Basic mechanisms of emotional regulation in gambling behavior: implications for learned compulsivity and gambling cognitions

DOCTORAL DISSERTATION

Basic mechanisms of emotional regulation in gambling behavior: implications for learned compulsivity and gambling cognitions

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Abstracts

Abstract

In 2013, Gambling Disorder was included in the chapter on Addictive and Substance-Related Disorders in the Diagnostic and Statistical Manual of Mental Disorders (DSM-V). This inclusion reflects a consensus on its addictive nature and constitutes a crucial step both practically and theoretically. However, this advancement appears insufficient. Given the increase in its prevalence, especially in specific population sectors, Gambling Disorder requires improvements in prevention and treatment strategies. Additionally, a better characterization of the underlying processes contributing to gambling becoming a disordered behavior is needed.

The general objective of this dissertation aims to address this issue. The studies focus on examining the processes involved in the aggravation of gambling, in which there are considerable gaps in knowledge. Understanding the etiology of the signs, symptoms, and behaviors in the heterogeneous population of individuals with gambling problems, based on understanding their causes and the processes that sustain them, could facilitate more effective treatments for alleviating this condition.

This thesis is structured as follows. The Introduction section presents various constructs linked to the maintenance and development of problematic gambling, which, although fundamental, are not directly part of the diagnostic criteria for Gambling Disorder. First, the construct of gambling-related cognitions is addressed, and various hypotheses about their possible etiology are proposed. Secondly, the transition from goal-directed behavior to

compulsive behavior is described as the core of the addictive process, encompassing the processes and elements according to the most studied scientific models in substance use disorders and their fit in Gambling Disorder. Additionally, the concept of craving is introduced as a potential driver of learned compulsivity. Finally, different mechanisms of emotional regulation are described, and how alterations in these mechanisms could underlie problematic gambling is discussed, based on existing empirical data.

In a second section, the motivation, justification, objectives, and hypotheses of this thesis are established, linked to the study of the mentioned constructs. These constructs are addressed in five studies, framed in four chapters, which constitute the fundamental core of this thesis.

Study I explores the association between abstract and probabilistic reasoning and gambling-related cognitions and whether the relationship between cognitive abilities and distortions depends on the level of gambling involvement. Significant differences were found in gambling-related cognitions between non-problematic gamblers and those diagnosed with Gambling Disorder, regardless of their reasoning abilities. The correlations between reasoning skills and distorted cognitions were mostly null, suggesting that these cognitions do not emerge from cognitive impairments.

Study II aims to understand and operationalize compulsivity in behavioral addictions, specifically in gambling, through a systematic review. Psychometric instruments related to this construct were analyzed, distinguishing six operationalizations of compulsivity. Items fitting these operationalizations were selected to develop and validate a compulsivity scale aimed at measuring this construct in behavioral addictions, a goal addressed in **Study III**. The Granada

Assessment for Cross-domain Compulsivity (GRACC90) scale was developed and validated, confirming that compulsivity fit better into a unidimensional model and that compulsivity scores correlated with other constructs as expected.

Study IV aimed to replicate and expand the findings of a previous study on the role of model-free emotional regulation in problematic gambling and the manifestation of craving. Associations between behavioral and psychometric markers were established. We found that positive urgency, used as a proxy for model-free emotional dysregulation, correlated with craving and gambling severity. Positive urgency was also associated with slower extinction of conditioned associations to emotionally charged stimuli, reinforcing its role as a marker of these processes. We discovered that craving mediated the relationship between generalized emotional dysregulation and the severity of problematic gambling.

Study V aimed to examine the role of model-based emotional regulation and identify psychometric and psychophysiological markers associated with performance in a cognitive reappraisal task. No significant relationships were found between emotional regulation and problematic gambling symptoms, but the relationship between gambling severity, generalized emotional dysregulation, and craving was confirmed. The results suggest that some gambling populations maintain their capacity to use intentional emotional regulation strategies, albeit maladaptively.

Finally, the last chapter is reserved for discussing the findings, drawing general conclusions, and establishing their clinical and practical implications. Furthermore, future lines of research are proposed to address the open questions in the areas studied in this dissertation.

