

FULL-LENGTH REPORT



No evidence for the role of intentional emotion regulation in gambling-related problems: Insights from self-report, behavioral, and heart rate variability measures

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ABSTRACT

Background: Emotion regulation strategies are central in models of gambling disorder. However, findings regarding the association between gambling-related problems and these strategies are mixed and mostly based on case-control studies with self-report measures. **Methods:** This study examines associations of gambling problems' severity (SOGS) and gambling-related craving with strategic emotion-regulation (the Emotion Regulation Questionnaire [ERQ], an experimental reappraisal task, and task-related vagally-mediated heart rate variability [vmHRV]) in community gamblers. Bayesian correlations between all constructs of interest were computed; Bayesian ANOVAs were used to examine the course of vmHRV over time-on-task, and its sensitivity to predictive constructs; and Bayesian regressions to investigate whether gambling problems' severity predicted the use of ERQ strategies, and to determine if the effect of emotion regulation demands on vmHRV could be predicted from the SOGS score. **Results:** Correlations did not show reliable relationships of SOGS scores and craving with intentional emotion regulation. The dispositional use of reappraisal and suppression (ERQ) did not predict differences in gambling problems' severity or craving. SOGS and craving scores predicted neither performance in the cognitive reappraisal task, nor task-related vmHRV. However, SOGS and craving correlated with urgency, and suppression and positive urgency predicted a stronger impact of time-on-task on vmHRV, independently of severity. **Discussion:** These results show no reliable evidence of differences in emotion regulation strategies or their vmHRV correlates traceable to gambling problems' severity or craving, and thus challenge the widespread role of intentional emotion regulation in gambling-related problems. Implications regarding the prevalence of neurocognitive alterations in non-clinical gamblers are discussed.

KEYWORDS

behavioral addiction, gambling, emotional regulation, cognitive reappraisal, suppression, heart rate variability

INTRODUCTION

In recent years, a considerable body of research has emphasized the centrality of emotion regulation mechanisms in the etiology, development, and maintenance of disordered gambling (Buen & Flack, 2022; Jara-Rizzo, Navas, Catena, & Perales, 2019; Navas, Contreras-Rodríguez, et al., 2017; Rogier & Velotti, 2018), and recent models suggest that impaired emotional regulation may be crucial to understand and treat gambling disorder, in ways that

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are partially distinct to other addictive disorders (Bonnaire et al., 2022; Navas, Contreras-Rodríguez, et al., 2017).

Emotional regulation is a transdiagnostic and multifaceted construct that refers to an individual's capacity to influence their own emotions, either positive or negative (Gross, 1999; Månsson, Molander, Carlbring, Rosendahl, & Berman, 2022; Velotti, Rogier, Beomonte Zobel, & Billieux, 2021). More specifically, it involves any mechanisms, processes or strategies that modulate the valence, intensity or time course of one's emotional experience and expression (Rogier & Velotti, 2018). According to some authors, these mechanisms must meet the condition of being adaptive (Månsson et al., 2022), whereas others suggest that they need not necessarily be (see Bonanno, Papa, Lalande, Westphal, & Coifman, 2004; Rogier, Garofalo, & Velotti, 2019). Similarly, the term emotional dysregulation refers to deficits in their functioning, or to any difficulties in implementing them (Buen & Flack, 2022; Estévez et al., 2021; Jara-Rizzo et al., 2019; Sancho et al., 2019). However, operationalizing both terms remains challenging, and emotion regulation and dysregulation are still considered as umbrella constructs for which a precise conceptualization is still a topic of debate (Marchica, Mills, Derevensky, & Montreuil, 2019; Velotti et al., 2021).

There are several ways in which emotion regulation can participate in gambling problems' etiology, course and complications. On the one hand, prominent models propose craving to be crucial in the transition between recreational and disordered gambling (e.g. Brevers & Noël, 2013; Cornil et al., 2019; Flaudias, Heeren, Brousse, & Maurage, 2019; Koob & Volkow, 2010; May, Kavanagh, & Andrade, 2015; Robinson, Robinson, & Berridge, 2013; Warlow et al., 2020; Zack, George, & Clark, 2020), as gambling behaviors can become instrumental in craving relief, namely, in resolving the tension created either by the abnormal expectancy of reward or the aversive withdrawal-like state disordered gamblers report to experience in situations where gambling opportunities are perceived as available. Whatever its precise content is, craving is conceptualized as an affect-laden state, so that emotion regulation mechanisms are hypothesized to participate in their regulation and, eventually, in modulating its impact on gambling-related problems (e.g. Giuliani & Berkman, 2015). On the other hand, emotion dysregulation can play a role in gambling behavior in a craving-independent manner; for instance, hampering the control of daily life emotions, so that gambling is perceived as a compensatory tool to cope with those emotions, or increasing the risk of comorbid symptoms (e.g. anger bursts, or anxiety) that can complicate the course and aggravate the consequences of gambling disorder (Caudwell, Bacovic, & Flack, 2024; Jara-Rizzo et al., 2019; Rogier & Velotti, 2018; Ruiz de Lara, Navas, & Perales, 2019).

Although there are several approaches to classifying emotion regulation mechanisms or strategies (e.g. adaptive vs. maladaptive, explicit vs. implicit, antecedent-focused vs. response-focused strategies; see Aldao, Nolen-Hoeksema, & Schweizer, 2010; Gross, 1998; Gyurak, Gross, & Etkin, 2011;

John & Gross, 2004; Wood & Williams, 2011), the neuro-cognitive model proposed by Etkin, Büchel, and Gross (2015) stands out as a preponderant one. This model proposes a distinction between incidental and intentional emotion regulation. The former refers to automatic associative processes, such as extinction or Pavlovian-to-instrumental transfer (Berkman & Lieberman, 2009; Picó-Pérez et al., 2019), that enable individuals to gradually and implicitly adjust their emotional responses to changing circumstances (Braunstein, Gross, & Ochsner, 2017). Previous works have shown that a deficit in these mechanisms probably underpins the disproportionate incentive value problem gamblers end up attributing to gambling-related cues, or the more general difficulties they experience in controlling impulses under the effect of intense emotions (Muela, Ventura-Lucena, Navas, & Perales, 2023; Quintero, Navas, & Perales, 2020).

In contrast, intentional mechanisms involve explicit or controlled regulation (Braunstein et al., 2017; Silvers, 2020). Unlike incidental mechanisms, these involve becoming aware of the target emotion and setting the goal of modifying it, its expression, or its impact (Fitzgerald, Kinney, Phan, & Klumpp, 2020; Gyurak et al., 2011). Therefore, they can be considered goal-oriented (albeit covert) behaviors. Malfunctioning or inadequate implementation of these strategies could lead to several complications in individuals with problem gambling. For instance, a lack of ability to use them can make individuals more prone to use overt behaviors (e.g. gambling) to regulate their emotions, or hinder the perception of gambling-related risk and thus reduce adherence to therapeutic instructions (Mennin, 2006). Some gamblers may also use these strategies in an 'inappropriate' but effective way to reinterpret the negative consequences of gambling, such as monetary losses, and thus justify excessive gambling behavior (Jara-Rizzo et al., 2019; Navas, Billieux, Verdejo-García, & Perales, 2019; Ruiz de Lara et al., 2019).

Intentional or explicit regulation can be assessed with different laboratory tasks and psychometric instruments. Among the latter, the Emotional Regulation Questionnaire (ERQ; Gross & John, 2003) and the Cognitive Emotional Regulation Questionnaire (CERQ; Garnefski & Kraaij, 2007) are the most widely used, although other scales are also available (see Gratz & Roemer, 2004). The ERQ measures the dispositional proneness to use two strategies, reappraisal and expressive suppression, while the CERQ specifically assesses cognitive regulation strategies, distinguishing between those that are considered as adaptive and those considered maladaptive (for positions contrary to this distinction, see Bonanno et al., 2004; Rogier et al., 2019).

Both scales include the reappraisal strategy, i.e., reinterpreting or reformulating the meaning of a stimulus or situation (emotional trigger) to reduce or alter its emotional impact (Gross, 1998; Månsson et al., 2022; Marchica et al., 2019; Velotti et al., 2021). This strategy is considered adaptive and antecedent-focused, and several studies suggest that it is useful in curbing negative emotional experiences in individuals with addictive disorders (Goldstein & Volkow, 2011; Månsson et al., 2022; Marchica et al., 2019; Velotti

et al., 2021). On the contrary, expressive suppression (which involves inhibiting the outward expression of emotions without addressing their underlying causes) is generally considered response-focused and often maladaptive or counterproductive (Marchica et al., 2019; Velotti et al., 2021). Different works suggest that attempting to suppress or avoid emotional states can increase arousal which, in turn, may perpetuate unwanted emotions (Campbell-Sills, Barlow, Brown, & Hofmann, 2006; Wenzlaff & Wegner, 2000; Williams, Grisham, Erskine, & Cassedy, 2012).

Research evidence shows mixed results regarding the relationships between the strategies measured by these instruments and gambling-related problems. On the one hand, some reports suggest that the dispositional use of reappraisal could prevent or reduce gambling-related problems (Bonnaire et al., 2022; Pace, Zappulla, Di Maggio, Passanisi, & Craparo, 2015; Rogier et al., 2019, 2022), whereas expressive suppression (and other avoidant coping strategies) could exacerbate them (Bonnaire et al., 2022; Navas, Contreras-Rodríguez, et al., 2017; Rogier et al., 2019, 2022). This finding is supported by two recent systematic reviews (Marchica et al., 2019; Neophytou, Theodorou, Artemi, Theodorou, & Panayiotou, 2023) and a meta-analysis (Velotti et al., 2021). On the other hand, some studies have found little evidence of these associations (Barrault, Bonnaire, & Herrmann, 2017, 2019; Mestre-Bach, Fernández-Aranda, Jiménez-Murcia, & Potenza, 2020; Navas, Contreras-Rodríguez, et al., 2017; Pace et al., 2015; Williams et al., 2012). These contradictory findings could, however, be partially reconciled by considering the role of supplementary factors as, for example, individual differences in impulsivity and cognitive distortions (Tan & Tam, 2023).

