deadline"; "Your property was damaged") is rated on a 7-point scale anchored with "Occurred but was not stressful" and "Caused me to panic". The DSI produces two scores: a frequency score, which is a tally of the number of items that were reported to have happened in the previous 24 hours (out of 58), and a sum score, which is the summation of the impact ratings for each item (out of 406). The DSI has been widely used in the literature (e.g., Dalton & Hammen, 2018, Elman et al., 2010). It was developed to assess minor stressors that contribute to "everyday" stress as opposed to stress induced by major life events (Brantley et al., 1987) and has been shown, via physiological stress markers, to be a valid measure of this construct (Brantley et al., 1988).

Gambling Craving Scale

The GACS is a 9-item scale that assesses three facets of craving: anticipation, desire, and relief. Each item (e.g., "Gambling would be fun right now. If I had the opportunity to gamble right now, I probably would take it") is rated on a 7-point scale, from 1 ("strongly disagree") to 7 ("strongly agree"). Response values are averaged for three different subscales: desire, anticipation, and relief, which have good reliability (α = .70, .79, and .81 respectively; Young &

Wohl, 2009). The GACS was administered three times during the AST procedure (after completing the consent process, immediately following the stress-induction procedure, and at the conclusion of the session). For the current sample, the Cronbach's alphas for the desire, anticipation, and relief scores at the first administration were .70, .66, and .70 respectively. For the second and third administrations, the alphas were .75, .77, and .47, respectively, and .83, .80, and .54, respectively.

Visual Analog Scale – Stress

Visual analog scales (VAS) are widely used and have been shown to be valid and reliable measures of stress in clinical samples (Lesage et al., 2012). The scale used for this study was a 10-point scale anchored with 'not stressed at all' and 'very stressed'. Participants rated their stress at three different points during the laboratory session: after completing the consent process, immediately following the stress-induction procedure, and at the conclusion of the session. In addition to stress, other feelings were also explored. When responding to the "stressed" VAS, participants were also asked to rate feelings of "enjoyment", "excitement", "involved", "good effects", "bad effects", and "stimulated".

Apparatus and Stimuli

Heart Rate and Skin Conductivity Measures

During the lab visit, participants were fitted with a Shimmer3GSR+ wrist device (Shimmer Research Ltd, Dublin, Ireland) that monitors skin conductance and heart rate. Specifically, the device measures electrodermal resistance to provide a galvanic skin response (GSR) measure and uses an optical pulse/PPG (photoplethysmogram) signal to estimate heart rate. Heart rate variability (HRV) was calculated as the root mean square of successive differences (RMSSD) of the R-R inter-beat interval.

Eye-gaze tracking

Participants viewed two types of images (neutral and gambling-related) on a 24-inch LED computer monitor while their eye gaze was tracked and recorded. Eye-tracking data was collected using an Eyelink 1000 system (SR Research Ltd, Ottawa, Ontario, Canada), which uses infrared video-based technology to monitor eye movements. The system has a 1000 Hz sampling rate, a 1-millisecond temporal resolution, and an average tracking error of less than 0.5 degrees of visual angle. A chin rest was used to minimize head movement while viewing the images to optimize tracking accuracy.

The images shown to participants were identical to those used by McGrath et al. (2021). The gambling-related images depicted four different types of gambling activities: casino table games, lottery, internet gambling, and electronic gambling machines. The neutral images consisted of images depicting various other objects or activities such as a person setting a table, bath towels, paint brushes, etc. Images pairs were chosen so that they depicted a similar number of people, shapes, landscapes, etc., to ensure there were no systematic differences between the images of a pair. Participants viewed 25 image pairs containing one gambling-related image and one neutral image (data trials), and 31 image pairs containing two neutral images (filler trials). As in McGrath et al. (2021), the filler trials were used to reduce the relative frequency of the gambling-related images during the task and thereby reduce the expectancy of a gambling theme in each trial. The filler trials also served to increase the novelty and salience of the gambling-related images, as the majority of the images were neutral images.

The image pairs were presented for 4 seconds. Images were presented on a 1,024 x 768-pixel display and occupied approximately 40% of the display area. The images in each pair were matched to be visually similar in terms of colour, brightness, complexity, etc. (e.g., a lottery

ticket and a music concert ticket). One image was presented to the right of centre and one an equal distance to the left. For the data trials, the gambling-related images were randomly selected to appear on the right or left.

Stress-Induction

As noted, the anticipatory speech task (AST) was used for the stress-induction procedure. The AST procedure elicits a stress response from the anticipation of presenting a speech in an evaluative setting (see Schlatter et al., 2021). During the lab visit, after obtaining consent and following the baseline period (during which the participant was left sitting alone in the testing room at rest for 5 minutes, and asked not to use their phone or other devices), participants were told that they would be giving a five-minute speech about a contentious issue in popular culture, and that their speech would be video recorded and subsequently evaluated on their ability to organize and articulate an informative speech.

Despite these instructions, the AST procedure does not require participants to give a speech, but this deception is a crucial aspect of the procedure as it creates anticipatory stress. Participants were provided with two options for their speech topic: “What do you think of the 2021 Freedom Convoy protests in Ottawa? Provide arguments for and against these protests”, and “What do you think of the government-mandated pandemic lockdowns? Provide arguments for and against these lockdowns.” The topical nature of these choices aided in convincing participants that they would be giving a speech. Participants were given 10 minutes to prepare their speech and were provided with a pen and paper to assist them while doing so. Participants were told that they would deliver their speech after the eye-tracking task. The researcher set up a video camera in front of the participant while explaining the procedure.

Procedure

When participants arrived at the lab for their visit they were greeted by a researcher dressed in semi-formal wear and a white lab coat. Participants provided informed consent prior to any data collection. The informed consent document informed them that during the session they would be asked to prepare a 5-minute speech and that they would have a choice of two topics. No more information about the speech was provided until after the 5-minute rest period. Participants then completed the DSI, the VAS-stress measure, and the GACS. They were then fitted with the Shimmer device on their non-dominant hand and asked to sit at rest for five minutes to collect baseline measurements of heart rate and GSR. During this time, they were left alone in the testing room, with the door closed, and asked not to use their phone or other devices. They were offered a notepad to draw on so that the baseline heart rate measurements were not disproportionately affected by movement artifacts compared to the speech-preparation phase of the AST (see Quintana & Heathers, 2014). After the 5-minute rest period, participants were provided with the instructions for the speech task, as described above. Following the ten-minute speech preparation period, participants were asked to complete the second GACS and VAS-stress measure before being led into a separate room for the eye-tracking task. Changes in physiological stress indicators from anticipatory stress across the approximate length of time of the AST (10 minutes) are associated with salivary cortisol increases 15 minutes post stress-induction and peaks reported up to 25 minutes after introduction of the stressor (Pulopulos et al., 2018).

Prior to the eye-tracking data collection, a brief calibration procedure was carried out to ensure accurate gaze tracking. Two image pairs were then presented as practice trials to familiarize the participants with the displays and procedure. Participants were informed that each

pair of images would be presented for 4 seconds and that they could view the images in any manner they desired. The trials started with the participant viewing a blank white screen with a black circle in the centre. The participants had to fixate on the circle to initiate the display of an image pair (which ensured that their gaze was in the centre of the screen when the image pair was presented). As described above, participants viewed 26 pairs of gambling-related and neutral image pairs (the data trials) and 31 pairs of two neutral images (the filler pairs). The data trials and the filler trials were presented in random order. Collecting the eye-tracking data required approximately 6 minutes. Participants were then taken back to the room where they prepared their speech and completed the final VAS-stress and GACS. They were then debriefed and informed that they would not be giving their prepared speech.

Statistical Analyses

The Eyelink Data Viewer software (SR Research) was used to process the eye-tracking data to filter for blinks and other recording artifacts (using the default settings). Only the data trials were analyzed. For each participant and for each pair of images, the total dwell time (in milliseconds) for the gambling-related and neutral images was calculated and then averaged across the 26 trials, producing a mean total dwell time for gambling-related images and a mean total dwell time for neutral images. For each participant, their AB was calculated as the difference (in milliseconds) between the mean total dwell time for gambling images and the mean total dwell time for neutral images. Positive AB values indicate a bias toward gambling images, with larger positive values reflecting a larger bias.

ConsensysPRO software (Consensys V1.6.0, Shimmer Research Ltd., 2019) was used to collect heart rate and skin conductivity measures from the Shimmer3GSR+ device. Data was recorded on a millisecond basis. The average skin conductivity, heart rate, and heart rate

variability were calculated for four 5-minute intervals: the 5-minute baseline measurement (Baseline), the first half of the 10-minute AST preparation period (Stress 1), the second half of the AST preparation period (Stress 2), and during the eye-tracking task (Eye-tracking). The R software (version 4.2.2, R Core Team, 2022), with the integrated development environment RStudio (version 2023.06.0 'Mountain Hydrangea', RStudio Team, 2023) was used to extract these means. Comparing the means of the Stress 2 period and the Baseline period allowed for an assessment of the stress response before and after the stress induction. Participants with missing HR data due to recording errors, movement, or poor recording quality had the time period excluded from analyses if there were less than 3 minutes of usable data (i.e., less than 60% usable data).

Statistical analyses were carried out using the Statistical Package for the Social Sciences (SPSS, version 29, IBM Corp, 2022). Pearson correlations were used to examine the relationships between AB, PGSI scores, GACS scores, VAS-stress ratings, heart rate variability, and skin conductance measures. It was expected that PGSI scores would positively correlate with ABs for gambling-related images (e.g., H. S. Kim et al., 2022; McGrath et al., 2021). To explore how acute stress impacts the relationship between gambling severity and AB, four hierarchical multiple regressions predicting ABs from PGSI scores, stress measures, and interaction effects were conducted. Separate regression models were created for the four different stress measures used (changes in VAS-stress ratings, heart rate, heart rate variability, and skin conductance, pre- vs. post-stress induction). Using multiple stress measures allowed for a more complete assessment of the potential moderating effect of acute stress on AB.

An a priori power analysis using G*Power 3.2 (Faul et al., 2007) indicated that, via a multiple regression approach with three predictors (a stress difference measure, gambling

severity as measured by PGSI score, and a stress difference x PGSI score interaction term), with 80% power and an $\alpha = .05$, the minimum sample size required to detect a 10% increase in variation due to the moderation effect is 73 participants.

Results

Participants

Five-hundred and forty-seven individuals completed the online survey. Sixty-three individuals agreed to follow-up contact, met PGSI eligibility requirements for the gambler or non-gambler group, and participated in the laboratory session. The sample demographics are presented in Table 1. The sample ranged in age from 18 to 38, with a mean age of 20.44, and was predominantly assigned female at birth (61.9%). Most participants had reached a high school level education (74.6% of the sample) and White/Caucasian was the most frequently endorsed ethnicity (38.1% of the sample). Forty-two participants had PGSI scores of zero and were categorized as “no-risk/non-gamblers”. Twenty-one participants had PGSI scores greater than zero and were categorized as “at-risk gamblers”. Table 2 shows the demographic characteristics of the two groups, mean scores for variables of interest, and comparisons between at-risk gamblers and no-risk/non-gamblers. As can be seen in Table 2, there were no statistically significant differences between the two groups for age, sex, anxiety (as assessed with the GAD-7), daily stress (as assessed with the DSI), and substance use (assessed via the WHO-ASSIST). There were also no group differences for changes in subjective (VAS-stress) or physiological stress (skin conductance, HR, HRV) as a result of the stress induction, which indicated that the induction was equivalently effective for participants in both groups. One participant in each group reported using prescription anxiolytics, and one participant in each group reported using oral contraceptives. Six participants in the no-risk/non-gambling group and one participant in the

at-risk group reported using anti-depressants. Gambling motivations assessed with the GMQ-F were significantly different between the groups, but only for enhancement motives (see Table 2).