Resumen

En 2013, el trastorno por juego de azar fue incluido en el capítulo de Trastornos Adictivos y Relacionados con Sustancias del Manual Diagnóstico y Estadístico de Enfermedades Mentales (DSM-V). Esta inclusión refleja un consenso sobre su naturaleza adictiva y constituye un paso crucial tanto en términos prácticos como teóricos. No obstante, este avance no parece del todo suficiente. A la vista del aumento de su prevalencia, especialmente en sectores específicos de la población, el trastorno por juego de azar requiere mejoras en las estrategias de prevención y tratamiento. También, una mejor caracterización de los procesos subyacentes que contribuyen a que el juego se convierta en una conducta desordenada.

El objetivo general de esta disertación pretende abordar esta cuestión. Los estudios se dirigen a examinar aquellos procesos involucrados en el proceso de agravación del juego y en los que, hasta el momento, existen algunas lagunas considerables de conocimiento. Comprender la etiología de los signos, síntomas y comportamientos en la población heterogénea de los individuos con problemas de juego, y en base al entendimiento de sus causas y los procesos que las sustentan, podría facilitar tratamientos más efectivos para aliviar esta condición.

La presente tesis se estructura de la siguiente manera. En la sección de Introducción se presentan diversos constructos vinculados al mantenimiento y desarrollo del juego problemático, que aun siendo fundamentales, no forman parte de manera directa de los criterios diagnósticos del trastorno por juego de

azar. Primero, se aborda el constructo de las cogniciones relacionadas con el juego y se plantean diversas hipótesis sobre su posible etiología. En segundo lugar, se describe la transición del comportamiento dirigido a objetivos hacia el comportamiento compulsivo como núcleo del proceso adictivo, abarcando los procesos y elementos según los modelos científicos más estudiados en los trastornos por abuso de sustancias y su encaje en el trastorno por juego de azar. Además, se introduce el concepto de craving como posible motor de la compulsividad aprendida. Finalmente, se describen diferentes mecanismos de regulación emocional y se discute cómo las alteraciones de estos mecanismos podrían estar en la base del juego problemático, basándose en datos empíricos existentes.

En una segunda sección, se establecen la motivación, justificación, objetivos e hipótesis de esta tesis, y se vinculan con el estudio de los constructos mencionados. Estos constructos se abordan en cinco estudios, enmarcados en cuatro capítulos, y que constituyen el núcleo fundamental de esta tesis.

El **Estudio I** explora la asociación entre el razonamiento abstracto y probabilístico y las cogniciones relacionadas con el juego, y si la relación entre las capacidades cognitivas y las distorsiones depende del nivel de implicación en el juego. Se encontraron diferencias significativas en las cogniciones relacionadas con el juego entre jugadores no problemáticos y aquellos diagnosticados con trastorno por juego de azar, independientemente de sus capacidades de razonamiento. Las correlaciones entre habilidades de razonamiento y cogniciones distorsionadas fueron mayormente nulas, sugiriendo que estas cogniciones no emergen de alteraciones cognitivas.

El **Estudio II** tiene como objetivo comprender y operacionalizar la compulsividad en las adicciones comportamentales, específicamente en el juego de azar, mediante una revisión sistemática. Se analizaron instrumentos psicométricos relacionados con este constructo, distinguiendo seis operacionalizaciones de la compulsividad. Se seleccionaron ítems que encajaran en estas operacionalizaciones para desarrollar y validar una escala de compulsividad dirigida a medir este constructo en las adicciones comportamentales, objetivo que se aborda en el **Estudio III**. Se desarrolló y validó la escala GRACC90, confirmando que la compulsividad se ajustaba mejor a un modelo unidimensional y que las puntuaciones en compulsividad correlacionaban con otros constructos de la manera esperada.