A possible limitation of these findings is that they largely arise from research with self-report questionnaires. These questionnaires are designed to measure individual differences in the tendency to use emotion regulation strategies, but not their actual effectiveness. Researchers have thus developed laboratory tasks to measure how successful people are at intentionally regulating their emotions. Among these, the cognitive reappraisal task (Phan et al., 2005) has been the most commonly used. This task presents participants with sequences of negatively valenced pictures, and participants are instructed to modify or reinterpret their meaning to down-regulate their emotional impact. This reappraisal condition is usually pitched against a control one in which the participant is asked to experience the picture-triggered emotion without trying to interfere with it (e.g. Bastiaansen et al., 2018; Picó-Pérez et al., 2022). Success at implementing reappraisal is assessed by comparing subjective estimates of the emotional discomfort caused by the pictures across conditions (i.e., after experiencing versus reappraising).

These subjective ratings are often complemented with objective psychophysiological measures. To date, however, few studies have investigated the neurobiological and psychophysiological mechanisms underlying intentional emotional regulation in individuals with problematic gambling or gambling disorder. One such study was conducted by

Navas, Contreras-Rodríguez, et al. (2017), and found that individuals with gambling disorder showed heightened activation of the frontal cortex and left premotor areas, which are linked to executive control, when reappraising negative emotional pictures, compared to control participants. However, there was no difference in task performance between the two groups. In a related study, Picó-Pérez et al. (2022) used an Independent Component Analysis (ICA) network analysis to assess the contribution of the activity of different brain networks to emotional processing and reappraisal in patients with gambling disorder or cocaine use disorder, compared to healthy controls. Both cocaine use and gambling disorder patients (relative to controls) showed underactivation of the limbic network during emotional processing, and, crucially, gambling disorder participants (relative to controls) showed increased activation in the ventral frontostriatal network during reappraisal. Taken together, the evidence from these two studies suggests that gambling disorder patients may need to overactivate areas of cognitive control to compensate for possible difficulties in regulation and attain the same level of performance in the task as control participants (Navas, Contreras-Rodríguez, et al., 2017). Or, in other words, individuals with gambling disorder may incur higher cognitive costs than healthy individuals when engaging in negative emotion regulation strategies such as cognitive reappraisal.

The present study

Our study aims to replicate and extend the abovementioned results by using the standard cognitive reappraisal task to conceptually reproduce the design employed in Navas, Contreras-Rodríguez, et al. (2017). In the present study, however, fMRI will be replaced by a vagally-mediated heart rate variability (vmHRV) measure.

Empirical research and previous theoretical proposals support the use of heart rate variability (HRV) as a reliable non-invasive marker of individual differences in the ability to regulate emotions (Appelhans & Luecken, 2006; Christou-Champi, Farrow, & Webb, 2015). HRV can provide information on emotion regulation at two levels. On the one hand, tonic HRV differences in resting-state vagal tone have been linked to an individual's ability to produce more adaptive emotional responses (Appelhans & Luecken, 2006). On the other hand, the prefrontal cortex has been attributed a role in modulating subcortical cardioaccelerator circuits associated with vagal function, which in turn is reflected in HRV (Hansen, Johnsen, & Thayer, 2003; Thayer & Lane, 2009). This implies that phasic task-related HRV dynamics can be used as a measure of mental load elicited by tasks involving emotional regulation (Segerstrom & Nes, 2007). Among the several HRV parameters available, the vagally-mediated components appear to provide the most accurate measurement of task-related modulations over time (Shaffer & Ginsberg, 2017) and have proven to be a highly sensitive proxy reflecting the autonomic demands of emotional regulation load contexts (Balzarotti, Biassoni, Colombo, & Ciceri, 2017), i.e., changes in autonomic functioning during

task execution. Consequently, if task-related HRV modulation is a proxy measure of the cognitive effort required to execute emotional regulation strategies, then there should be a larger decrease in vagally-mediated HRV (vmHRV) during cognitive reappraisal in gamblers with a higher degree of problem severity and higher levels of dispositional emotional dysregulation.

Despite the almost identical protocol, however, the sample of the present study differs from that of Navas, Contreras-Rodríguez, et al. (2017) in several aspects. Instead of patients with gambling disorder and matched controls, we recruited active gamblers from the community (excluding occasional and lottery-only players). This approach allows for the exploration of the whole severity continuum and also avoids the overrepresentation of participants in its high end, who are more likely to present complications and comorbidities that may act as confounders in the specific links between emotion regulation and gambling problems (see Christensen et al., 2023, for a similar argument in the general domain of behavioral addictions).

Based on the available literature on gambling and emotion regulation, we posit several hypotheses. Firstly, building upon the findings of the studies by Navas, Contreras-Rodríguez, et al. (2017), and Picó-Pérez et al. (2022), we expect to find (i) a positive correlation between expressive suppression and gambling problems' severity, as well as (ii) a negative correlation between gambling problems' severity and gamblers' resting state vagal tone. However, (iii) we expect to find no substantial correlation between regulation success in the cognitive reappraisal task and gambling problems' severity (as individuals with more severe problems have been observed to compensate for emotion regulation difficulties in this task by allocating more resources to it).

Complementarily, based on studies showing a substantial impact of mental fatigue on vmHRV, and assuming that individuals with emotion regulation difficulties find the reappraisal task more cognitively taxing than individuals with better emotion regulation abilities, we predict that (iv) gamblers with more severe gambling-related problems (compared with gamblers with lower severity levels) will manifest a stronger impact of time-on-task on vmHRV (as measured across inter-block rest periods during the cognitive reappraisal task). Hypotheses concerning the influence of other psychometric variables on vmHRV modulation throughout the task remain open. If any, known correlates of gambling problems' severity (e.g. positive and negative urgency) are expected to exert an effect on vmHRV in the same direction as severity.

Finally, we expect to find evidence that individuals with more severe gambling problems will also show (v) a more frequent dispositional use of expressive suppression, as well as (vi) a relatively stronger vmHRV decrement during the emotion regulation blocks in the cognitive reappraisal task. In light of the mixed findings in the reviewed literature, we refrain from making predictions regarding the association between gambling problems' severity and dispositional use of cognitive reappraisal.

METHODS

Participants and procedure

Seventy community gamblers participated in this study, with 10 of them self-identifying as female and none as non-binary. Recruitment was conducted using a diversified method, including virtual (i.e. social networks-based) and in-person dissemination (i.e. through distribution of flyers in various neighborhoods, gambling venues, and University facilities). Snowball sampling was used to reach other potential participants. Once they contacted one of the researchers, a telephone interview was conducted to confirm that they met the inclusion criteria, i.e. being over 18 years of age, fluent in Spanish, and having gambled at least once a month during the past year. This threshold was selected to ensure the inclusion of participants with regular gambling behavior, while also allowing for variability in gambling frequency within the sample. Additionally, prior studies suggest that this frequency is optimal for minimizing false positives and avoiding the inadvertent exclusion of individuals experiencing genuine gambling-related harm (Stone et al., 2015; Williams & Volberg, 2009, 2012; Williams et al., 2021). Individuals with a history of psychopathological treatment or diagnosis (e.g., treatment or diagnosis related to addictive disorders, mood disorders, anxiety disorders, or psychotic disorders), neurological disease, or brain trauma resulting in a loss of consciousness for 10 min or more were excluded from the study. Additionally, participants whose gambling activity was limited to purchasing lottery tickets were also excluded. Table 1 displays the sociodemographic and psychometric characteristics of the complete sample.

Following selection, the participants were invited to attend two assessment sessions in the laboratory where the experiment was conducted. Each participant completed one session per day, and the order of the sessions was randomized. During one of the sessions, participants completed emotion- and gambling-related questionnaires. The other session involved performing the cognitive reappraisal task. At the beginning of the first session, participants were required to fill out the informed consent form and were assigned an arbitrary identification code to maintain anonymity and preclude any linkage of the recorded information with personal data. Participants received €50 as compensation. Two male participants failed to attend one of the sessions and were removed from further analyses, so the final sample consisted of the 68 participants who completed the entire protocol.

During the cognitive reappraisal task, two psychophysiological measurements were recorded. Brain activity was recorded using BrainVision Recorder (Brain Products GmbH, version 1.20.0801), while HRV was recorded using a Polar V800 device and a Polar H7 sensor (Polar Electro Oy, Kempele, Finland). For the purposes of this study, only the second recording was analyzed (see Measurements section). To avoid undue selective reporting, the electroencephalography (EEG) measures remain unanalyzed to this date.