Efficacy of the Stress-induction

As noted, physiological stress measures were collected throughout four 5-minute intervals during the lab session. Twelve participants were excluded from all analyses that included HR or HRV because of missing data. To assess the efficacy of the AST in eliciting a stress response (Hypothesis 1), paired *t*-tests were used to compare subjective measurements of stress, skin conductance, HR, and HRV between the baseline and stress phase of the AST. For the physiological measures, means from the 5-minute baseline period were compared with the means from the second half of the 10-minute speech preparation stress period (Stress 2). The subjective stress measures (VAS-stress) were administered immediately before the baseline period and immediately after the speech preparation. Compared to baseline, the AST elicited a statistically significant increase in subjective stress ($M = 0.67$, $SD = 1.93$), $t(56) = 2.60$, $p = .012$, $d = 0.34$, skin conductance ($M = 1.06$ µS, $SD = 1.31$), $t(54) = 5.97$, $p < .001$, $d = 0.81$, and heart rate ($M = 6.41$ bpm, $SD = 5.82$), $t(50) = 7.86$, $p < .001$, $d = 1.10$. There was a pre- versus post-AST reduction in HRV ($M = -3.47$, $SD = 14.48$), but this change was not statistically significant, $t(50) = 1.71$, $p = .093$, $d = 0.24$. Figures 1-4 illustrate the changes observed for the VAS-stress measure and each physiological measure across the duration of the laboratory session.

Correlational Analyses

Correlations between demographic characteristics and other variables in the study are shown in Table 3. An alpha of 5% was used to evaluate statistical significance. Sex (assigned at birth) was significantly correlated with age ($p < .001$), PGSI scores ($p < .05$), and GAD-7 scores ($p < .001$), as male participants, as compared to female participants, were older, had higher PGSI

Table 1.
Demographic characteristics (N = 63).

	mean (*SD*)
Age	20.44 (3.45)
	n (%)
Sex	
Male	24 (38.1)
Female	39 (61.9)
Education Completed	
High School	47 (74.6)
Trades or apprenticeship certificate or diploma	1 (1.6)
College, or other non-university certificate or diploma	3 (4.8)
Bachelor's Degree	11 (17.5)
Doctorate or other professional degree	1 (1.6)
Ethnicity	
White/Caucasian/European	24 (38.1)
South Asian	13 (20.6)
East Asian	6 (9.5)
Multi-racial/multi-ethnic	6 (9.5)
Southeast Asian	4 (6.3)
Black/Sub-Saharan African	3 (4.8)
Latin American/Hispanic	3 (4.8)
West Asian	2 (3.2)
Arab/Northern African	2 (3.2)
Employment Status	
Employed full-time (30 hours per week or more)	4 (6.3)
Employed part-time (fewer than 30 hours per week)	12 (19.1)
Unemployed	2 (3.2)
Student (full-time)	45 (71.4)
Household Income (n = 62)	
Under $10,000	4 (6.5)
$10,000 - $19,999	4 (6.5)
$20,000 - $29,999	6 (9.7)
$30,000 - $39,999	4 (6.5)
$40,000 - $49,999	7 (11.3)
$50,000 - $59,999	3 (4.8)
$60,000 - $69,999	2 (3.2)
$70,000 - $79,999	5 (8.1)
$80,000 - $89,999	7 (11.3)
$90,000 - $99,999	5 (8.1)
$100,000 - $124,999	4 (6.5)
$125,000 - $149,999	3 (4.8)
$150,000 - $199,999	4 (6.5)
$200,000 and over	4 (6.5)

Note. SD=standard deviation.

Table 2.
Sample characteristics of at-risk gamblers (n = 21) and no-risk/non-gamblers (n = 42) regarding sex, age, prescription medications, problem gambling severity (PGSI), gambling motives (GMQ-F), generalized anxiety (GAD7), substance use (WHO-ASSIST), daily stress (DSI), gambling craving (GACS), stress measure changes following the stress-induction, and gambling (attentional) bias.

	No-risk/non- gamblers	**At-risk gamblers**		
	Female/Male		χ^2	***p***
Sex	29/13	10/11	2.73	.099
	Range	Mean (SD)	***t* (*df*)**	***p***
Age	18 – 38	20.17 (2.42)	21.00 (4.94)	0.73 (24.91)	.472
PGSI	0 – 27	—	2.48 (2.25)	—	—
GMQ-F					
• **enhancement**	0 – 15	2.76 (4.10)	5.19 (3.30)	2.36 (61)	**.022**
• **social**	0 – 15	2.07 (2.76)	3.05 (2.84)	1.31 (61)	.195
• **coping**	0 – 15	0.43 (1.50)	0.52 (1.36)	0.37 (61)	.715
• **financial**	0 – 12	2.45 (3.49)	3.29 (3.57)	0.89 (61)	.378
GAD7	0 – 21	9.74 (5.90)	9.24 (5.54)	.324 (61)	.747
WHO-ASSIST					
• **tobacco**	0 – 31	8.15 (8.99), *n* = 14	6.30 (7.78), *n* = 10	0.52 (22)	.606
• **alcohol**	0 – 39	8.00 (7.72), *n* = 32	9.47 (5.42), *n* = 15	0.66 (45)	.512
• **cannabis**	0 – 39	6.64 (9.06), *n* = 22	8.55 (10.06), *n* = 11	0.55 (31)	.586
• **cocaine**	0 – 39	4.00 (1.41), *n* = 2	6.67 (11.55), *n* = 3	0.31 (3)	.778
• **amphetamines**	0 – 39	2.80 (4.76), *n* = 5	4.20 (3.70), *n* = 5	0.52 (8)	.618
• **inhalants**	0 – 39	—	—		
• **sedatives**	0 – 39	13.33 (8.02), *n* = 3	3.50 (4.12), *n* = 4	2.15 (5)	.084
• **hallucinogens**	0 – 39	2.25 (3.30), *n* = 4	2.75 (2.50), *n = 4*	0.24 (6)	.817
• **opioids**	0 – 39	—	—		
DSI Frequency	0 – 58	20.96 (6.67)	23.86 (7.59)	1.54 (61)	.128
DSI Sum	0 – 406	66.93 (33.02)	74.86 (41.07)	.827 (61)	.411

Change in GACS Desire	—	0.05 (0.33), *n* = 41	-0.03 (0.46), *n* = 20	0.84 (59)	.407
Change in GACS Anticipation	—	0.07 (0.33), *n* = 41	-0.08 (1.00), *n* = 20	0.68 (59)	.502
Change in GACS Relief	—	-0.03 (0.45), *n* = 41	-0.08 (0.32), *n* = 20	0.45 (59)	.651
Change in VAS-Stress	—	0.68 (2.03), *n* = 37	0.65 (1.81), *n* = 20	0.05 (55)	.962
Change in Skin Conductance (μS)	—	1.09 (1.45), *n* = 36	0.98 (1.04), *n* = 19	0.30 (53)	.763
Change in Heart Rate (bpm)	—	6.76 (6.13), *n* = 34	4.62 (8.90), *n* = 17	0.60 (49)	.554
Change in Heart Rate Variability	—	-2.76 (15.66), *n* = 34	-4.89 (12.08), *n* = 17	0.49 (49)	.625
Gambling (Attentional) Bias (ms)	—	-320.12 (424.51), *n* =41	-583.82 (618.80), *n* =20	1.72 (28.02)	.097
Prescription anti-depressants (count)		6	1		
Prescription anxiolytics (count)		1	1		
Oral contraceptives (count)		1	1		

Note. PGSI = Problem Gambling Severity Index. GMQ-F = Gambling Motives Questionnaire-Financial. GAD7 = 7-item Generalized Anxiety Disorder questionnaire. WHO-ASSIST = World Health Organization Alcohol Smoking and Substance Involvement Screening Test. DSI = Daily Stress Inventory (Frequency = number of stressful events, Sum = summation of the impact ratings of each stressful event). Change refers to the difference between Baseline and Stress 2 phases for the physiological measures, and between the second and first administration for the self-report measures. GACS = Gambling Craving Scale (desire, anticipation, and relief are 3 domains of the GACS). Heart rate variability is calculated with the RMSSD. Attentional bias is calculated by subtracting the total dwell time on neutral images from the total dwell time on gambling-related images. SD = standard deviation.

Table 3

Bivariate correlations among the variables in the study.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
1. Age	—													
2. Sex	−.329**	—												
3. PGSI	.045	−.250*	—											
4. GMQF-Enhance	−.107	.192	.236	—										
5. GMQF-Social	−.084	−.100	.120	.576**	—									
6. GMQF-Coping	−.152	−.195	.181	.494**	.271*	—								
7. GMQF-Financial	−.192	−.070	.233	.524**	.448**	.236	—							
8. GAD7	−.309*	.337**	−.171	.129	.173	−.107	.199	—						
9. DSI-Frequency	−.255*	−.021	.209	.230	.192	.289*	.112	.141	—					
10. DSI-Sum	−.262*	.087	.174	.123	.122	.249*	.079	.267*	.868**	—				
11. Change in VAS-stress	.032	.181	.056	−.105	−.144	−.020	−.137	.042	−.065	−.119	—			
12. Change in Skin Conductance (µS)	−.071	.179	−.083	.044	−.042	.113	.026	.151	−.002	−.092	.203	—		
13. Change in Heart Rate (bpm)	−0.83	.116	−.178	−.074	.022	−.073	.088	.213	.040	.116	.145	.155	—	
14. Change in HRV	−.100	−.258	−.146	.011	.062	−.016	.060	.161	.091	.153	−.214	.256	.044	—
15. Attentional Bias (ms)	.011	−.041	−.027	0.34	.022	−.068	.193	.084	−.167	−.032	−.081	−.059	.046	−.080

Notes. ** Correlation is significant at the .01 level; * Correlation is significant at the .05 level

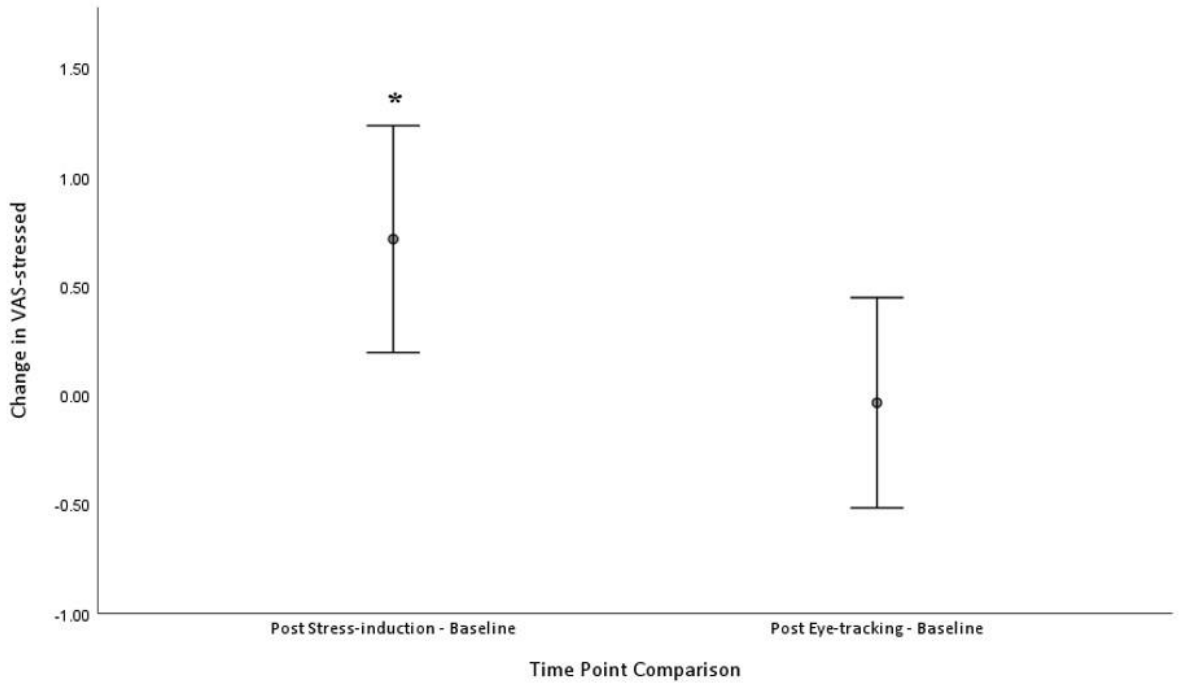

Figure 1. Change in visual analog scale stress scores (VAS-stress) from baseline to timepoints throughout the lab visit. Baseline is represented by the value of 0.00 on the y-axis. Bars indicate 95% confidence intervals and * indicates a significant difference from baseline at $\alpha = .05$.