El **Estudio IV** pretendía replicar y ampliar los hallazgos de un estudio previo relativos al papel de la regulación emocional model-free en el juego problemático y en la manifestación del craving. Se establecieron asociaciones entre marcadores conductuales y psicométricos. Encontramos que la urgencia positiva, utilizada como proxy de la desregulación emocional model-free, correlacionaba con el craving y la gravedad del juego. La urgencia positiva también se asoció con una extinción más lenta de asociaciones condicionadas a estímulos cargados emocionalmente, reforzando su papel como marcador de estos procesos. Descubrimos que el craving mediaba la relación entre la desregulación emocional generalizada y el nivel de severidad del juego problemático.

El **Estudio V**, por su parte, pretendía examinar el papel de la regulación emocional model-based e identificar marcadores psicométricos y psicofisiológicos asociados con el rendimiento en una tarea de reappraisal cognitivo. No se encontraron relaciones significativas entre la regulación emocional y los síntomas del juego problemático, pero se confirmó la relación entre la gravedad del juego, la desregulación emocional generalizada y el craving. Los resultados parecen sugerir que algunas poblaciones de jugadores mantienen intacta su capacidad de usar estrategias de regulación emocional intencional, aunque de manera desadaptativa.

Finalmente, el último capítulo se reserva para discutir los hallazgos, extraer conclusiones generales y establecer las implicaciones clínicas y prácticas de los mismos. Además, se proponen futuras líneas de investigación que permitan responder a aquellas preguntas que permanecen abiertas en los ámbitos estudiados en esta disertación.

CHAPTER I:

General Introduction

Unveiling the fundamentals: a comprehensive introduction to the concept of gambling disorder

The year 2013 witnessed a significant milestone in the study and diagnosis of mental disorders. For the first time, the chapter dedicated to substance-related disorders (including addictive disorders) in the Diagnostic and Statistical Manual of Mental Disorders (DSM-V; American Psychiatric Association, 2000) was re-conceptualized and expanded to incorporate gambling disorder. Until that point, pathological gambling (as it was previously known) was categorized under the label Impulse-control disorders not elsewhere classified (DSM-III, IV and IV-TR; American Psychiatric Association, 1980, 1994, 2000). This adjustment was not arbitrary but instead addressed a long-standing debate that had been simmering among the scientific community for several years (i.e., whether those disorders that do not involve substances but share clinical, phenomenological, and biological characteristics with substance abuse or dependence should be considered addictions; Potenza et al., 2009; Fauth-Bühler, Mann & Potenza, 2016; Gottheil et al., 2007; Petry, 2006, 2007). The inclusion of gambling disorder in this category resulted from various factors and marked a resolution to this controversial question.

At that time, the characterization of pathological gambling had, for several years, been treading a fine line that placed it on a theoretical boundary between two diagnostic categories. On the one hand, the defining and constitutive feature of the disorder was the loss of control over gambling behavior, explicitly described as "*a chronic and progressive failure to resist impulses to gamble,*" a failure that "*compromises, disrupts, or damages* *personal, family, or vocational pursuits,"* which, in other words, would significantly impair the individual's functioning across a multitude of life domains (APA, 1980, p. 324; also McGarry, 1983; National Research Council, 1999). On the other hand, empirical evidence leaned in the opposite direction, pointing strongly towards an evident similarity with substance use disorders based on significant common elements of a different nature. In the following section, as an introduction to this thesis, a synthesis of those factors that tipped the balance toward characterizing pathological gambling as an addictive disorder will be presented. These factors are considered essential for understanding the current context of the scientific literature in this field of knowledge.

From impulse control to addictive disorders: towards a new characterization of pathological gambling

Broadly speaking, two factors contributed to the reclassification of pathological gambling as an addictive disorder.