Table 1. Descriptive statistics for sociodemographic variables, scores in target measures of the sample, and scores in discomfort experienced on each condition of the cognitive reappraisal task

Sociodemographics and measures						
	Mean	Median	SD	Minimum	Maximum	L/H (median-split)
Age	21.88	21.00	3.78	18.00	44.00	–
Neg. urg.	2.50	2.50	0.75	1.00	4.00	28/26
Pos. urg.	2.57	2.50	0.64	1.25	4.00	27/27
Cog. Reap.	4.71	4.80	0.94	2.80	7.00	34/20
Exp. Supp.	3.93	4.25	1.30	1.00	6.25	33/21
Severity	5.10	5.00	2.93	0.00	14.00	31/23
Craving	3.16	3.17	0.89	1.00	5.00	24/30
Cognitive reappraisal task ratings						
	Mean	Median	SD	Minimum	Maximum	
Observe cond.	5.29	3.60	4.53	0.65	20.48	–
Experience cond.	47.27	50.24	23.21	4.50	89.67	–
Regulate cond.	23.53	20.95	16.64	2.00	69.17	–
Reactivity	41.77	44.29	22.05	1.43	86.17	–
Success	23.73	18.69	20.46	–6.27	83.63	–

Abbreviations. SD standard deviation. L/H (median split) refers to the number of participants divided into two groups based on whether they scored below (L. low) or above (H. high) the median cutoff for the measure of interest. Cognitive reappraisal task scores (*observe*, *experience* and *regulate* conditions) range from 0 to 100. *Reactivity* score is calculated by subtracting *observe* condition scores from *experience* condition scores. *Success* is calculated by subtracting *experience* condition scores from *regulate* condition scores.

Measures

Gambling problems’ severity. The severity of disordered gambling symptoms (henceforth, gambling problems’ severity) was assessed using the South Oaks Gambling Screen (SOGS; Lesieur & Blume, 1987), a reliable and widely used screening instrument (Esparza-Reig, Guillén Riquelme, Martí Vilar, & González Sala, 2021). The SOGS rates items on a one-point scale (yes/no) and calculates total scores by summing the 14 items. A score of ≥ 5 on the SOGS indicates “probable pathological gambling”. The Spanish version of this instrument has shown good psychometric properties (Echeburúa, Báez, Fernández-Montalvo, & Páez, 1994). In this study, the scale’s Cronbach α value was 0.709.

Negative and positive urgency. Negative and positive urgency scores were obtained from the corresponding subscales of the Spanish version of the short UPPS-P questionnaire (Whiteside y Lynam, 2001; validation of the short Spanish version used here by Cándido, Orduña, Perales, Verdejo-García, & Billieux, 2012). This questionnaire evaluates impulsivity in a multidimensional way, including three other traits: sensation seeking, lack of premeditation, and lack of perseverance. The UPPS-P items are rated on a four-point scale (ranging from 1, *strongly agree*, to 4, *strongly disagree*). Each subscale is assigned a total score, which is calculated by averaging the scores of all items within that subscale. In our sample, we used both measures of urgency as proxies for generalized emotional dysregulation (Muela et al., 2023). Cronbach α was 0.810 and 0.753 for negative and positive urgency, respectively.

Cognitive reappraisal and expressive suppression. The Emotion Regulation Questionnaire (ERQ; Gross & John,

2003; Spanish validation by Cabello, Salguero, Fernández-Berrocal, & Gross, 2013) was administered to assess the dispositional use of cognitive reappraisal and expressive suppression. The ERQ items are scored on a scale ranging from strongly disagree (1) to strongly agree (7). Each subscale is scored independently, with the mean of the item scores being calculated for each one. A higher score indicates a greater dispositional use of the corresponding strategy. Cronbach’s α for cognitive reappraisal and emotional suppression was 0.552 and 0.776, respectively. Given the low internal consistency of the reappraisal measure, an examination of item-rest correlations was carried out, which showed that item 5 (“When I’m faced with a stressful situation, I make myself think about it in a way that helps me stay calm”) did not meaningfully correlate with the other items in the subscale (item-rest correlation = -0.075). This item was thus removed from all further analyses, which rendered a Cronbach’s α of 0.672 for the reappraisal subscale. Although this level of reliability can be considered acceptable, it is still far from optimal, so the possibility that correlations and other statistical effects involving reappraisal are underestimated due to measurement error must be taken into consideration.

Gambling-related craving. For this study, we used a gambling-related craving scale described in previous works (Muela et al., 2023; Quintero et al., 2020). This scale has consistently shown good reliability, even when used in different cultures or adapted to other addictive behaviors (Rivero et al., 2023). It consists of three items aimed at capturing distinct facets of craving experiences: (1) intense urges (*At times, I cannot help feeling an intense desire to gamble*), (2) stimulus-driven behavior (*Some situations, events or stimuli incite me to gamble, even if I had not planned it*), and (3) attentional hijacking (*Gambling-related*

situations, events or stimuli immediately grab my attention). Each item is rated on a Likert-type scale from 1 to 5, with higher scores indicating increased craving. The total craving score is calculated as the mean value of the individual item scores. For the present study, the craving scale showed a good level of internal consistency (Cronbach's $\alpha = 0.715$).

Cognitive reappraisal task. The cognitive reappraisal task used in this study is an adaptation of Phan et al.'s (2005; also previously used by Navas, Contreras-Rodríguez, et al., 2017). Participants were exposed to neutral and negatively valenced pictures, all extracted from the IAPS catalog (Lang, Bradley, & Cuthbert, 1997). The task consists of three different trial types, in which participants are told to (1) *observe* neutral images (control condition), (2) *experience* the emotion elicited by negative images (emotional reactivity condition), or (3) *regulate* the emotion elicited by the negative pictures using a pre-trained emotion regulation strategy (emotional regulation condition). Each trial (of a total of 120) begins with the presentation of a fixation point (2,000 ms), followed by an instruction indicating the strategy to be followed depending on the condition (*Observe*, *Experience*, or *Regulate*; 2,000 ms). Then, two different pictures of the same category (neutral or negative valence; 5,000 ms for each picture) are presented sequentially. Immediately afterward, participants are asked to report the intensity of the discomfort experienced by using a visual analog scale (VAS) ranging from 0 (no discomfort/neutral emotion) to 100 (extreme discomfort).

In the present version of the task, the 120 trials were divided into four 30-trial blocks: two of the blocks (henceforth, low-demand blocks) contained *observe* and *experience* trials, i.e. participants were asked just to observe the neutral pictures and to experience the emotional impact of negative pictures, without trying to alter that experience. The other two blocks (high-demand blocks) contained *observe* and *regulate* trials, i.e. participants were asked to observe the neutral pictures and, crucially, to reappraise the negative pictures. These blocks were intertwined and presented in one of two possible orders during the task (HLHL or LHLH) for each participant. The trials were also randomized within each block. In other words, both high- and low-demand blocks contained negatively valenced (and thus emotionally impactful) pictures, but only in the former type participants were instructed to downregulate such an impact by reappraising the picture. Success in regulating the negative emotions elicited by negative pictures is measured as the difference between averaged self-reported discomfort judgments for *experience* and *regulate* trials (see Table 1).

Participants were instructed to rest for six minutes before and after each block. During these inter-block rest periods, they were also told to breathe normally and minimize movement. These periods will be referred to as initial baseline (B0) and return-to-baseline (B1, B2, B3, B4) intervals. Heart-rate variability measures during these periods reflect HRV dynamics (carryover effects) during the task, not acutely depending on mental activity within the task blocks.

HRV measures. For HRV data acquisition, we used a Polar H7 heart rate sensor and a Polar v800 receiver unit to continuously monitor and register the participants' heart rate and R–R intervals during the experimental session. An elastic electrode transmitter belt was placed on the chest of the participant at the level of the lower third of the sternum, below the pectoral muscles, after moistening the electrode area (following the manufacturer's instructions). These electrodes are designed to detect the voltage change in the skin with each heartbeat. The H7 sensor is physically connected to the elastic strap to continuously transfer the signal detected by the electrodes to the V800 device via Bluetooth. The data were collected at a sampling rate of 1,000 Hz, providing a temporal resolution of 1 ms for each RR interval. The Polar equipment has been validated and proven to be a reliable and accurate method for measuring HRV during short periods (Giles, Draper, & Neil, 2016).

After collection, the data were transferred to a private account on the cloud (<https://flow.polar.com>) using the Polar FlowSync 4.0.11 software. The files were then downloaded and saved with the participant's identification code (see Participants and Procedure subsection). Raw inter-beat intervals data were then processed in Kubios HRV software (version 3.4) using the threshold-based method for correcting artifacts and ectopic beats (Tarvainen, Niskanen, Lipponen, Ranta-aho, & Karjalainen, 2014). This method automatically identifies artifacts and ectopic beats by comparing every R–R interval value against a local average interval based on a previously defined correction threshold. Following visual inspection of the data, the appropriate correction level for each dataset was individually adjusted among 'very low' or 'low' thresholds (i.e., inter-beat intervals larger/smaller than 0.45 or 0.35 s thresholds, respectively). These thresholds have proven to be optimal in HRV data processing to ensure the lowest correction level while identifying all artifacts, thus preventing potential overcorrection (Tarvainen et al., 2014). Detected ectopic beats or abnormal inter-beat intervals series were corrected by replacing corrupted RR times with interpolated RR values by using cubic spline interpolation. All files were checked to ensure that the number of corrected beats remained below 5% of the sample (0.75% of corrected beats on average) to avoid significant distortion in the analysis outcomes. After the artifact corrections were made, the R–R interval time series was then considered normal and defined as N–N intervals (Shaffer & Ginsberg, 2017). We applied the smoothness prior method with a Lambda value of 500 to remove disturbing low frequency baseline trend components (Tarvainen et al., 2014).