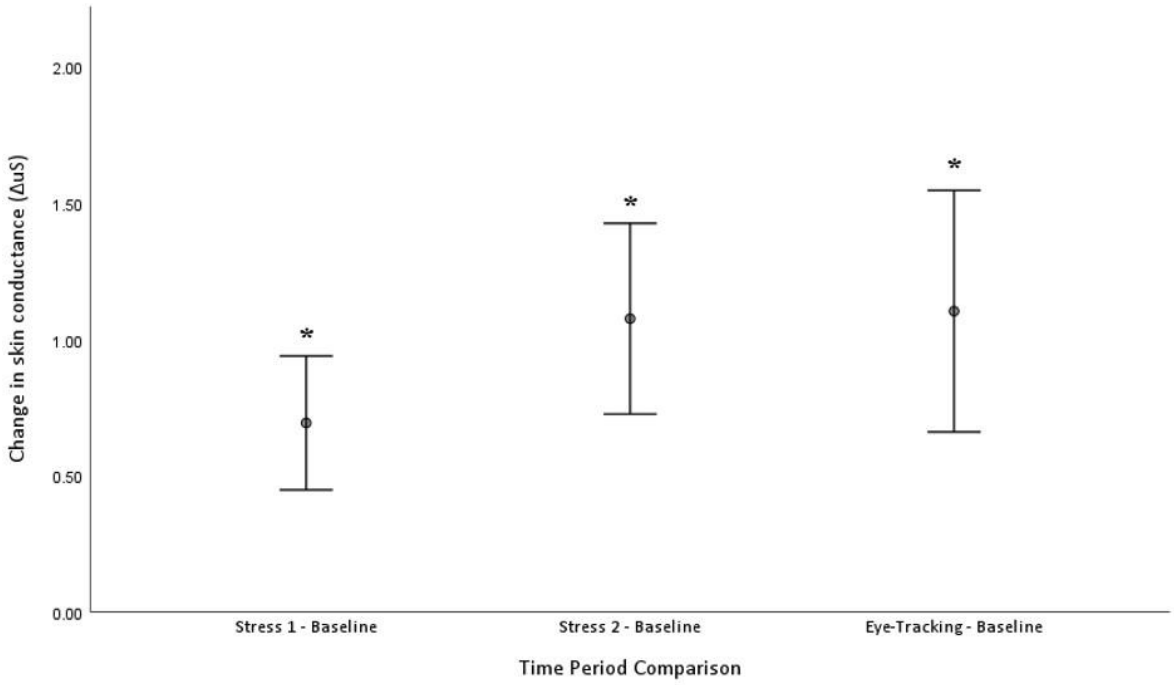

Figure 2. Change in mean skin conductance from baseline to timepoints throughout the lab visit. Values are displayed as the difference of means between three 5-minute time frames and the 5-minute baseline period. Stress 1 refers to the first 5 minutes of the anticipatory speech task; Stress 2 refers to the second 5 minutes of the task. Baseline is represented by the value of 0.00 on the y-axis. Bars indicate 95% confidence intervals and * indicates a significant difference from baseline at $\alpha = .05$.

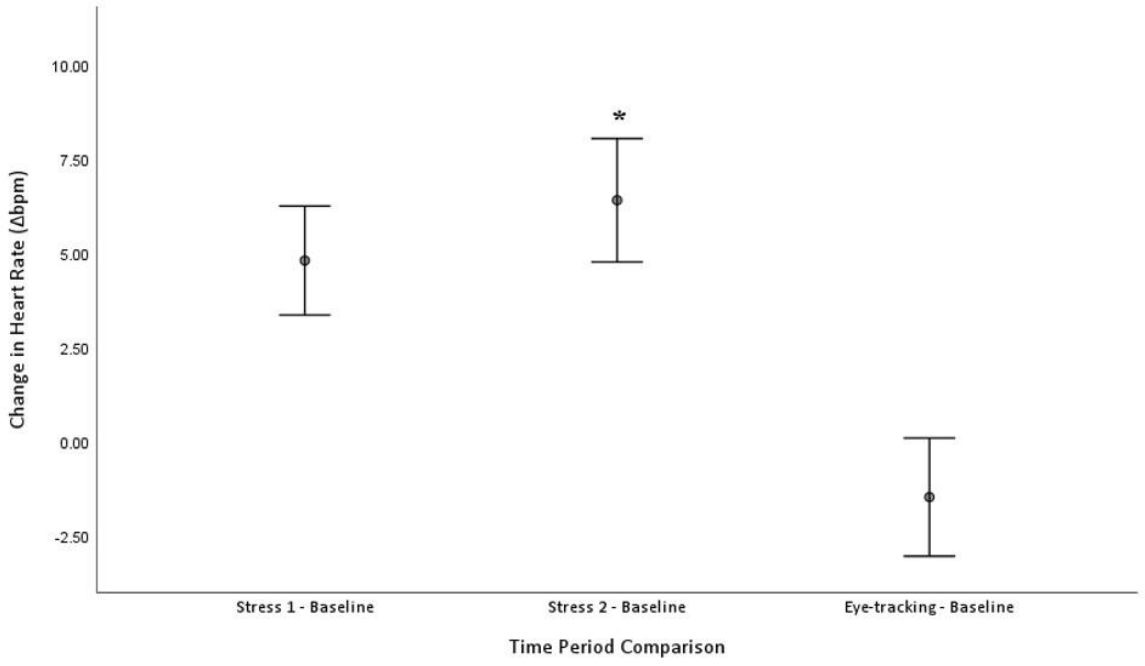

Figure 3. Change in heart rate from baseline to timepoints throughout the lab visit. Values are displayed as the difference of means between three 5-minute time frames and the 5-minute baseline period. Stress 1 refers to the first 5 minutes of the anticipatory speech task; Stress 2 refers to the final 5 minutes of the task. Baseline is represented by the value of 0.00 on the y-axis. Bars indicate 95% confidence intervals and * indicates a significant difference from baseline at $\alpha = .05$.

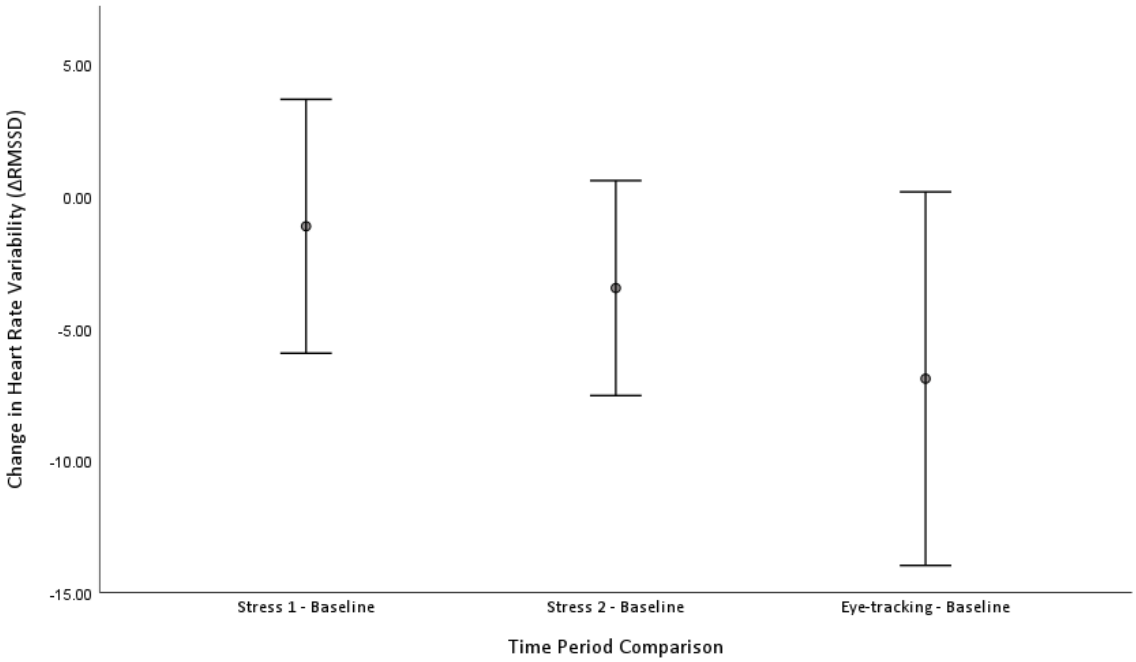

Figure 4. Change in heart rate variability from baseline to timepoints throughout the lab visit. Values are displayed as the difference of means between three 5-minute time frames and the 5-minute baseline period. Stress 1 refers to the first 5 minutes of the anticipatory speech task; Stress 2 refers to the final 5 minutes of the task. Baseline is represented by the value of 0.00 on the y-axis. Bars indicate 95% confidence intervals and * indicates a significant difference from baseline at $\alpha = .05$.

scores, and lower GAD-7 scores. Age was correlated with daily stress and GAD-7 scores, such that older participants had lower DSI frequency and DSI sum scores, as well as lower GAD-7 scores. All the GMQ-F sub-scores (enhancement, social, coping, and financial) were positively correlated, with the exception of the correlation between social, financial, and coping scores. The GMQ-F coping scores were correlated with the DSI measures such that participants who had higher DSI frequency scores and higher DSI sum scores (reflecting a greater number of daily stressors or a greater total impact score) were more likely to report coping as a motivation for gambling.

Analysis of Gambling-Related Craving

To assess Hypothesis 2, that at-risk gamblers would report a significant increase in gambling craving from baseline as a result of the stress induction, differences between baseline and post- stress induction in gambling craving, as indicated by the three GACS scores (desire, anticipation, and relief), were assessed via paired *t*-tests (for the 21 at-risk gamblers only). Contrary to what was hypothesized, the AST did not cause a significant change in the desire scores ($M = -0.12$, $SD = 0.42$), $t(19) = 1.23$, $p = .232$, $d = .28$, anticipation scores ($M = -0.28$, $SD = 1.07$), $t(19) = 1.18$, $p = .252$, $d = .26$, or relief scores ($M = 0.00$, $SD = 0.39$), $t(19) = 0.00$, $p = 1.00$, $d = .00$.