The first of these is the *de facto* confirmation that many diagnostic criteria for pathological gambling share similarities with those for substance use and dependence el-Guebaly et al., 2011; Blaszczynski et al., 2007; Wareham & Potenza, 2010; Goudriaan, van den Brink, & van Holst, 2019; Grant & Chamberlain, 2015). This was unsurprising since this evolution traces back to the inception of pathological gambling as a distinct diagnostic category in DSM-III (Chóliz, 2014), where the criteria primarily focused on several direct negative consequences of monetary losses (e.g., the inability to meet debts, family conflicts, or neglect of financial responsibilities) and the need for economic resources to manage them (e.g., resorting to obtaining money through illegal means; APA, 1980). However, with the publication of the DSM-III-R, the diagnostic criteria adopted a significantly different emphasis, expanding to include more indicators specific to substance dependence disorders (APA, 1987; Ridenour et al., 2008; Sim et al., 2012). This shift aimed to address the need to provide a more comprehensive description of the disorder while emphasizing its similarity to substance-related disorders in terms of diagnostic criteria (Chóliz, 2014). Subsequent editions of the diagnostic manual introduced several refinements, eliminating redundancies and improving the precision and objectivity of certain criteria. However, with the publication of the DSM-IV-TR (APA, 2020), the overlap between these criteria and those of substance use disorders remained evident (Goudriaan, van den Brink & van Holst, 2019).

For instance, among the diagnostic criteria that were either common or closely related to those included in various addictive disorders, we observed *tolerance* (playing with increasing amounts to achieve the desired excitement, similar to needing markedly greater amounts of the substance to achieve the desired intoxication or effect); *withdrawal syndrome* (experiencing restlessness or irritability when attempting to reduce or stop playing, resembling the development of a substance-specific withdrawal syndrome due to intense or prolonged cessation or reduction of substance use); *loss of control over behavior* (repeated unsuccessful efforts to control, reduce, or stop playing, comparable to a persistent desire or unsuccessful efforts to reduce or control substance use); maintenance of problematic activity despite negative consequences; and interference with daily functioning (Romanczuk-Seiferth, van den Brink & Godriaan, 2014; Goudriaan, van den Brink & van Holst, 2019).

Other criteria are relevant and do not correspond to the two diagnostic labels, either because they reflect the unique nature of the gambling activity itself or because they are linked to certain unresolved issues that are considered important. For example, *loss-chasing* (i.e., the tendency to return immediately to gambling or increase bets in an effort to recover losses; Zhang et al., 2020) falls into the first category. This criterion has been present in the diagnostic criteria for gambling since the publication of the DSM-III-R but is absent from the criteria for other addictive disorders for obvious reasons. Another example is the tendency to gamble as a means to escape from problems or alleviate feelings of distress. This criterion has been reformulated in the latest edition of the DSM as "often gambles when feeling distressed" and is also absent from the criteria for substance abuse (e.g. Buchanan et al., 2020), where *craving* (e.g., irresistible desire or craving for the substance) has become part of the diagnostic profile. This criterion was introduced in the DSM-5 and presents an interesting case. While a substantial body of literature suggests that craving or an intense desire to gamble could be integral to gambling problems, this issue has been set aside, at least for the time being, due to insufficient evidence regarding its etiology and other intrinsic aspects of its characterization (e.g. see Goudriaan, van den Brink, & van Holst, 2019). Craving and other factors seemingly central to addictive processes (such as cognitive biases related to gambling or emotional dysregulation problems) will be addressed in later sections of this manuscript.

In addition to nosological issues, the second factor driving the reclassification of pathological gambling as an addictive disorder resulted from a wealth of multidisciplinary research spanning various fields. Findings from epidemiology, biology, clinical and experimental psychology, and neuroscience, among others (Grant et al., 2010; Leeman & Potenza, 2012; Romanczuk-

Seiferth, van den Brink, & Goudriaan, 2014), played a pivotal role in shifting the debate toward recognizing pathological gambling as a behavioral or "non-chemical" addiction (Goudriaan, 2004; Potenza, 2013). Even at that time, evidence of similarity between pathological gamblers and substance abusers at the behavioral and (neuro)cognitive levels had emerged, namely (1) the presence of high impulsivity and trait compulsivity (Petry, 2001;; Whalter, Morgentern & Hanewinkel, 2012; Lawrence et al., 2009; Fineberg et al., 2010; Brewer & Potenza, 2008; Verdejo-García, Lawrence & Clark, 2008), (2) numerous deficits in executive functions, such as inhibition, cognitive control, working memory, planning, cognitive flexibility, and decision-making (Fauth-Buler, Mann & Potenza, 2016; Brand et al., 2005; Brewer & Potenza, 2008; Goudriaan et al., 2006), (3) heightened salience of stimuli related to the problematic activity compared to other rewarding stimuli, linked to (4) an apparent impairment of reward and punishment processing (Ruiter et al., 2009; van Holst et al., 2010a; van Holst et al., 2010b; van Holst, 2011; Joutsa et al., 2012; Wolfling et al., 2011; Littel et al., 2012), and (5) the persistence of gambling behavior despite negative consequences, or repeated unsuccessful attempts to reduce its frequency or eliminate it entirely (Potenza, 2003; van Holst et al., 2010; Fauth-Buler, Mann & Potenza, 2016).