Following the identification and correction of the artifacts, temporal segments of interest for statistical analyses (see Statistical Analyses section for details) were selected from the N–N interval series for the calculation of the HRV parameters. Our primary measure of vmHRV was the time domain metric RMSSD (root mean square of the successive differences between normal heartbeats), considered a robust marker of vmHRV (Laborde, Mosley, Bellenger, & Thayer, 2022). In order to adhere to HRV reporting standards (Malik, 1996) and provide an overview of different vmHRV

parameters, we also extracted additional time- and frequency-domain HRV parameters: the proportion of NN50 (pNN50) which reflects the number of pairs of successive NNs that differ by more than 50 ms (relative to the total number of NN intervals) for the time-domain, and the HFms2 (0.15–0.40 Hz) for the frequency-domain (via Fast Fourier Transform). All HRV parameters were obtained by using custom Matlab scripts and the HRVTool toolbox (Vollmer, 2019).

All results concerning vmHRV in the main text of the manuscript refer to RMSSD, whereas data concerning pNN50 and HF can be found in Tables S2 and S3 in the OSF platform (https://osf.io/em9br/?view_only=87dda3273b4e4dd7ae488ed1ccd8987f). The denotations and definitions for the HRV parameters in this manuscript follow the guidelines given in Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology (Malik, 1996).

Finally, and of particular interest (as stated in the Correlation Analyses section), we encountered recording issues in 14 out of the 68 participants. In all instances, these issues were attributed to connection problems between the Polar H7 sensor and the Polar V800 device, rather than factors such as a high percentage of artifacts or other potential causes. These technical difficulties led to the exclusion of these participants' HRV data from further analyses, ensuring that the remaining dataset was of optimal quality for reliable interpretation.

Statistical analyses

Correlation analyses. Pairwise Bayesian correlation analyses were conducted between the variables of interest (see Table 2). As assumptions for parametric analyses were not guaranteed for some of them (especially the normality assumption for the distributions of measures based on symptoms or discrete behaviors counts, which are well-known to be strongly asymmetric), and for the sake of consistency and comparability, Kendall's Tau index was

used for correlations involving the two UPPS-P urgency variables, the two ERQ dimensions (cognitive reappraisal and expressive suppression), gambling problems' severity, gambling craving, regulation success score on the cognitive reappraisal task, and the initial resting baseline vmHRV measure (B0). On the one hand, Kendall's Tau measures rank order correlations instead of linear correlations, making it more robust to the presence of outliers. This means that, in cases where linear correlations heavily depend on extreme values, Kendall's Tau tends to yield smaller values, which must not be considered a weakness but a sign of robustness. On the other hand, Tau is equally sensitive to linear and non-linear relationships, provided that the rank order is maintained, which is aligned with the idea that allegedly continuous constructs (such as impulsivity measures) do not necessarily translate linearly into disordered behaviors or symptom counts.

As described in the Methods section, the regulation success score was calculated by subtracting the averaged emotional discomfort score attributed to negative pictures in the *experience* condition from the one attributed to negative pictures in the *regulate* condition (reflecting how effective participants were at reducing the emotional impact of negative pictures when instructed to do so, relative to the condition in which they were instructed just to experience the emotion caused by those pictures).

The tests were carried out using two-way Bayes factors (BF10), computed with the default settings in JASP software (JASP Team, 2023). Importantly, these default settings include a stretched beta prior width of 1, corresponding to a uniform distribution. For the sake of robustness, correlational analyses will be also performed with a more informed 0.33 width (meaning that medium-sized correlations are considered a priori more likely than extreme ones). The main results of these alternative analyses are reported along the main ones, and are available in full in the corresponding JASP file (*Correlations_n = 68.jasp*) that can be accessed via the OSF link accompanying this manuscript.

Table 2. Bayesian correlation tests (bidirectional Bayes factors for Kendall's τ) between variables of interests

		Neg. urg.	Pos. urg.	Cog. Reap.	Exp. Supp.	Severity	Craving	ER success
Pos. urg.	τ	0.318***	–					
	BF ₁₀	215.747	–					
Cog. Reap.	τ	0.095	0.144	–				
	BF ₁₀	0.302	0.689	–				
Exp. Supp.	τ	–0.009	–0.097	0.094	–			
	BF ₁₀	0.159	0.309	0.296	–			
Severity	τ	0.231	0.273**	0.108	0.205	–		
	BF ₁₀	7.189	33.155	0.364	3.196	–		
Craving	τ	0.214	0.252*	0.154	0.074	0.319***	–	
	BF ₁₀	4.133	14.643	0.864	0.234	225.167	–	
ER success	τ	–0.036	0.010	–0.060	–0.030	–0.086	0.017	–
	BF ₁₀	0.173	0.159	0.205	0.169	0.269	0.161	–
BL0 †	τ	0.105	–0.052	0.004	0.079	0.117	–0.009	–0.106
	BF ₁₀	0.328	0.205	0.177	0.251	0.380	0.178	0.329

Abbreviations. † sample size $n = 54$, τ Kendall's tau, ER Emotion Regulation, BL0 Initial Baseline *BF₁₀ > 10, **BF₁₀ > 30, ***BF₁₀ > 100. Bold values indicate substantial evidence in favor of the alternative hypothesis.

Given the multiplicity of correlations and the fact that many of them do not respond to predefined hypotheses, only BF_{10} larger than 10 and smaller than $1/10$ will be interpreted as portraying substantial evidence in favor of the alternative and the null hypothesis, respectively, whereas BF larger than 30 and smaller than $1/30$ will be interpreted as strong evidence.

For the reasons described earlier, correlations involving only psychometric variables were performed on data from the full sample ($n = 68$), whereas those involving HRV were conducted on data from 54 participants.

Analyses of variance. In order to examine the course of vmHRV over time-on-task, and its potential sensitivity to predictive constructs of interest, six (4×2) Bayesian repeated-measures ANOVAs were conducted with a nominal group variable (high, low) as between-participants factor, and 4 measurements of vmHRV at return-to-baseline periods (B1–B4) as a repeated-measures factor.

The within-participant vmHRV measures were extracted from the four resting intervals immediately following each reappraisal task block (intended to allow the participant to return to baseline heart rate values; see Measures section). For each one of these four intervals and each participant, the raw vmHRV measure was translated into a proportional change value, with the individual's initial baseline measure (B_0 , recorded before the first task block) as reference. For instance, proportional change for B1 was computed as $(vmHRV_{B1} - vmHRV_{B0})/vmHRV_{B0}$. Proportional change values for B1, B2, B3 and B4 thus represent the individual time-related HRV dynamics (how vmHRV changes throughout the task), once the individual differences at B_0 have been removed. Positive values represent proportional increases in vmHRV, relative to the initial baseline, whereas negative values represent proportional decreases.

In each one of the six independent ANOVAs, the predictor of interest was dichotomized using a median-split method, resulting in a high and a low group in negative urgency, positive urgency, cognitive reappraisal, expressive suppression, gambling problems' severity, and gambling craving (in each ANOVA, respectively). Dichotomization is justified by the necessity to analyze the interactions between the (dichotomized) predictor of interest (High, Low) and the within-participant vmHRV measurement point (1–4) factor. In addition to the between-participants group factor, the within-participant measurement point factor, and the interaction between the two, the models for all ANOVAs also included the counterbalance sequence group (HLHL, LHLH) and its interaction effects as potential confounders. The marginal and interactive effects of the counterbalance sequence were included to eliminate any contamination of other effects arising from the size unbalance caused by differential participants' attrition in the two counterbalance groups, but were not considered for the interpretation of results.

For all ANOVAs, the across-matched-models BF_{inc} was extracted for the effects of interest (the main effect of group and the group $\times$ time interaction, with BF_{inc} measuring the

evidential support for the models with the effect of interest included, relative to the models without that effect). Given that these tests are guided by pre-determined hypotheses, no corrections for multiplicity were implemented, and thus BF_{inc} values larger than or equal to 3 will be interpreted as substantial evidence in favor of H_1 , BF_{inc} values smaller than or equal to $1/3$ will be interpreted as substantial evidence in favor of H_0 , and BF_{inc} values between $1/3$ and 3 will be interpreted as negligible evidence (henceforth 'negligible' will be consistently used to refer to the anecdotal evidence range). Any BF_{inc} factors below $1/10$ or above 10 will be considered indicative of strong evidence in favor of H_0 and H_1 , respectively.

All ANOVAs were carried out with JASP defaults. Importantly, these include a 0.5 r scale value for fixed effects priors, thought to avoid prior mass spreading across unreasonably large effect sizes (Rouder, Morey, Verhagen, Swagman, & Wagenmakers, 2017). Where considered necessary, and for the sake of robustness, alternative 0.2 and 1 values were also used. The main results of these alternative analyses are reported along the main ones, and are available in full in the corresponding JASP file (RM ANOV-AS_Baselines_rmssd.jasp) that can be accessed via the OSF link accompanying this manuscript.

Regression analyses. Two Bayesian linear regressions were conducted to investigate whether gambling problems' severity (SOGS scores) predicted the use of dispositional emotional regulation strategies (cognitive reappraisal and expressive suppression from the ERQ). Gambling problems' severity was used as the input variable, while reappraisal and suppression were used as output variables.

A third Bayesian linear regression was performed to determine if the difference in HRV between high-demand and low-demand blocks (i.e. the potential effect of emotion regulation demand on vmHRV) could be predicted by the gambling problems' severity score. To compute this differential effect, the summed low-demand blocks' vmHRV values were subtracted from those for high-demand blocks ($vmHRV_{high} - vmHRV_{low}$). Before subtraction, and to remove any contamination of this effect by individual differences at baseline, vmHRV values in high- and low-demand blocks were translated into proportional change values, using the individual initial baseline vmHRV as reference.