Analysis of Attentional Biases

The correlation between participants' AB for gambling-related images and their PGSI score was used to test Hypothesis 3 (participants with greater problem gambling would have larger ABs). (Two participants were missing eye-tracking data due to gaze calibration failures and were therefore excluded from these analyses.) As shown in Tables 2 and 3, PGSI scores were not significantly correlated with ABs for gambling-related images ($r = .027$). In addition,

the ABs of at-risk gamblers (M = −583.82, SD = 618.80) and no risk/non-gamblers (M = −320.12, SD = 424.51) were not significantly different, $t(28.02) = 1.72$, $p = .097$, $d = .53$ (correcting for unequal variances). Interestingly, for both groups the mean AB was negative, which indicated that gambling-related images were attended to less than neutral images (the opposite result reported by McGrath et al., 2021, who used the identical images, although a longer presentation time of 8 s). A depiction of the mean AB for each group, for each image pair, is shown in Figure 5. As can be seen in Figure 5, for most of the trials, both groups attended to the neutral image more than the gambling-related image, resulting in a negative AB. This outcome indicates that both at-risk gamblers and no-risk/non-gamblers preferentially attended to the neutral images rather than the gambling-related images during most of the image presentations.

The statistical significance of the overall AB (combining at-risk and no-risk/non-gamblers) was evaluated using a paired *t*-test that compared fixation times for neutral images to fixation times for gambling-related images, thereby testing whether the mean overall AB was different than zero. The mean difference (M = −406.58, SD = 506.93) was statistically less than zero, $t(60) = 6.26$, $p < .001$, $d = .80$, which confirmed that gambling-related images were fixated significantly less than neutral images. The AB of the at-risk group (M = −583.82, SD = 618.80) was significantly different than zero, $t(19) = 4.22$, $p < .001$, $d = .94$, as was the AB of the no-risk group (M = −320.12, SD = 424. 41), $t(40) = 4.83$, $p < .001$, $d = .75$. As noted above, the groups did not differ in their mean ABs. Taken together, these results indicate that for both at-risk and no-risk/non-gamblers, neutral images were attended to more than gambling-related images, and that the magnitude of this bias did not differ significantly between the groups.

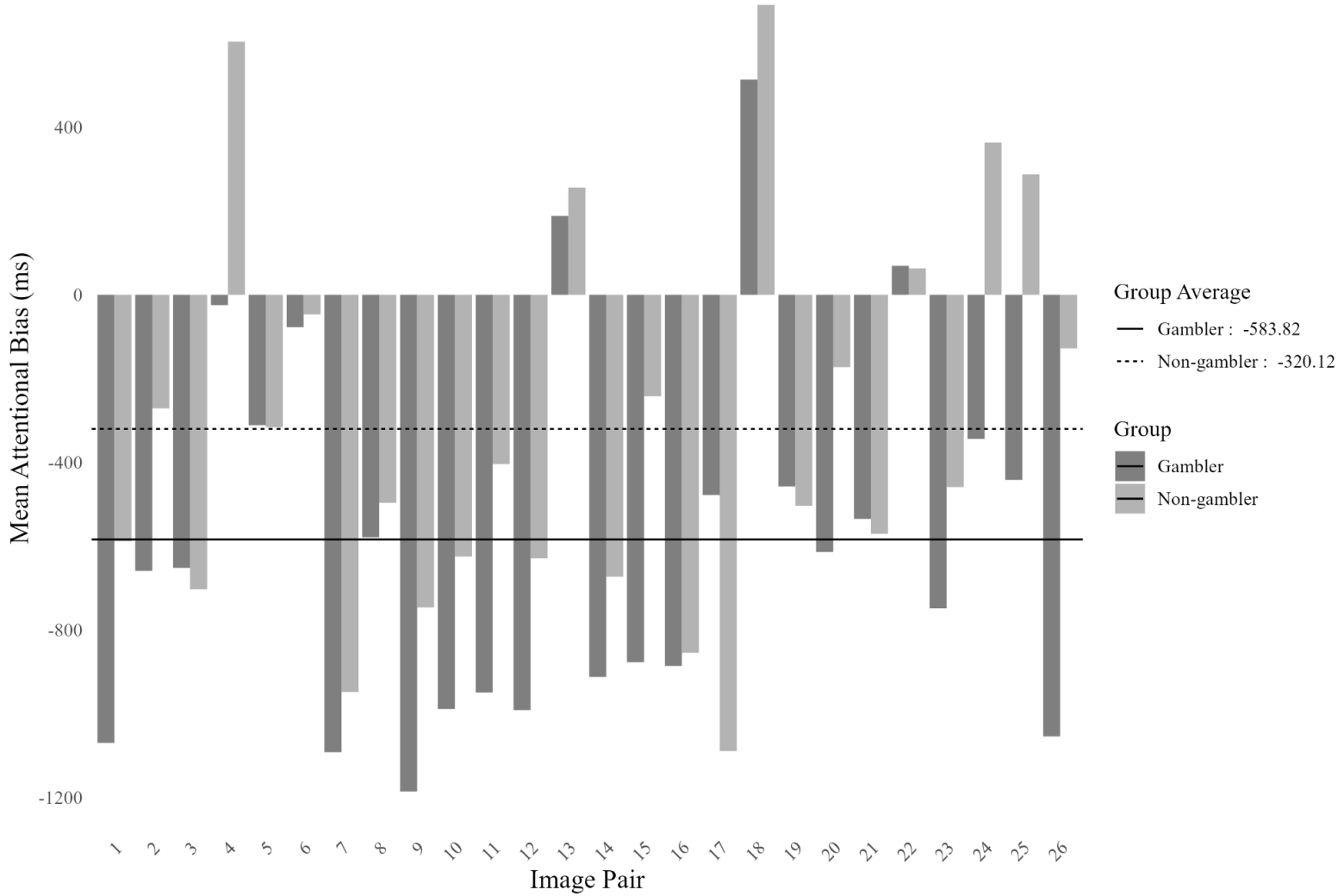

Figure 5. Mean differences in dwell time between gambling-related images and neutral images, for at-risk gamblers (n = 20) and no-risk/non-gamblers (n = 41), for each image pair.

Testing for Moderation of Attentional Bias by Acute Stress

Hierarchical multiple regression analyses were used to test Hypothesis 4, that the association between PGSI scores and ABs would be modulated by the relative amount of stress caused by the AST, such that individuals with the highest PGSI scores and who experienced the greatest increases in post-AST stress would have the largest AB. For these analyses, PGSI scores and one of the four stress response measures (i.e., the difference in skin conductance, heart rate, and HRV, between the Stress 2 and Baseline periods, and subjective reports between post-stress induction and baseline) were entered in Model 1. An interaction term was entered in Model 2. The test of the interaction in Model 2 determined whether the interaction between the two predictors in Model 1 accounted for additional variance in AB above and beyond the two predictors. No other predictors were included in the analyses because the correlational analyses did not reveal any significant associations with AB (age, sex, gambling motivations, trait anxiety, daily stress). As can be seen in Tables 4-7, only the interaction between PGSI scores and VAS-stress ratings was statistically significant, although the interactions with heart rate and HRV approached significance (p = .078, and p = .059, respectively). For the PGSI x VAS-stress interaction, the addition of the interaction term (Model 2; Table 4) led to a 12.5% increase in the percentage of variance accounted for, $F(1, 51) = 7.31$, p = .009. Figure 6 shows the nature of the interaction (moderation) effect, which was followed up using simple slopes analyses.

For participants who had an increase of three points on the VAS-stress ratings (corresponding to the 88th percentile of VAS-stress ratings), PGSI scores were significantly positively associated with ABs, such that individuals with higher PGSI scores had larger ABs for gambling-related images, $t(51) = 2.26$, p = .028. For participants who had an increase of one point on the VAS-stress (the 50th percentile), PGSI scores were not significantly associated with ABs, $t(51) = 0.50$,

Table 4.

Results of hierarchical multiple regression moderation analysis predicting gambling (attentional) biases with PGSI scores and AST elicited changes in subjective stress assessed with visual analog scales (VAS-Stress; N = 55).

	b	*SE*	*β*	*t*	R^2	ΔR^2	*F*	*p*
Model 1					.007	.007	0.187	.830
Intercept	−414.387	83.662		−4.953				< .001
Change in VAS-stress	−22.607	37.052	−.084	−.610				.544
PGSI	−.566	39.620	−.002	−.014				.989
Model 2					.132	.125	7.313	.009
Intercept	−361.615	81.378		−4.444				< .001
Change in VAS-stress	−64.845	38.317	−.242	−1.692				.097
PGSI	−106.089	54.059	−.371	−1.962				.055
Change in VAS-stress x PGSI	87.009	32.175	.540	2.704				.009

Note. AST = Anticipatory Speech task; PGSI = Problem Gambling Severity Index

Table 5.

Results of hierarchical multiple regression moderation analysis predicting gambling (attentional) biases with PGSI scores and AST elicited changes in skin conductance (N = 54).

	b	*SE*	*β*	*t*	R^2	ΔR^2	*F*	*p*
Model 1					.007	.007	0.186	.942
Intercept	−366.990	98.910		−3.710				< .001
Change in Skin Conductance (Δ μS)	−30.309	54.403	−.077	−.557				.580
PGSI	−11.344	38.901	−.040	−.292				.772
Model 2					.007	.000	0.002	.969
Intercept	−367.715	101.539		−3.621				< .001
Change in Skin Conductance (Δ μS)	−29.409	59.446	−.075	−.495				.623
PGSI	−9.783	55.666	−.035	−.176				.861
Change in Skin Conductance x PGSI	−2.166	54.735	−.008	−.040				.969

Note. AST = Anticipatory Speech task; PGSI = Problem Gambling Severity Index

Table 6.

Results of hierarchical multiple regression moderation analysis predicting gambling (attentional) biases with PGSI scores and AST elicited changes in heart rate (N = 51).

	b	*SE*	*β*	*t*	R^2	ΔR^2	*F*	*p*
Model 1					.002	.002	0.060	.942
Intercept	−378.291	111.668		−3.388				.001
Change in Heart Rate (Δ bpm)	4.043	11.993	.049	.337				.737
PGSI	4.971	37.442	.019	.133				.895
Model 2					.067	.065	3.252	.078
Intercept	−398.650	109.720		−3.633				< .001
Change in Heart Rate (Δ bpm)	11.678	12.462	.143	.937				.354
PGSI	60.421	47.797	.236	1.264				.212
Change in Heart Rate x PGSI	−21.027	11.660	−.336	−1.803				.078

Note. AST = Anticipatory Speech task; PGSI = Problem Gambling Severity Index

Table 7.

Results of hierarchical multiple regression moderation analysis predicting gambling (attentional) biases with PGSI scores and AST elicited changes in heart rate variability (HRV; N = 51).

	b	*SE*	*β*	*t*	R^2	ΔR^2	*F*	*p*
Model 1					.006	.006	0.153	.859
Intercept	−356.983	75.919		−4.702				< .001
Change in HRV	−2.626	4.790	−.080	−.548				.586
PGSI	−.254	37.172	−.001	−.007				.995
Model 2					.079	.073	3.730	.059
Intercept	−315.968	76.841		−4.112				< .001
Change in HRV	.528	4.937	.016	.107				.915
PGSI	−123.980	73.559	−.485	−1.685				.099
Change in HRV x PGSI	−11.168	5.782	−.575	−1.931				.059

Note. AST = Anticipatory Speech task; PGSI = Problem Gambling Severity Index

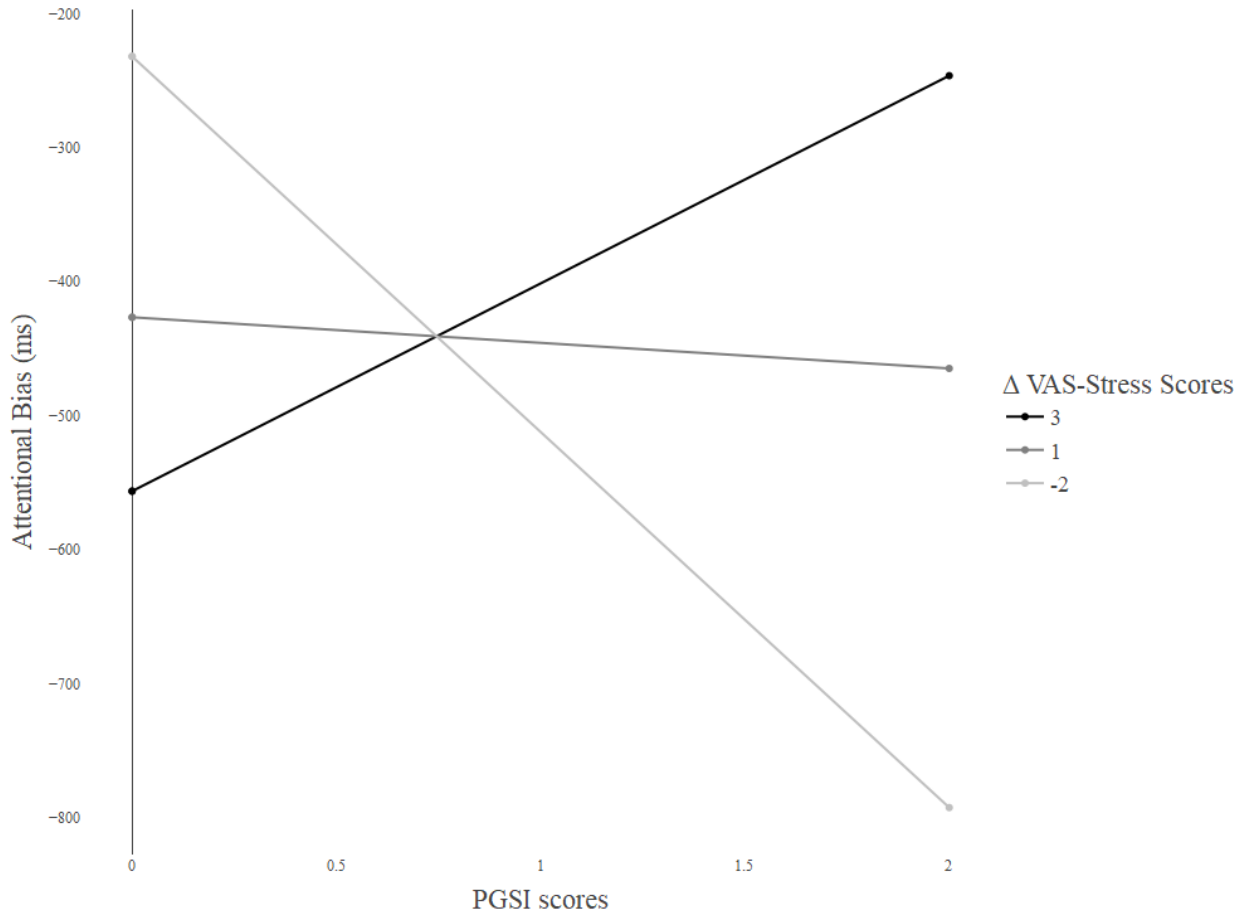

Figure 6. The moderating effect of post-AST change in subjective stress (Δ visual analog scale stress ratings; VAS-stress) on the relationship between PGSI scores and ABs. The relationship between Problem Gambling Severity Index (PGSI) scores and attentional bias (AB) are shown at the 12th, 50th, and 88th percentiles of change in VAS-stress ratings. A positive Δ VAS-stress ratings indicates an increase in subjective stress (on a 10-point scale) post-AST and a negative value indicates a decrease in subjective stress.

p = .618. For participants who had a two-point decrease in their VAS-stress ratings (the 12th percentile), there was a significant negative association between PGSI scores and ABs, $t(51)$ = 2.55, p = .014. This relationship was such that lower PGSI scores were associated with larger ABs and higher PGSI scores were associated with smaller ABs (Figure 6). Note that for these participants, the stress induction was least successful relative to the other participants in the sample.

Analysis using the Johnson-Neyman method (Finsaas & Goldstein, 2021; P.O. Johnson & Fay, 1950) indicated that PGSI scores significantly predicted ABs when VAS-stress ratings increased by 2.52 units or more and when they decreased by 0.06 units or more (Figure 7). For changes in VAS-stress ratings of 2.52 and greater (87th percentile), higher PGSI scores were significantly associated with larger ABs. and lower PGSI scores were significantly associated with smaller ABs. For changes in VAS-stress ratings of −0.06 (21st percentile) and lower, higher PGSI scores were significantly associated with smaller ABs and lower PGSI scores were significantly associated with larger ABs. For changes in VAS-stress ratings between −0.06 and 2.52, PGSI scores were not significantly associated with ABs.

As hypothesized (Hypothesis 4), for participants who had the largest increases in subjective stress between the first and second administration of the VAS-stress, there was a positive association between PGSI scores and ABs, such that those with higher PGSI scores had larger ABs. This relationship was such that for participants with a PGSI score of two (for example), a one-point increase in VAS-stress was associated with a 109 ms larger AB for gambling-related images, on average. For participants with PGSI scores of zero (the no-risk group), a one-point increase in VAS-stress was associated with a 65 ms smaller AB for gambling-related images, on average. That is, the association between PGSI scores and ABs

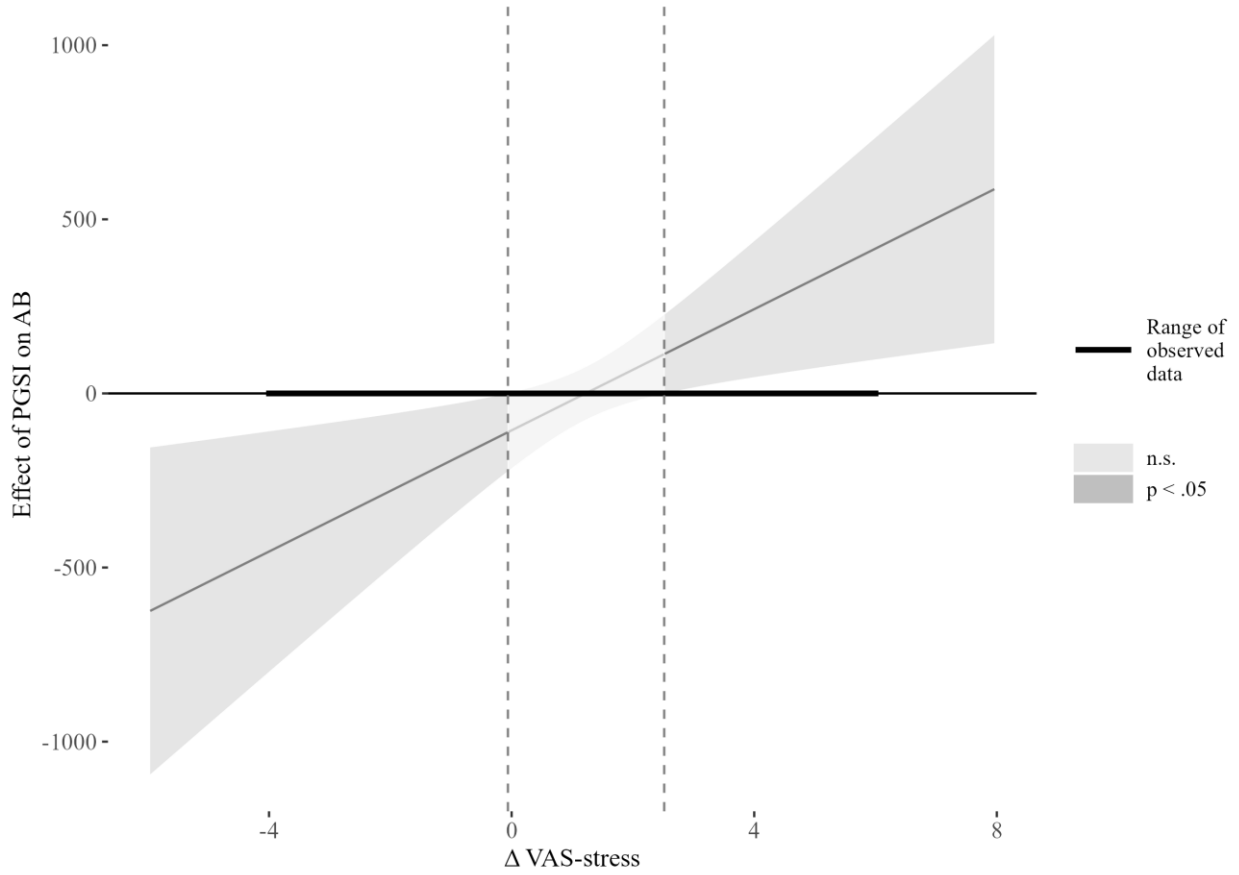

Figure 7. A Johnson-Neyman plot representing regions of significant association between PGSI scores and ABs at values of the moderator (change in VAS-stress ratings; Δ VAS-stress). The values of Δ VAS-stress that correspond to a of change in significance illustrated here are −0.06 and 2.52. A positive Δ VAS-stress rating indicates an increase in subjective stress (on a 10-point scale) post-AST and a negative value indicates a decrease in subjective stress.

depended on the change in subjective stress reported. Unexpectedly, the participants least affected by the stress induction showed the largest changes in ABs, with those with higher PGSI scores having smaller ABs. See the appendix for additional exploratory hierarchical regressions that include demographics, daily stress, and gambling motives (Tables A1-A4), as well as for plots of the marginally significant interactions involving heart rate and HRV (Figures A1 and A2).

Discussion

This study investigated the influence that acute stress has on gambling-related ABs, with the anticipatory speech task used to create an acute stress response. Subjective stress self-reports were collected pre- and post-stress induction and heart rate and skin conductance were collected throughout the AST procedure. The degree to which the stressful experience affected participants' ABs in relation to their PGSI scores was the focus of this research.

It was hypothesized that both subjective and objective stress measures would indicate a statistically significant increase in stress compared to baseline values. Subjective stress, heart rate, and skin conductance were predicted to increase, and HRV was predicted to decrease, all of which reflect a stress response (H.-G. Kim et al., 2018; Lesage et al., 2012; Lupien et al., 2015; Mackersie et al., 2015). As hypothesized, subjective stress, heart rate, and skin conductance significantly increased post-AST, whereas for HRV the pre- versus post-AST changes were not significant.

This outcome leads to the question of why HRV did not change significantly in response to the AST while the other measures did. Heart rate and HRV are thought to reflect separate physiological mechanisms of the stress response. The sympathetic nervous system is responsible for increasing heart rate, and the parasympathetic nervous system for slowing heart rate (H.-G.

Kim et al., 2018). During a stressful situation, both systems undergo changes that result in increases in heart rate. The parasympathetic branch is actively slowing heart rate under normal conditions and its influence is reduced when stressed, which increases heart rate (Gordan et al., 2015; H.-G. Kim et al., 2018). In fact, resting heart rate in humans is known to be approximately 100 beats per minute without parasympathetic influence (Gordan et al., 2015; Katona et al., 1982). The complex interplay of the sympathetic and parasympathetic nervous systems greatly influences heart rate, but also how heart rate changes. Heart rate variability is a measure of the duration between individual heartbeats (inter-beat intervals; IBIs) and is much more sensitive to the near-instantaneous effects (which can be measured in milliseconds) of the parasympathetic nervous system (Berntson et al., 1993; Chung et al., 2019; H.-G. Kim et al., 2018; Quintana & Heathers, 2014; Russo et al., 2017). This is largely because breathing has a significant beat-by-beat effect on the parasympathetic influence on the heart. The sympathetic nervous system's effect on heart rate, by contrast, takes seconds (Berntson et al., 1993; Russo et al., 2017). For this reason, HRV is thought to better represent parasympathetic nervous system activity than heart rate.