Each of the three Bayesian linear regression analyses was supplemented with two complementary ones. In one of them, negative urgency was added as a covariate, to examine whether the *gambling problems' severity $\times$ negative urgency* interaction predicted the dispositional use of emotion regulation strategies or differential vmHRV, as hypothesized in the introduction. In a more exploratory fashion, that same analysis was also carried out with positive urgency. Sex and age were used as control variables in all Bayesian linear regressions. The counterbalance sequence variable (HLHL, LHLH) was also included as a potential confounder in regression analyses involving differential HRV.

The thresholds for BF interpretation were the same as those used in the ANOVAs described in the previous section. We conducted all our analyses using the default

settings for Bayesian statistics of the JASP software (JASP Team, 2023). For all regressions, the across-matched models BF_{inc} were extracted for the effects of interest. Thresholds for BF interpretation were the same as in ANOVAs. Regressions involving only psychometric variables were performed on data from the full sample ($n = 68$), whereas those involving HRV were conducted on data from 54 participants.

All Bayesian regression analyses were carried out with JASP defaults. Importantly, these include a 0.354 r scale value for (JZS type) priors, again, thought to avoid prior mass spreading across unreasonably large effect sizes. For the sake of robustness, in full models (those including all variables of interest and interactions), alternative 0.1 and 1 values were considered. The main results of these alternative analyses are reported along the main ones, and are available in full in the corresponding JASP file (*Regressions UPPSP, ERQ, Severity_bayesian approach_n = 68; Regressions UPPSP, Severity, HRV rmssd_bayesian approach_n = 54*) that can be accessed via the OSF link accompanying this manuscript.

Ethics

The procedure of this study complies with the ethical standards of the Helsinki Declaration of 1975, as revised in 2008, and was approved by Human Research Institutional Review Board of the University of Granada, as part of the GBrain2 Project (Reference: PSI2017-85488-P, IRB approval number 406/CEIH/2017). All participants were informed about the nature of the study and all provided informed consent.

RESULTS

Correlations

Table 2 shows the correlations between variables of interest and their corresponding Bayes factors. As expected, we found strong evidence for (a) a correlation between the two dimensions of urgency, and (b) a correlation between gambling craving and gambling problems' severity (SOGS). In addition, there was (c) strong evidence of a correlation between positive urgency and SOGS severity score, and (d) substantial evidence of a correlation between positive urgency and craving. Finally, (e) the evidence of a correlation of negative urgency with craving and severity was assessed as negligible (due to the $BF > 10$ established as evidential threshold). In other words, positive urgency was a better predictor of gambling problems' severity and craving than negative urgency.

All other Bayes factors anecdotally supported non-correlation ($1/10 < BF < 0$), except for the one between SOGS severity score and the dispositional use of reappraisal ($BF = 3.196$). Regarding the latter, it is important to note that, although the evidence favoring a positive correlation can be considered negligible (due again to the $BF > 10$ established as evidential threshold), there is strong evidence *against a negative correlation*. To explicitly test this, we computed the BF for the

directional negative correlation between ERQ reappraisal and SOGS severity score –computed under the same assumptions–, which resulted to be 0.045 (i.e., $BF < 0.10$). This means that the hypothesis that individuals who are more prone to use reappraisal are less likely to experience gambling-related problems is convincingly undermined by the current evidence.

The size of correlations portraying substantial confirmatory evidence ranges between 0.25 and 0.32 (with 0.3 being customarily considered as a moderate effect), which is what one should expect from correlations between theoretically related but not overlapping constructs. Correlations only slightly smaller than these are assessed not to portray substantial evidence due to the establishment of a stricter criterion ($BF > 10$ instead of the customary $BF > 3$) to correct for multiplicity (for a discussion on the necessity to establish correction procedures for multiple Bayesian tests, see Westfall, Johnson, & Utts, 1997).

Complementary correlation analyses using a frequentist approach yielded very similar results. So did the Bayesian analysis with a more informed prior (0.33 stretched width), with the only difference that Bayes Factors were slightly larger for correlations in the intermediate range, so that the correlation between positive urgency and SOGS score surpassed the evidential threshold to be considered substantial ($BF = 10.35$).

Changes in HRV over time-on-task

Figure 1 shows the results of the previously described Bayesian repeated-measures ANOVAs. The complete results and statistical analysis, including parameters or statistical indices omitted in this table, are available in the corresponding file in the OSF platform.

BF_{inc} values for the main effect of time-on-task provided no substantial evidence against or in favor of the alternative or the null hypothesis. Note, however, that all measures are referenced to the initial baseline (B0), so generally positive proportional change values indicate that, relative to B0, time-on-task was associated with an HRV increase.

More importantly, analyses of the main and interactive effects of (dichotomized) severity, negative urgency, cognitive reappraisal, expressive suppression, and gambling craving on HRV (measured in B1–B4, as proportional change relative to B0) yielded no substantial support for the alternative or the null hypothesis. Evidence, although mostly negligible, was generally in favor of the null hypothesis.

The only exceptions were (a) the Bayes factor for the main effect of positive urgency ($BF_{inc} = 11.377$), and (b) the Bayes factor for the interaction between time and expressive suppression ($BF_{inc} = 5.484$). Participants with higher positive urgency scores, and those more prone to use suppression showed larger increases in vmHRV during the task. The substantial main effect of positive urgency is indicative of a difference that remains approximately constant between B1 and B4, whereas the time $\times$ suppression interaction indicates that such a difference starts to emerge in B2 (so that differences are more clearly related to time-on-task).

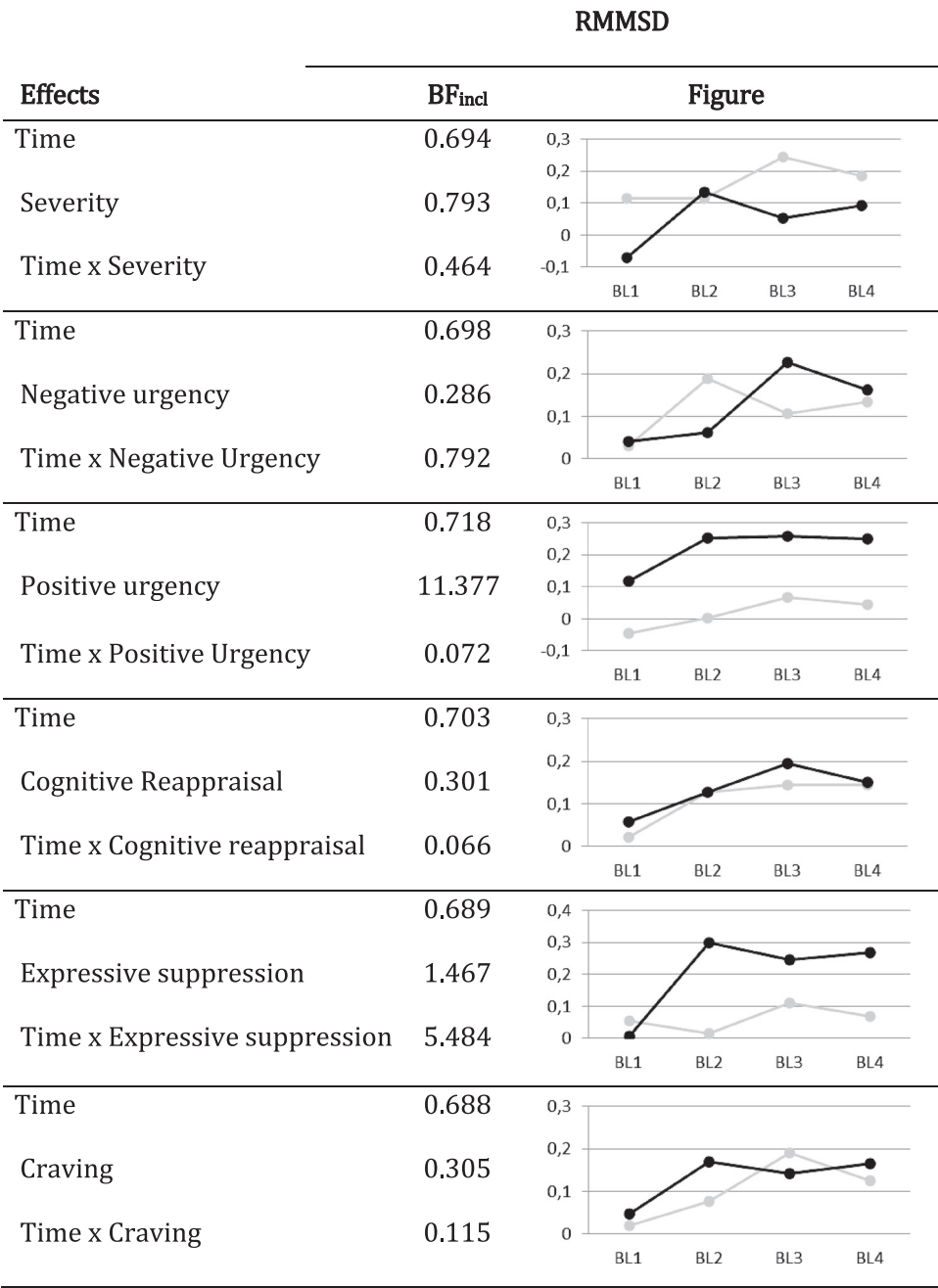


Fig. 1. Bayesian repeated-measures ANOVAs for dichotomized predictors of interest (problems severity, negative and positive urgency, dispositional use of reappraisal and suppression, and gambling-related craving) as input variables, and vmHRV (RMMSD) as output variable

Abbreviations. RMMSD root mean square of successive differences between normal heartbeats (obtained by first calculating each successive time difference between heartbeats in milliseconds). Grey and black lines represent scores under and above the median of the predictor of interest, respectively.

For these effects, and for the sake of robustness, wider ($r = 1$) and narrower ($r = 0.2$) priors for effects of interest were also considered (see [supplemental results in the OSF link](#)). BF_{inc} for positive urgency and the time x positive urgency interaction were 9.22 and 0.29, respectively, with the $r = 0.2$ prior, and 9.23 and 0.014 with the $r = 1$ prior. Similarly, the BF_{inc} for the time x suppression interaction was 4.96, with the $r = 0.2$ prior, and 2.96 with the $r = 1$ prior. Thus,

in general, results were not largely affected by varying the prior dispersion, provided that this is kept within reasonable limits (i.e., it does not overestimate the prior probability of very large effects that are extremely rare in Psychology).

Linear regressions

Summary results for these analyses can be found in [Tables 3 and 4](#).

Table 3. Results of Bayesian linear regression analyses to examine gambling problems' severity, urgencies, and urgencies x severity interactions as a predictors of dispositional use of intentional emotion regulation strategies

Effect	Dependent variable					
	Cognitive reappraisal			Expressive suppression		
	BF _{inc}	95% Credible Interval		BF _{incl}	95% Credible Interval	
		Lower	Upper		Lower	Upper
Gambling severity	1.141	-5.411×10^{-4}	0.121	0.999	-0.014	0.143
Gambling severity	1.125	-0.032	0.174	0.713	-0.141	0.153
NU	0.283	-0.280	0.283	0.397	-0.413	0.376
Gambling severity x NU	0.432	-0.054	0.009	0.650	-0.008	0.088
Gambling severity	1.079	-0.101	0.153	1.130	-0.159	0.352
PU	0.396	-0.262	0.376	0.946	-0.920	0.254
Gambling severity x PU	0.447	-0.002	0.076	0.437	-0.113	0.071

Note. NU Negative urgency, PU Positive urgency. BF_{inc} variable inclusion's Bayes Factor computed using the *across-matched-models* method. Sex and age were introduced as control variables.

Table 4. Results of Bayesian linear regression analyses to examine gambling problems' severity, urgencies, and urgencies x severity interactions as a predictors of changes in vmHRV (RMMSD)

Effect	RMMSD		
	BF _{inclusion}	95% Credible Interval	
		Lower	Upper
Gambling severity	0.288	-0.025	0.006
Gambling severity	0.271	-0.060	0.022
NU	0.268	-0.119	0.110
Gambling severity x NU	0.987	-0.002	0.022
Gambling severity	0.282	-0.021	0.016
PU	0.379	-0.145	0.015
Gambling severity x PU	0.481	-0.001	0.001
Gambling severity	0.262	-0.031	0.012
Cog. Reapp.	0.245	-0.060	0.045
Gambling severity x Cog. Reapp.	0.485	0.000	0.000
Gambling severity	0.281	-0.028	0.016
Exp. Supp.	0.306	-0.013	0.071
Gambling severity x Exp. Supp.	0.499	-5.122×10^{-4}	0.003

Note. UN negative urgency, PU positive urgency, RMSSD root mean square successive difference. BF_{inc} variable inclusion's Bayes Factor computed using the *across-matched-models* method. Sex, Age and Counterbalance sequence are used as control variables.

The first analysis examined the relationship between SOGS gambling problems' severity and ERQ expressive suppression. Main effects analysis (across matched models) showed negligible evidence regarding the influence of gender and age (BF_{inc} = 1.343 and 1.394, respectively) on expressive suppression, while gambling problems' severity remained again uninclined in favor of or against this effect (BF_{inc} = 0.999). The inclusion of negative urgency and its interaction with severity in the analysis did not alter the previous results, although the presence of this factor in the models nullified any support for a main effect of gender and age. The data negligibly supported the absence of main effects of negative urgency (BF_{inc} = 0.397), gambling

problems' severity (BF_{inc} = 0.713), and their interaction (BF_{inc} = 0.650) on expressive suppression. With a narrower $r = 0.1$ prior, the corresponding BF_{inc} were 0.81, 1.16, and 0.91, whereas, with an ultrawide $r = 1$ prior, they were 0.09, 0.20, and 0.29, respectively.

When positive urgency was included in the regression model in place of negative urgency, the results provided no evidence (BF_{inc} = 1.130) for an effect of gambling problems' severity. Evidence against the effect of positive urgency, and against the interaction between positive urgency and gambling problems' severity were also negligible (BF_{inc} = 0.946, and BF_{inc} = 0.437, respectively). With a narrower $r = 0.1$ prior, the corresponding BF_{inc} were 1.58, 1.38, and 0.69, whereas, with an ultrawide $r = 1$ prior, they were 0.30, 0.27, and 0.17, respectively.

In the same vein, we examined the relationship between gambling problems' severity and cognitive reappraisal. Main effects analysis showed again negligible evidence (BF_{inc} = 1.141) supporting the influence of gambling problems' severity on cognitive reappraisal. When negative urgency was included in the model, we found negligible evidence (BF_{inc} = 1.125) in favor of the main effect of gambling problems' severity, moderate evidence (BF_{inc} = 0.283) against the main effect of negative urgency, and negligible evidence (BF_{inc} = 0.432) against an interaction effect of gambling problems' severity with negative urgency. With a narrower $r = 0.1$ prior, the corresponding BF_{inc} were 1.51, 0.67, and 0.75, whereas, with an ultrawide $r = 1$ prior, they were 0.45, 0.08, and 0.15, respectively.

The inclusion of positive urgency in place of negative urgency in the model yielded negligible evidence (BF_{inc} = 1.079) in favor of a main effect of gambling problems' severity, and negligible evidence against any main or interactive effect of positive urgency (BF_{inc} = 0.396 and 0.447, respectively). With a narrower $r = 0.1$ prior, the corresponding BF_{inc} were 1.44, 0.79, and 0.76, whereas, with an ultrawide $r = 1$ prior, they were 0.44, 0.13, and 0.16, respectively.

The last set of analyses was aimed at examining the relationship between gambling problems' severity and vmHRV during task performance. As described earlier,

vmHRV measures in these analyses refer to the difference between high-demand blocks (containing *regulate* and *observe* trials) and low-demand blocks (containing *experience* and *observe* trials), with vmHRV during these blocks previously translated into proportional change scores with B0 as reference). That is, vmHRV measures in the present analyses are a measure of vmHRV decrease in high-demand blocks relative to low-demand ones. The main effects analysis revealed moderate evidence against the influence of gambling problems' severity on vmHRV ($BF_{inc} = 0.288$). When negative urgency was included as a covariate, the main effects analysis showed again moderate evidence against the effects of gambling problems' severity ($BF_{inc} = 0.271$) and negative urgency ($BF_{inc} = 0.268$), and negligible evidence regarding the severity $\times$ negative urgency interaction effect ($BF_{inc} = 0.987$). With a narrower $r = 0.1$ prior, the corresponding BF_{inc} were 0.68, 0.68, and 1.14, whereas, with an ultrawide $r = 1$ prior, they were 0.07, 0.07, and 0.45, respectively.

Similarly, when positive urgency and its interaction with severity were included in the model (in place of positive urgency), the main effects analysis showed moderate evidence ($BF_{inc} = 0.282$) against a gambling problems' severity effect on vmHRV. Additionally, negligible evidence was found against a main effect of positive urgency effect, and against an interaction effect of gambling problems' severity and positive urgency ($BF_{inc} = 0.379$ and 0.481 , respectively). With a narrower $r = 0.1$ prior, the corresponding BF_{inc} were 0.70, 0.73, and 0.80, whereas, with an ultrawide $r = 1$ prior, they were 0.05, 0.06, and 0.08, respectively.

For the regressions reported in this section, BF_{inc} mostly remained in the same evidential range when narrower priors were used, whereas, as expected, a substantially wider prior tended to push small BF_{inc} towards supporting the null hypothesis. In none of the cases, a $BF_{inc} < 3$ surpassed that threshold after assuming narrower or flatter priors.

DISCUSSION

The main objective of this study was to assess the linkages of gambling-related problems and craving with several measures of intentional emotion regulation (and other complementary emotion-related constructs of interest) in a sample of active community gamblers. Intentional emotion regulation was measured (a) with dispositional variables (ERQ reappraisal and expressive suppression), (b) as performance success in a lab-based reappraisal task, (c) as HRV sensitivity to time-on-task measured in return-to-baseline periods following each block in that task, and (d) as HRV sensitivity to emotion regulation-related task demands within blocks. Hypotheses were mostly based on previous evidence that patients with gambling disorder presenting emotion-regulation difficulties over-activate executive, control-related brain areas during reappraisal in the task to attain levels of task performance comparable to matched controls.

Previewing the conclusions, although gambling craving and severity of problems correlated with indices of incidental

regulation (positive and negative urgency), intentional emotion regulation-related indices (either dispositional or task-related) did not vary as a function of gambling-related problems or craving in the expected direction, either in correlation or regression analyses. In other words, in the range of severity explored in the present work, we found little or no evidence supporting the proposal that altered intentional emotion regulation plays a sizeable role in problematic gambling or its manifestations. In ANOVAs and regression analyses testing the links specifically involving HRV, only measures during return-to-baseline intervals (relative to initial baseline) showed effects of positive urgency and dispositional use of suppression, but not of gambling problems' severity, craving, negative urgency, or reappraisal. Neither raw baseline HRV measures, nor differential measures comparing high-load vs low-load blocks were meaningfully predicted by any of the constructs of interest.