With these facts in mind, there are two possible explanations for why HRV did not significantly change in response to the AST. First, because HRV is a better indicator of parasympathetic activity, which changes rapidly and with the individual's respiration rate, it is possible that some participants responded to the AST by holding their breath, breathing more deeply to calm themselves, etc., which may have created larger variability in this measure and reduced the power to detect smaller changes. If so, one solution would have been to control for the rate and depth of respiration, using a pneumotachometer or strain gauge to identify significant deviations of typical respiratory oscillations (Chu et al., 2019; Quintana & Heathers,

2014), or to employ a respiration rate estimation algorithm for PPG signals (Iqbal et al., 2022), neither of which was not possible in the present study. Second, it has been well documented that there are a wide range of individual differences in the response to psychological stressors, such that some individuals experience sympathetic activation, some experience parasympathetic withdrawal, and some a reciprocal combination of the two (H.-G. Kim et al., 2018). Given the relatively small sample size in this study, and that post-AST HRV changes were marginally significant (p = .057), it is very possible that a larger sample size would have resulted in sufficient statistical power to detect post-AST changes in HRV despite these individual differences.

The second hypothesis of this study was that for at-risk gamblers, gambling craving, as assessed by the three GACS domains (Young & Wohl, 2009), would be greater after the AST than at baseline. Contrary to this hypothesis, neither the desire, relief, or anticipation subscales of the GACS were significantly different post-AST. Note that only a few studies have investigated the effects of acute stress on gambling craving, and the conclusions are contradictory. In some studies, gambling craving is thought to increase when stressed, but many of the conclusions are related to risky decision-making and increased gambling involvement, with the assumption that craving must increase before subsequent gambling behaviours (see Biback & Zack, 2015, for a review). A recent review of brain areas associated with stress-induced craving in GD suggests that stress can trigger gambling cravings and therefore promote gambling-related cognitions and subsequent gambling behaviours (Spagnolo et al., 2019), but also indicated that negative emotional states may be a better predictor of gambling craving than stress per se.

Negative emotions can be brought about by acute stress, but one cannot expect this will invariably be the case. That is, theoretically, acute stress may create a negative emotional state,

which promotes gambling-related craving and subsequently engagement with gambling activities as a mechanism of escape, but negative emotional states may not occur as a result of the stressor (depending on the nature of the stressor), in which case the feeling of a need to escape may not be elicited. In line with this reasoning, other research that has found the predictive association between psychosocial stress (as measured with the DSI) and craving may be explained by negative emotional states (Elman et al., 2010). Indeed, the DSI assesses stressors that produce not just stress, but negative emotions as well. It is possible that stress-induced cravings are not immediately activated following an acute stressor but instead arise after an accumulation of multiple stressors (daily stress), or only from specific types of stressors (those that create negative emotional states). It is also possible that the craving induced by a stressor is context-dependent, and cravings for gambling may only be elicited in a context where gambling is an activity that may relieve stress or serve as a distraction. It was not possible to test either of these possibilities with the current research design, but they should be investigated in the future. It is also worth noting that the range of PGSI scores observed in this study was limited and skewed toward the lower scores on the inventory. Future research should investigate stress-induced gambling craving in a sample of gamblers with higher PGSI scores, to rule out the possibility that those with low scores simply did not experience detectable levels of stress-induced craving.

For the third hypothesis, it was predicted that there would be a positive association between PGSI scores and ABs, such that individuals with higher PGSI scores would have larger ABs for gambling-related images (larger positive AB values). Contrary to this hypothesis, the overall AB was negative, not positive, which indicated that on average participants attended to the neutral images more than the gambling-related images. This was true for both groups. As discussed above, there is an abundance of research that has identified a robust positive

relationship between addiction-related ABs and addiction severity (e.g., Anderson, 2016b; Christiansen et al., 2015; Cox et al., 2014; Field et al., 2014, 2016; Field & Cox, 2008; Marhe et al., 2014), and specifically between PGSI scores and gambling-related ABs (Coelho et al., 2023; H. S. Kim et al., 2022; McGrath et al., 2018, 2021). The negative ABs observed in this study, which can be considered an avoidance bias (as attention was directed away from gambling-related images and toward neutral images) were relatively consistent across each image pair (Figure 5). The nature of this bias is opposite to what McGrath et al. (2021) observed in their study, which used the same images (albeit with a longer presentation time than was used here; 8 s vs. 4 s). Because the images are related to a range of gambling activities (casino table games, bingo, electronic gambling machines, slot machines, etc.), it is unlikely that this outcome was due to a mismatch between an individual's preferred gambling activity and the type of gambling depicted in the images. Moreover, even if there were such a mismatch, the expectation would be that the overall AB for gamblers would be close to a null effect. Because the negative AB was observed for at-risk gamblers and no-risk/non-gamblers, it is possible that the avoidance bias observed is related to overarching cultural or geographically associated influences, which affected all participants in this study similarly (recall that all participants were students at the University of Calgary).

Why would gamblers exhibit an avoidance bias for gambling-related images? In August of 2021, gambling legislation in Canada was relaxed to permit single-game sports betting, which initiated a plethora of new operators to begin hosting gambling services and advertisements (Naraine & Bradish, 2022). It is possible that this legislation change acted to homogenize the types of gambling that participants were familiar with and reduced the effectiveness of the study images to capture AB. This may explain some of the difference between the present study and

McGrath et al. (2021) because, although both studies used the same images, only the present study assessed AB after the changes to gambling legislation. It is possible that these images no longer reflect the current gambling context and therefore do not draw gamblers' attention as effectively as they did in the past. Of course, while this may explain why there were no ABs for the gambling-related images in this study, it does not explain the avoidance bias observed (i.e., preferential attention to neutral images over gambling-related images).

One possibility is that the liberalization of gambling regulations and the influx of gambling advertisements and harm-reduction messages has resulted in increased awareness of gambling-related harms, which may create a stigma about gambling that manifests as an avoidance bias in the laboratory. Stigmatization of gamblers includes stereotypes of irrationality and greed and is often associated with feelings of shame (Dhillon et al., 2011). For this reason, stigma is often associated with reduced treatment-seeking and concealment of gambling involvement (Leslie & McGrath, 2023; Quigley, 2022). Delfabbro et al. (2021) investigated contributors to gambling stigma in multiple countries and found evidence that liberalization of gambling regulations can result in increased stigma during an initial market growth phase, which sparks public concern for harms associated with gambling. This type of cultural shift may explain why avoidance bias was seen even in no-risk/non-gamblers, which, while surprising, has also been observed in other recent studies (Coelho et al., 2023). In addition, abstinent gamblers, who are well-known to be aware of the harms associated with gambling, also show an avoidance bias for gambling-related images (Ciccarelli et al., 2016a), which is consistent with this idea.

The final hypothesis, which predicted that stress would moderate the relationship between PGSI scores and ABs for gambling-related images, such that greater stress increases would increase the magnitude of the positive association between PGSI scores and ABs. As

hypothesized, stress, as measured by the VAS-stress ratings, significantly moderated the relationship between PGSI scores and ABs, but not as expected. Specifically, higher stress resulted in a decrease in avoidance biases. The moderation was such that for participants who had increases in VAS-stress ratings of more than 2.52 points there was a significant positive association between PGSI scores and ABs, such that individuals with higher PGSI scores had larger ABs for gambling-related images. Of course, given that the overall bias was to attend to neutral images more than gambling-related images, a larger AB for gambling-images was in effect a smaller avoidance bias for these images. Thus, for participants with an increase in VAS-stress ratings greater than 2.52, there was a significantly *negative* association between PGSI scores and *avoidance* biases (those with higher PGSI scores and smaller avoidance biases). With no changes in stress, and with decreases of a magnitude greater than 0.06, there was a significant positive association between PGSI scores and avoidance biases, such that individuals with higher PGSI scores had larger avoidance biases for gambling-related images. Together these findings indicate that for participants experiencing average or high levels of AST-induced stress, their avoidance biases, which were particularly pronounced in at-risk gamblers, were reduced or weakened. This outcome could be due to a diversion in mental attention caused by stress. Indeed, the phenomena of revealing implicit biases (in this case, gambling-related biases that may be deliberately hidden to avoid feeling stigmatized) while stressed, or under cognitive load, is well documented in the racial bias literature (Ito et al., 2015; T. J. Johnson et al., 2016).

If gambling-related stigma was influential in this study, then participants may have deliberately directed their attention away from the gambling-related images (particularly those with higher PGSI scores, who may feel to be the target of such stigma), thereby creating the negative AB (avoidance bias) observed. In the present study, the avoidance biases observed

appear to have been impacted by the stress experienced from the AST. Because the avoidance bias was significant (a significant negative association between PGSI scores and ABs) for individuals who had more than a 0.06 reduction in stress on the VAS-stress, which can be practically considered as no change in stress, it can be argued that the observed biases represented these participants' natural way of viewing gambling stimuli. As noted, this avoidance bias may reflect the current cultural context surrounding gambling, which offers an explanation as to why at-risk gamblers who experienced higher increases in stress did not attend to gambling-related images more than neutral images. That is, if stress influences ABs in gamblers, but the gamblers in this study had stigma-induced avoidance biases, then it makes sense that their AB would be more positively associated with PGSI scores when stressed (a reduction in the avoidance biases), but that the overall bias may still be negative (more attention was paid to the neutral images than the gambling images).

With respect to the physiological measures of acute stress, there was some evidence that HRV also moderated the association between problem gambling severity and ABs such that the relationship between PGSI scores and ABs depended on the change in HRV created by the stress induction. On the other hand, skin conductance and heart rate did not significantly moderate the relationship between PGSI scores and ABs, contrary to hypotheses. Skin conductance is a reliable indicator of sympathetic nervous system activation, and heart rate, while influenced by the parasympathetic nervous system as discussed above, also reflects sympathetic activation (McEwen, 2008). The results, therefore, appear to indicate that at the levels of induced stress observed, fluctuations in parasympathetic influence may be a more important moderator of the relationship between gambling severity and ABs than sympathetic arousal. Although these moderation effects were not statistically significant, only the analysis with HRV was consistent

with the predicted moderation. That is, for participants who experienced greater decreases in HRV post-AST (reflecting a larger stress response), PGSI scores were positively associated with ABs. For participants with higher PGSI scores, the general pattern in the data mirrored the VAS-stress x PGSI interaction, where increases in HRV (indicating lower levels of stress than at baseline) were associated with larger avoidance biases, and decreases in HRV (indicating an increase in stress) were associated with smaller avoidance biases.

Limitations and Future Directions

While this study provides novel insights into the effects of acute stress on gambling-related attentional biases, there were several limitations. Concerning the study participants, the small sample size likely weakened the ability to detect more nuanced effects, especially those concerning minor variations in heart rate and HRV post-AST. A larger sample size would provide a better understanding of the impact of physiological stress on gambling-related attentional biases. In addition, because the participants were all students attending the University of Calgary, the results may not generalize to the wider population's varied reactions to gambling-related stimuli when stressed. Future research should recruit participants with more diverse backgrounds to ensure more generalizable findings. Future research should also focus on recruiting participants with more severe gambling involvement (as reflected by higher PGSI scores) to examine the effects of stress in those that are more susceptible to gambling biases. The range of PGSI scores was somewhat limited in the present sample, and skewed toward the lower end of possible scores, so it will be important to avoid this limitation in future studies.