Bivariate associations between gambling problems and other constructs of interest

First, we performed pairwise correlation analyses on relevant psychometric variables, performance in the cognitive reappraisal task, and resting-state vmHRV. As expected, these analyses revealed a strong relationship between positive urgency and negative urgency, as well as between the severity of gambling problems and gambling craving. The evidence supporting the relationship between negative urgency and these variables remained negligible at the $BF > 10$ threshold, whereas the evidence of associations of positive urgency with these variables was substantial or strong. In other words, positive urgency was more strongly related to the severity of gambling symptoms and gambling craving than negative urgency.

This differential association replicates previous findings with similar community samples and has been interpreted as evidence that gambling craving is predominantly driven by appetitive rather than aversive states. A recent comprehensive review (López-Guerrero, Navas, Perales, Rivero, & Muela, 2023) has corroborated this finding and suggested a significant mediational role of gambling craving in the relationship between positive urgency and gambling problems (that was less consistently observed for negative urgency). It has also been proposed, however, that this association between positive urgency and gambling problems via craving could be especially characteristic of participants with a preference for skill-based games (Muela et al., 2023; Vintró-Alcaraz et al., 2022). These gamblers would tend to lose control of their behavior under positive affective states and experience higher levels of craving in the presence of reward-related cues, which, in turn, could hinder their attempts to control gambling behavior. In line with that proposal, most participants in our sample showed a marked preference for this type of games.

Our correlational results also show some evidence of a positive association between the dispositional use of cognitive reappraisal and the severity of gambling problems. This correlation can be taken at face value, but, additionally,

a directional Bayesian test actually provided evidence against the more prototypical association in the opposite direction. As noted in the introduction, the more usual, and less counterintuitive, finding is a negative relationship between the use of reappraisal and gambling problems (Bonnaire et al., 2022; Pace et al., 2015; Rogier et al., 2019), as it has been reported for most other mental health conditions (Aldao et al., 2010; Lincoln, Schulze, & Renneberg, 2022). However, there are also exceptions to this trend that are worthy of note. For instance, Neophytou et al. (2023) have discussed in some detail the mixed pattern of results regarding the links between reappraisal and problem gambling. Based on studies by Troy, Shallcross, and Mauss (2013) and Ruiz de Lara et al. (2019), they argued that reappraisal may work as a double-edged sword. On the one hand, reappraisal can be an adaptive and protective strategy against the development of problem gambling, if it is implemented efficiently and aimed at impacting the right emotions. For instance, the reappraisal of daily-life distress in a functional way can help curb such a negative state, reducing the need to gamble (i.e. functional covert emotion regulation strategies to cope with aversive states may reduce the compensatory use of gambling with that same aim). On the other hand, this strategy could also “be used to avoid coming into contact with, and learning to tolerate aversive experiences, turning it into an escape strategy” (Neophytou et al., 2023, p. 139). Similarly, some gamblers could employ the reappraisal strategy after engaging in problematic behavior, in order to justify their gambling and minimize the negative consequences of persevering in it, making the individual perceive their gambling behavior as less problematic than it actually is, and precluding them from deciding to stop gambling. Moreover, this mechanism can even artificially reduce some individuals’ awareness of their gambling problems, compromising the validity of self-report measures.

As mentioned for the link between positive/negative urgency and craving, the inconsistency of results regarding the associations between reappraisal and gambling problems could also be determined by the predominant type of gamblers in the sample of study (clinical vs non-clinical samples, or with a preference for skill vs chance games). On the one hand, some emotional problems found in clinical samples could be attributed, not directly to gambling problems but to the frequent presence of comorbidities and complications in these samples. For instance, Williams et al. (2012) found no differences in dispositional use of cognitive reappraisal and expressive suppression between pathological gamblers and a clinical comparison group consisting of participants with other psychopathological diagnoses (but not gambling disorder), but both groups differed from healthy controls. In a different measure of effective emotion regulation strategies (DERS; Gratz & Roemer, 2004), however, the mixed clinical sample showed more severe deficits than pathological gamblers, with the latter not differing from healthy controls. In other words, some similarities in emotion regulation difficulties in gambling disorder and other psychopathologies could be driven by the partial overlap between them.

And, on the other hand, and independently of gambling severity, gamblers with different game preferences also exhibit differences in their use of emotional regulation strategies. For instance, Barrault, Mathieu, Brunault, and Varescon (2019) found no general differences in the dispositional use of reappraisal or suppression between problem and non-problem gamblers, but found strategic gamblers to use cognitive reappraisal more frequently than mixed-type gamblers. As noted in the introduction, there is some evidence that strategic gamblers could use customarily adaptive emotion regulation strategies to cope with emotional difficulties arising from gambling losses and other threats to one’s self-concept. Or, in other words, for some gamblers, normally adaptive emotion regulation strategies could paradoxically turn into problematic ones. Very tentatively, our sample of predominantly strategic gamblers from the community may have been particularly propitious for this study to find a positive association between dispositional use of reappraisal and gambling problems.

The lack of evidence of substantial correlations of dispositional emotion regulation with gambling-related variables with success in the reappraisal task is also worthy of note. Navas, Contreras-Rodríguez, et al. (2017) failed to find differences between gambling disorder patients and controls in the same task (in line with the lack of correlation here between gambling problems’ severity and task performance) but did report a positive association between success in the reappraisal task and negative urgency, as well as between negative urgency and dispositional use of expressive suppression, restricted to the gambling disorder patients group. These effects were interpreted as suggesting that patients with altered incidental emotion regulation (those scoring higher in negative urgency) are more prone to use suppression as the default intentional emotion regulation strategy.

In the present study, on the contrary, no evidence of associations between urgency or dispositional suppression and performance in the reappraisal task was found (and even, in some cases, evidence was substantial against those links, see Table 2). Again, the contrasting results can be a consequence of the different populations the participants were sampled from across studies. More frequent use of suppression and its association with urgency may be characteristic of individuals at the high end of the severity continuum, who are also more likely to present complications and comorbidities that are not generalizable to the whole range of severity in the community.

In any case, the lack of correlation of reappraisal task performance with scores of dispositional emotional regulation as measured by self-report questionnaires strongly suggests that both tools are sensitive to different processes, or, what amounts to be the same, it should not be assumed that more frequent use of reappraisal in daily life, as subjectively perceived by the individual, is indicative of a more efficient reappraisal in the laboratory task.

In a similar vein, individual differences in baseline HRV (B0) showed no direct or inverse correlation with any of the constructs of interest, with $BF_{10} < 1/3$ for six of the seven

correlations present, against the customary prediction that higher HRV values are indices of emotional flexibility and adaptiveness in the general population.

Course of HRV with time-on-task

In general, HRV increased throughout the task, as reflected by the fact that proportional change HRV measures in B1–B4 (all computed with pre-task B0 as reference) were positive on average. This finding is, in appearance, counterintuitive, as HRV has been consistently shown to decrease with mental workload (Mulcahy, Larsson, Garfinkel, & Critchley, 2019), and subjective estimates of mental workload, in turn, increase with the fatigue that accumulates with increasing time on task (Luque-Casado, Perales, Cárdenas, & Sanabria, 2016).

However, a recent systematic review of the effect of time-on-task on HRV reveals a more nuanced picture (Csathó, Van der Linden, & Matuz, 2024). Most studies in this review found HRV (and particularly, rMSSD) to increase as time accumulates in cognitive tasks, even in cases in which task performance decreases and subjective fatigue increases as the task progresses. The authors formulated two possible explanations for this effect. According to the first one, mental fatigue would be primarily associated with an enhanced parasympathetic tone, which is reflected in temporal dominance indices such as rMSSD. Alternatively, parasympathetic dominance could result, not from fatigue itself, but from disengagement from the task as fatigue accumulates and motivation to perform well decreases. Supporting this argument, a recent study has found that an increase in HRV during a response inhibition task was linked to an increase in subjective mental fatigue, a worsening of task performance, and a decrease in brain activity associated with response inhibition (Van Cutsem et al., 2022).

Results from our study should be interpreted in light of these findings. In addition, it must be taken into account that, to avoid contamination from differences in task load between high-load and low-load blocks, time-locked HRV measures were taken during return-to-baseline intervals, so they do not reflect acute load caused by the task, but its residual effects (e.g. carryover mental fatigue). Keeping that in mind, our results suggest that the course of HRV during the experimental task was not compellingly influenced by most constructs of interest (gambling problems' severity, craving, negative urgency, and ERQ reappraisal). The only exceptions were the effect of positive urgency and the interaction between time and expressive suppression. In both cases, poorer emotion regulation (heightened positive urgency and more frequent use of suppression) strengthened the effect of task course on HRV (with the difference between high- and low-urgency individuals showing up as early as in B1, and remaining approximately constant during the rest of the task; and the difference between high- and low-suppression arising from B2 on).

Although any interpretation of these results is still tentative, the lack of association between time-related HRV measures and gambling problems and craving is in line with the lack of correlation of these variables with any other

measures of intentional emotion regulation. In other words, people with more severe gambling-related problems and urges (at least in our sample of community gamblers) do not seem to undergo a stronger impact of the mental fatigue caused by a lab-based emotional task. Nonetheless, poorer regulation of positive emotions (as measured by positive emotion-driven impulsivity) and a more frequent use of suppression, regardless of gambling problems, are associated with heightened time-related task effects. Tentatively, and in line with Van Cutsem et al.'s (2022) account, these participants could find the task more demanding or distressing, so they are more prone to disengage from it.

Linear regressions

The results of the first set of regression analyses did not provide substantial evidence to support or reject severity of gambling problems as a predictor of the dispositional use of cognitive reappraisal or expressive suppression. Additionally, there was no evidence suggesting an interaction effect between gambling problems' severity and positive or negative urgency on those dispositional emotion regulation measures.

In a second set of regressions, the vmHRV difference between high- and low-load blocks was used as a potential index of HRV sensitivity to the allocation or cognitive resources to emotion regulation efforts (which was expected to be higher for blocks containing a 50% of *regulate* trials than for blocks containing a 50% of *experience* trials). These regressions did not provide substantial evidence in favor or against effects of any of the constructs of interest. So, the prediction, directly derived from Navas, Contreras-Rodríguez, et al.'s (2017) fMRI results, that participants with more severe gambling problems, and especially those showing higher levels of negative urgency and dispositional use of suppression, would suffer a more pronounced decrease in vmHRV in high-load blocks was not confirmed.

CONCLUSIONS

Results are globally consistent in providing no support for the involvement of intentional emotion regulation in gambling problems in active community gamblers. Moreover, this lack of substantial relations between gambling problems and craving with intentional emotion regulation was observed at three different behavioral levels: (1) dispositional use of intentional emotional regulation strategies as measured by the ERQ, (2) performance in a cognitive reappraisal task involving the active implementation of an emotional regulation strategy, and (3) vmHRV changes potentially associated to the cognitive effort associated with such an implementation.

It is important to stress, however, that the absence of conclusive evidence must not be interpreted as evidence of its absence. In other words, the possibility that this absence of evidence is due to lack of sensitivity must not be prematurely discarded. This potential lack of sensitivity may

arise from the relatively small sample size (especially in analyses involving HRV measures), as well as from increased measurement error in scores from scales with relatively low internal reliability (mainly the ERQ reappraisal dimension). Despite this potential limitation, our design was sensitive enough for gambling problems and craving to substantially correlate with urgency (and especially with positive urgency, replicating our previous results), and positive urgency and the propensity to use of suppression were associated with a stronger effect of time-on-task on vmHRV, with both effects surviving quite stringent robustness checks across a wide range of prior dispersion values.

Actually, Bayesian tests were intentionally adopted here to discriminate between putative effects for which we have no conclusive evidence of a link (those with BFs in the anecdotal evidence range) and those for which we have non-trivial evidence supporting their inexistence (those with BFs below the 1/3 or 1/10 threshold, depending on whether the analyses are primarily exploratory or confirmatory). Throughout the whole analysis and reporting process, transparency regarding the analytical decisions has been prioritized, while trying to avoid overstatements concerning the interpretation of results, and to disclose all relevant results regardless of their evidential value or whether they supported or not our previous findings or hypotheses.

All in all, the general pattern of results tends to align with previous reports failing to find meaningful associations between the severity of problems derived from putative addictive behaviors and neurocognitive transdiagnostic dimensions in community participants (Christensen et al., 2024). In general, community participants distributed across the severity continuum (even though a significant part of them may present severity scores above the threshold for a positive screening) are less likely to present many of the complications or comorbidities that characterize clinical samples (i.e. individuals who are currently in treatment or have sought for professional help). So, the finding of differences in such transdiagnostic dimensions in case-control studies, but much more restricted or null associations between them and continuous severity scores ranging from non-problematic to compulsive levels of the activity, could suggest that these neurocognitive factors could be more related to features of the clinical samples than to the progression of specific activities towards compulsivity. In line with that argument, a recent systematic review has found no or inconsistent longitudinal associations between neurocognition and behavioral-addiction-related outcomes (Christensen et al., 2023).

Another important factor to be taken into account is the heterogeneity in participants' psychological features and gambling preferences both within and between studies. Most etiological models (e.g. Blaszczynski & Nower, 2002; Navas et al., 2019) highlight the importance of emotional vulnerability and difficulties in coping with negative emotions in the development of gambling problems. However, there is also extensive evidence that a subgroup of problem gamblers (prototypically younger, with a preference for strategic games, and with a more distorted perception of their own

gambling abilities; see Navas, Billieux, et al., 2017) are more driven by appetitive gambling-related motives than by negative ones. This interpretation is reinforced by our consistent finding that positive urgency is more predictive of gambling craving than negative urgency. Unfortunately, the importance of mechanisms for the regulation of positive emotions has been mostly neglected (for similar arguments, see Weiss, Forkus, Contractor, & Schick, 2018; Zou, Plaks, & Peterson, 2019).

To summarize, our study has provided results that differ from our original hypotheses, but are consistent with research conducted on similar samples. Our findings shed light on the source of the apparent inconsistency in results found in the existing literature. Therefore, it is important to exercise caution when interpreting and generalizing these results across substantially different samples.

Limitations and strengths

Our study is not exempt from potential shortcomings. The first of them has to do with the limitations of self-report measures. When responding to questions regarding disposition emotional regulation (ERQ), participants need to make a retrospective evaluation of the emotional regulation strategies they use in daily life. However, it is a well-known fact that emotion regulation problems in some individuals have to do with their poor emotional metacognition. Moreover, during this process, self-perception could be affected by desirability and ego-protective biases. To mitigate the tendency to seek approval from the experimenter, the questionnaires were individually and privately administered, and instructions emphasized the importance of responding with utmost honesty, and stressed that there were no inherently good or bad responses.

Problems attributable to retrospective recall are less of a problem in the cognitive reappraisal task, as participants provide immediate scores. However, as performance in the task is ultimately measured as a difference between self-report scores, these are also sensitive to biases (and particularly to a tendency to comply with what participants perceive as the task demands). These problems are partially surpassed by the use of HRV. Unfortunately, the lack of sensitivity of HRV measures to regulation-related activity does not allow to distinguish potential sensitivity problems in the measurement from actual lack of effects of the predictors of interest.

A second potential limitation has to do with the recording of EEG activity during the experimental reappraisal task (data not yet analyzed). Fitting the 64-electrode cap used for EEG recording took between 30 and 60 min for each participant, depending on the difficulty of achieving sufficiently low impedance at each electrode. This pre-experimental phase could have caused psychophysiological reactions that might subsequently influence the baseline of HRV recorded at rest just before the task initiation. It is possible that the vmHRV measure was reflecting a response to potential discomfort experienced during the cap placement, or other unpleasant sensations such as fatigue or boredom.

A third limitation arises from the selection of community gamblers for our study. Although the sample comprised gamblers across a broad spectrum of severity (with a mean SOGS score of 5), the majority of them were young gamblers, with college education, and with a preference for skill games (e.g., poker, other card games, and sports betting, with few exceptions). This sample composition has surely overrepresented certain endophenotypes, and could limit generalizability to more diverse populations, or those consisting of gambling disorder patients.

A fourth limitation relates to the underrepresentation of women in our sample, which may limit the generalizability of our findings to this population. Given that women are more likely to engage in non-strategic forms of gambling (Baño et al., 2021; Grant, Chamberlain, Schreiber, & Odlaug, 2012; Jimenez-Murcia, Granero, Fernandez-Aranda, & Menchon, 2020; Odlaug, Marsh, Kim, & Grant, 2011; Subramaniam et al., 2016), future research should aim to include larger, gender-balanced samples or focus specifically on women. Such efforts would facilitate a more nuanced examination of gender-specific relationships between gambling behaviors and emotion regulation strategies.

In this sense, gender differences in gambling behaviors and emotion regulation strategies may be influenced by broader psychological and sociocultural factors (but see, for example, Toneatto & Wang, 2009; Vintró-Alcaraz et al., 2022; Moragas et al., 2015). For instance, women may experience greater stigma or societal pressure regarding gambling, which could affect both the way they engage in gambling and the strategies they use to regulate their emotions. Men, by contrast, may display gambling behaviors more strongly driven by risk-taking and reward-seeking motives (Hing, Nuske, Gainsbury, & Russell, 2016; Holdsworth, Hing, & Breen, 2012; Merkouris, Thomas, Browning, & Dowling, 2016). In any case, gender differences in emotion regulation strategies appear to emerge from complex interactions between individual, contextual, and motivational variables, rather than gender *per se*. Although our study did not specifically examine these nuances due to the limited number of women in the sample, future research addressing gender differences could yield valuable insights.

Five, the complexity and length of the research protocol made recruitment slow and difficult. Based on a power analysis for a related study, we set the desirable sample size at 70 participants. However, two of them failed to attend their appointment, and the HRV records from 14 more were not usable. This left sample sizes of $n = 68$ and $n = 54$ for behavioral and psychophysiological measures, respectively. To partially remediate this problem, we opted for Bayesian analyses, that allow for assessment of the evidential strength for the alternative and the null hypothesis in a continuous fashion. We have been careful not to over-interpret Bayes factors that fell within the negligible evidence range.

Our study also presents some notable strengths. The most important of them is the study of emotion regulation strategies using a variety of measures (self-report, lab-task-based, and psychophysiological). Confidence in our results is supported by the consistency of results across levels, despite

the fact that most of them go against our hypotheses. Additionally, all data and analyses are available without restrictions for reanalysis or aggregation by other teams if necessary.

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Data availability: The open database, along with the primary and supplementary analyses, additional results and tables, as well as the code files used for these analyses, are available in the Open Science Framework repository at <https://osf.io/em9br/>.

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SUPPLEMENTARY MATERIALS

Supplementary files and data to this article can be found online at https://osf.io/em9br/?view_only=87dda3273b4e4dd7ae488ed1ccd8987f.

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