The stress response observed from the AST was relatively small in magnitude and the measures observed limit any explanation as to why that was the case. One possibility is that some participants' baseline level of stress was elevated beyond what would be observed in

normal day-to-day activity and were therefore less affected by the introduction of a stressor than participants who were at a "normal" level of stress during the baseline period. Although this study partially accounted for this by using only the difference from baseline as a measure of stress, this adjustment could have been improved by instead calculating the relative change from baseline as the stress response. This study was also limited in its ability to detect the nuances of the individual participant responses (emotional responses for example), which may have had important implications in the interpretation of the AST response. As discussed above, the relationship between acute stress and gambling cravings may not be detectable unless negative emotional states are accounted for in the study design. Future research should investigate a more diverse set of measures of the AST response to get a more detailed understanding of the how this task is interpreted by participants (i.e., are they anxious, angry, etc.). Future research should also explore the possibility that the influence of a stressful situation on craving may be mediated by, or depend on, emotional states.

This study was also limited in its ability to test for other explanations for the attentional biases observed. As discussed, the avoidance bias may be related to recent cultural shifts and the subsequent stigmatization of gambling-related content, but this could not be assessed directly. Future studies should include measures of stigma to control for this effect so that the effects of stress on gambling-related AB may be more clearly identified.

One interesting possibility that should be investigated in future studies is that the AST procedure itself is responsible for the avoidance biases observed in this study. Recall that it was argued that for individuals who did not experience a change in stress post-AST, their avoidance biases may have reflected their viewing behavior in their natural non-stressed state. However, it is possible that the AST procedure, regardless of whether it induces stress, creates increases in

perceptions and feelings of being judged or stigmatized, which creates the avoidance biases observed. A control condition, which examined participants' viewing behavior to the same images in the absence of the AST procedure, would allow one to test for this possibility. Future research using the AST to understand the effects of induced acute stress on gambling-related ABs should use such a design.

Conclusion

This study investigated the degree to which stressful experiences affected participants' ABs in relation to their problematic gambling involvement. Also assessed was the effect of laboratory-induced acute stress on participant cravings for gambling engagement, as craving states are thought to precede risky gambling behaviours. The AST was used to induce stress over a ten-minute period through which heart rate and skin conductance were monitored and pre- and post-subjective stress rating scales were administered. After the AST, participants took part in an eye-tracking procedure to measure their AB. The AST effectively induced a stress response on average, but gambling craving did not increase, and an overall avoidance of gambling-related imagery was observed. This avoidance bias was most pronounced in at-risk gamblers who responded to the AST with no change, or a reduction, in stress. However, for at-risk gamblers who experienced an increase in stress, their avoidance of gambling-related images was reduced (i.e., they attended to gambling-related images more than at-risk gamblers who were not stressed). The findings support the notion that subjective stress can moderate the relationship between gambling involvement and ABs for gambling-related imagery. While the physiological measures of stress did not mirror this moderation effect, there were strong indications that the same trend existed when HRV was the moderator in the analyses. Although an overall avoidance

bias of gambling-related images was observed here, these results suggest that AB is very quickly influenced by a stressful situation.

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Appendix

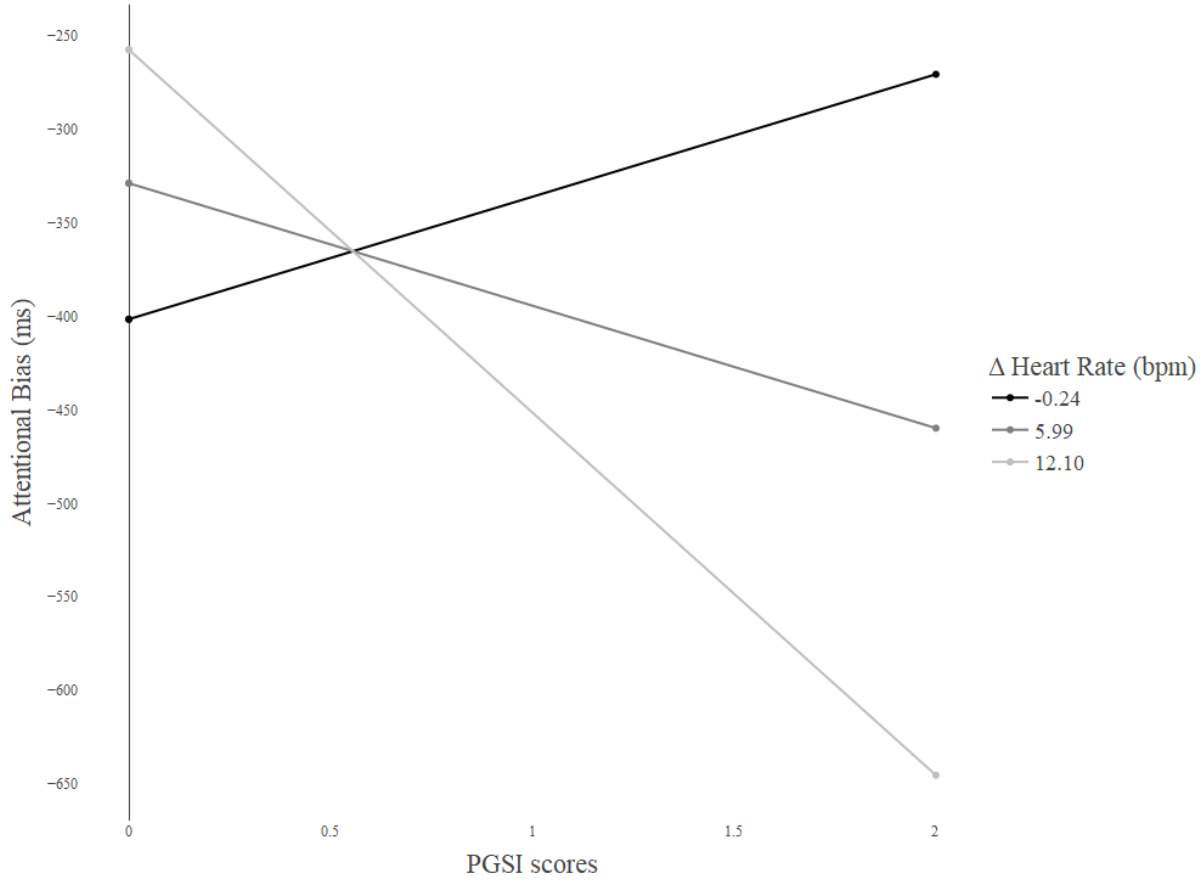

Figure A1. The moderating effect of post-AST change in heart rate on the relationship between PGSI scores and ABs. The relationship between Problem Gambling Severity Index (PGSI) scores and attentional bias (AB) are shown at the 16th, 50th, and 84th percentiles of change in heart rate.

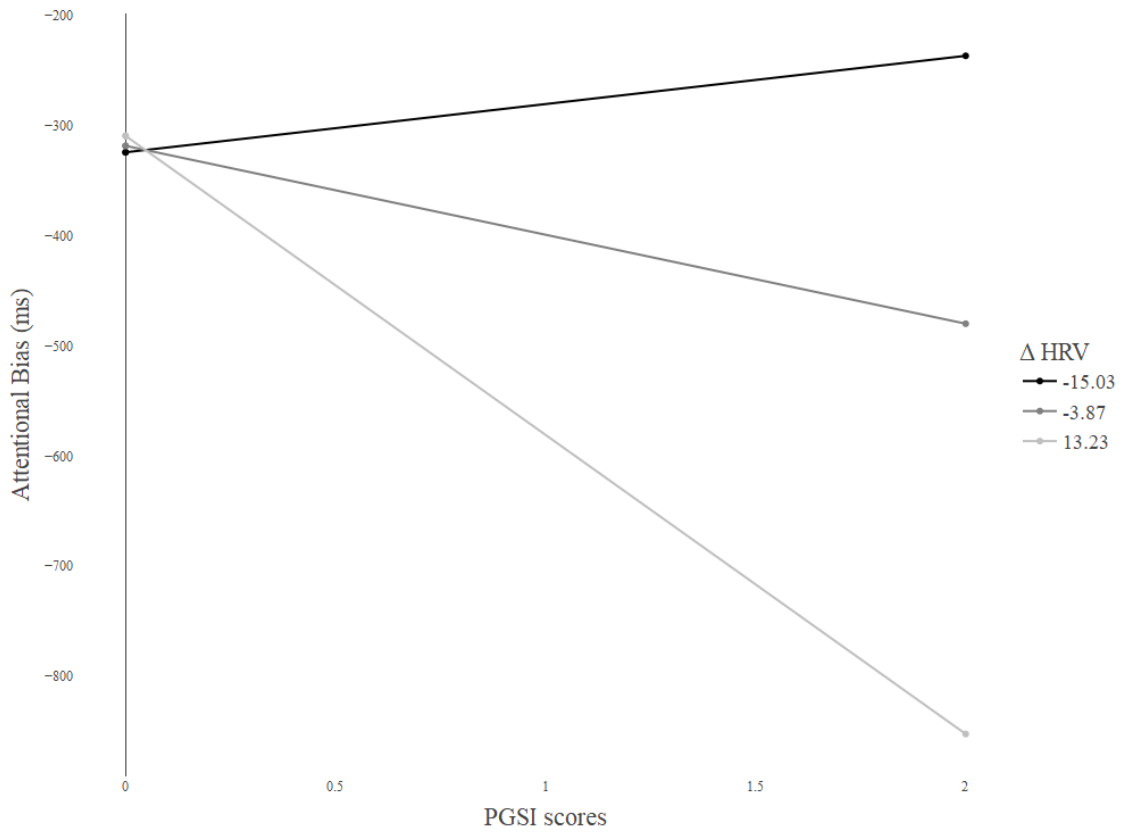

Figure A2. The moderating effect of post-AST change in HRV on the relationship between PGSI scores and ABs. The relationship between Problem Gambling Severity Index (PGSI) scores and attentional bias (AB) are shown at the 16th, 50th, and 84th percentiles of change in heart rate variability (HRV).

Table A1.

Results of a hierarchical multiple regression moderation analysis predicting gambling (attentional) biases with demographic and other control variables, PGSI scores, and AST-elicited changes in subjective stress reports (n = 55).

	b	*SE*	*β*	*t*	R^2	ΔR^2	*F*	*p*
Model 1					.003	.003	0.087	.917
Intercept	-384.827	473.614		-.813				.420
Sex	-62.157	154.405	-.059	-.403				.689
Age	-.429	21.027	-.003	-.020				.984
Model 2					.074	.071	0.585	.741
Intercept	-130.408	643.978		-.203				.840
Sex	-62.997	181.530	-.059	-.347				.730
Age	-1.730	23.382	-.012	-.074				.941
GMQ-F Enhance	-1.684	29.277	-.012	-.058				.954
GMQ-F Social	-4.567	33.906	-.024	-.135				.893
GMQ-F Coping	-15.449	59.799	-.045	-.258				.797
GMQ-F Financial	31.417	26.230	.199	1.198				.237
GAD7	5.136	14.835	.057	.346				.731
DSI Frequency	-14.950	11.622	-.200	-1.286				.205
Model 3					.078	.004	0.099	.906
Intercept	-141.584	657.493		-.215				.830
Sex	-48.855	190.403	-.046	-.257				.799
Age	-.750	23.960	-.005	-.031				.975
GMQ-F Enhance	-1.427	30.077	-.010	-.047				.962
GMQ-F Social	-6.168	34.908	-.033	-.177				.861
GMQ-F Coping	-13.478	61.236	-.040	-.220				.827
GMQ-F Financial	30.911	27.580	.196	1.121				.268
GAD7	5.335	15.360	.059	.347				.730
DSI Frequency	-15.045	12.111	-.201	-1.242				.221
Change in VAS score	-17.738	40.727	-.066	-.436				.665
PGSI	-1.347	46.791	-.005	-.029				.977
Model 4					.196	.118	6.294	.016
Intercept	-611.061	648.757		-.942				.352
Sex	-63.724	179.985	-.060	-.354				.725

Age	15.199	23.513	.105	.646	.521
GMQ-F Enhance	9.591	28.753	.068	.334	.740
GMQ-F Social	-43.996	36.263	-.236	-1.213	.232
GMQ-F Coping	33.718	60.836	.099	.554	.582
GMQ-F Financial	24.087	26.198	.153	.919	.363
GAD7	13.846	14.903	.154	.929	.358
DSI Frequency	-6.087	11.986	-.081	-.508	.614
Change in VAS score	-75.130	44.765	-.281	-1.678	.101
PGSI	-138.562	70.325	-.484	-1.970	.055
Change in VAS score x PGSI	105.859	42.194	.657	2.509	.016

Note. PGSI = Problem Gambling Severity Index. GMQ-F = Gambling Motives Questionnaire-Financial. GAD7 = 7-item Generalized Anxiety Disorder questionnaire. DSI = Daily Stress Inventory (frequency = number of stressful events. Change refers to the difference between Baseline and Stress 2 phases for the physiological measures, and between the second and first administration for the self-report measures. Attentional bias is calculated by subtracting the total dwell time on neutral images from the total dwell time on gambling-related images. SD = standard deviation.

Table A2.

Results of a hierarchical multiple regression moderation analysis predicting gambling (attentional) biases with demographic and other control variables, PGSI scores, and AST-elicited changes in skin conductance (n = 55).

	b	*SE*	*β*	*t*	R^2	ΔR^2	*F*	*p*
Model 1					.001	.001	0.022	.978
Intercept	-322.415	463.714		-.695				.490
Sex	-26.010	150.799	-.025	-.172				.864
Age	-3.491	20.648	-.025	-.169				.866
Model 2					.081	.080	0.667	.676
Intercept	-216.507	648.255		-.334				.740
Sex	-73.718	169.475	-.071	-.435				.666
Age	-1.821	23.100	-.013	-.079				.938
GMQ-F Enhance	-10.134	27.070	-.079	-.374				.710
GMQ-F Social	-3.867	31.338	-.021	-.123				.902
GMQ-F Coping	-12.397	58.472	-.037	-.212				.833
GMQ-F Financial	38.850	27.776	.249	1.399				.169
GAD7	9.563	14.637	.107	.653				.517
DSI Frequency	-11.171	11.155	-.152	-1.002				.322
Model 3					.090	.009	0.223	.801
Intercept	-211.412	660.354		-.320				.750
Sex	-64.208	175.425	-.062	-.366				.716
Age	-.739	23.571	-.005	-.031				.975
GMQ-F Enhance	-9.823	27.546	-.076	-.357				.723
GMQ-F Social	-6.124	32.062	-.033	-.191				.849
GMQ-F Coping	-6.090	60.359	-.018	-.101				.920
GMQ-F Financial	41.405	29.037	.266	1.426				.161
GAD7	9.911	15.171	.111	.653				.517
DSI Frequency	-10.774	11.622	-.147	-.927				.359
Change in Skin Conductance (Δ μS)	-35.151	58.826	-.090	-.598				.553
PGSI	-14.591	44.555	-.052	-.327				.745
Model 4					.096	.006	0.296	.589
Intercept	-142.121	677.791		-.210				.835
Sex	-66.393	176.892	-.064	-.375				.709

Age	-4.529	24.763	-.032	-.183	.856
GMQ-F Enhance	-12.638	28.248	-.098	-.447	.657
GMQ-F Social	-2.888	32.865	-.016	-.088	.930
GMQ-F Coping	-18.268	64.839	-.055	-.282	.779
GMQ-F Financial	45.306	30.138	.291	1.503	.140
GAD7	8.790	15.432	.098	.570	.572
DSI Frequency	-10.580	11.722	-.144	-.903	.372
Change in Skin Conductance (Δ μS)	-17.732	67.402	-.045	-.263	.794
PGSI	11.944	66.325	.043	.180	.858
Skin Conductance x PGSI	-36.457	67.048	-.135	-.544	.589

Note. PGSI = Problem Gambling Severity Index. GMQ-F = Gambling Motives Questionnaire-Financial. GAD7 = 7-item Generalized Anxiety Disorder questionnaire. DSI = Daily Stress Inventory (frequency = number of stressful events. Change refers to the difference between Baseline and Stress 2 phases for the physiological measures, and between the second and first administration for the self-report measures. Attentional bias is calculated by subtracting the total dwell time on neutral images from the total dwell time on gambling-related images. SD = standard deviation.

Table A3.

Results of a hierarchical multiple regression moderation analysis predicting gambling (attentional) biases with demographic and other control variables, PGSI scores, and AST-elicited changes in heart rate (n = 51).

	b	*SE*	*β*	*t*	R^2	ΔR^2	*F*	*p*
Model 1					.026	.026	0.628	.538
Intercept	63.090	441.251		.143				.887
Sex	-147.631	146.670	-.153	-1.007				.319
Age	-15.628	19.322	-.123	-.809				.423
Model 2					.115	.090	0.711	.643
Intercept	384.283	652.153		.589				.559
Sex	-209.199	167.918	-.216	-1.246				.220
Age	-20.080	22.306	-.158	-.900				.373
GMQ-F Enhance	-17.381	26.054	-.147	-.667				.508
GMQ-F Social	-1.867	29.156	-.011	-.064				.949
GMQ-F Coping	-36.222	54.250	-.121	-.668				.508
GMQ-F Financial	32.489	26.730	.228	1.215				.231
GAD7	2.816	13.652	.035	.206				.838
DSI Frequency	-9.582	10.933	-.140	-.876				.386
Model 3					.116	.000	0.008	.992
Intercept	381.506	668.564		.571				.571
Sex	-211.582	173.663	-.219	-1.218				.230
Age	-20.051	22.906	-.157	-.875				.387
GMQ-F Enhance	-16.900	27.085	-.143	-.624				.536
GMQ-F Social	-2.177	29.997	-.013	-.073				.943
GMQ-F Coping	-36.204	55.604	-.121	-.651				.519
GMQ-F Financial	32.482	28.527	.228	1.139				.262
GAD7	2.442	14.311	.030	.171				.865
DSI Frequency	-9.515	11.389	-.139	-.835				.408
Change in heart rate (Δ bpm)	1.135	12.907	.014	.088				.930
PGSI	-3.040	42.325	-.012	-.072				.943
Model 4					.219	.103	5.135	.029
Intercept	11.130	657.121		.017				.987
Sex	-179.361	165.938	-.185	-1.081				.286

Age	-5.310	22.756	-.042	-.233	.817
GMQ-F Enhance	-22.331	25.896	-.189	-.862	.394
GMQ-F Social	24.175	30.834	.144	.784	.438
GMQ-F Coping	-64.699	54.407	-.216	-1.189	.242
GMQ-F Financial	36.631	27.219	.258	1.346	.186
GAD7	-.440	13.684	-.005	-.032	.975
DSI Frequency	-9.305	10.843	-.136	-.858	.396
Change in heart rate (Δ bpm)	12.363	13.249	.151	.933	.356
PGSI	80.574	54.635	.315	1.475	.148
Change in heart rate x PGSI	-31.378	13.846	-.502	-2.266	.029

Note. PGSI = Problem Gambling Severity Index. GMQ-F = Gambling Motives Questionnaire-Financial. GAD7 = 7-item Generalized Anxiety Disorder questionnaire. DSI = Daily Stress Inventory (frequency = number of stressful events. Change refers to the difference between Baseline and Stress 2 phases for the physiological measures, and between the second and first administration for the self-report measures. Attentional bias is calculated by subtracting the total dwell time on neutral images from the total dwell time on gambling-related images. SD = standard deviation.

Table A4.

Results of a hierarchical multiple regression moderation analysis predicting gambling (attentional) biases with demographic and other control variables, PGSI scores, and AST-elicited changes in heart rate variability (n = 51).

	b	*SE*	*β*	*t*	R^2	ΔR^2	*F*	*p*
Model 1					.026	.026	0.628	.538
Intercept	63.090	441.251		.143				.887
Sex	-147.631	146.670	-.153	-1.007				.319
Age	-15.628	19.322	-.123	-.809				.423
Model 2					.115	.090	0.711	.643
Intercept	384.283	652.153		.589				.559
Sex	-209.199	167.918	-.216	-1.246				.220
Age	-20.080	22.306	-.158	-.900				.373
GMQ-F Enhance	-17.381	26.054	-.147	-.667				.508
GMQ-F Social	-1.867	29.156	-.011	-.064				.949
GMQ-F Coping	-36.222	54.250	-.121	-.668				.508
GMQ-F Financial	32.489	26.730	.228	1.215				.231
GAD7	2.816	13.652	.035	.206				.838
DSI Frequency	-9.582	10.933	-.140	-.876				.386
Model 3					.148	.033	0.779	.466
Intercept	469.809	659.337		.713				.480
Sex	-306.094	186.627	-.317	-1.640				.109
Age	-24.395	22.738	-.191	-1.073				.290
GMQ-F Enhance	-19.753	26.285	-.167	-.751				.457
GMQ-F Social	-1.857	29.421	-.011	-.063				.950
GMQ-F Coping	-39.983	54.641	-.133	-.732				.469
GMQ-F Financial	34.992	27.480	.246	1.273				.210
GAD7	6.418	14.182	.079	.453				.653
DSI Frequency	-8.604	11.150	-.126	-.772				.445
Change in heart rate variability (ΔHRV)	-6.766	5.435	-.205	-1.245				.220
PGSI	-14.942	41.962	-.058	-.356				.724
Model 4					.191	.042	2.048	.160
Intercept	318.462	659.397		.483				.632

Sex	-305.832	184.228	-.316	-1.660	.105
Age	-21.329	22.548	-.167	-.946	.350
GMQ-F Enhance	-16.809	26.029	-.142	-.646	.522
GMQ-F Social	.090	29.075	.001	.003	.998
GMQ-F Coping	-31.787	54.241	-.106	-.586	.561
GMQ-F Financial	30.618	27.298	.215	1.122	.269
GAD7	9.634	14.179	.119	.679	.501
DSI Frequency	-4.896	11.308	-.072	-.433	.667
Change in heart rate variability (Δ HRV)	-4.440	5.606	-.135	-.792	.433
PGSI	-118.783	83.547	-.465	-1.422	.163
Change in heart rate variability x PGSI	-9.217	6.440	-.474	-1.431	.160

Note. PGSI = Problem Gambling Severity Index. GMQ-F = Gambling Motives Questionnaire-Financial. GAD7 = 7-item Generalized Anxiety Disorder questionnaire. DSI = Daily Stress Inventory (frequency = number of stressful events. Change refers to the difference between Baseline and Stress 2 phases for the physiological measures, and between the second and first administration for the self-report measures. Heart rate variability is calculated with the RMSSD. Attentional bias is calculated by subtracting the total dwell time on neutral images from the total dwell time on gambling-related images. SD = standard deviation.