Additionally, numerous studies have examined the functional and structural neurobiological features underlying pathological gambling, revealing overlaps with other substance use disorders (Leeman & Potenza, 2012). The evidence has increasingly implicated multiple neurotransmitter systems (e.g. dopaminergics, glutamatergic, serotoninergics, noradrenergics, opioidergics) as key players in the pathophysiology of pathological gambling (Petry, 2007;

Potenza, 2008; Zack & Poulos, 2009; Wareham & Potenza, 2010). At the same time, neuroimaging research has revealed deficits in the mesolimbic reward system, a hallmark of drug addiction. Studies in this domain have demonstrated decreased volume of structures such as the ventral striatum and ventromedial prefrontal cortex, along with hypoactivation of the ventrolateral prefrontal cortex. These findings suggest a weakened neurophysiological response to rewards and losses (Reuter et al., 2005; De Ruiter et al., 2009; Leeman & Potenza, 2012). Moreover, these neurobiological findings directly or indirectly correlate with the symptomatological and behavioral similarities reported in the previous paragraph.

Taking all these data together, it became apparent that maintaining pathological gambling within the category of impulse control disorders was not supported by clinical or empirical evidence, nor did it align with the findings yielded by the scientific literature thus far. While pathological gambling was associated with the presence of difficulties in impulse control, it was also characterized by distinct features more closely resembling those related to substance use or consumption disorders (which also included this feature). In essence, it appeared to correspond to a distinct entity distinguished by the unique combination of already existing semiological characteristics: a behavioral or non-substance addictive disorder.

Gambling disorder: a “young” addiction (that) is on the rise

As mentioned at the beginning of this introduction, the latest edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-V; American Psychiatric Association, 2013) included significant changes. In particular, pathological gambling (renamed *gambling disorder*; see Petry et al., 2013 for the rationale behind the new designation) was reclassified and moved to the *Substance-Related and Addictive Disorders* category. Consequently, gambling disorder became the only recognized non-substance-related addictive disorder (currently conjoined by Internet Gaming Disorder, present in the International Classification of Diseases, 11th Revision, ICD-11; World Health Organization, 2018). Within this latest edition, gambling disorder is defined as a pattern of persistent and recurrent problem gambling behavior leading to clinically significant impairment or distress.

This definition is accompanied by nine diagnostic criteria, namely: 1) Needs to gamble with increasing amounts of money to achieve the desired excitement; (2) Feels restless or irritable when attempting to cut down or stop gambling; (3) Has made repeated unsuccessful efforts to control, cut back, or stop gambling; (4) Frequent gambling preoccupations, such as persistent thoughts about reliving past gambling experiences, anticipating or planning the next gamble, and thinking about ways to get money to gamble; (5) Often gambles when feeling distressed (e.g., helpless, guilty, anxious, depressed); (6) After losing money gambling, often returns another day to get even ("chasing" one's losses); (7) Lies to conceal the extent of gambling involvement; (8) Has jeopardized or lost a significant relationship, job, or educational or career opportunity because of gambling; and (9) Relies on others to provide money to relieve desperate financial situations caused by gambling (American Psychiatric Association, 2013).

This enumeration of criteria includes aspects that resemble those related to substance use disorders, such as tolerance (1), withdrawal syndrome (2), loss of control over behavior (3), and the persistence of behavior despite negative consequences (8). However, as mentioned in the previous subsection, criteria (5) and (6) refer specifically to behaviors related to gambling.

The DSM-5 also brought about several adjustments concerning various issues pertinent to addictive disorders in general and gambling disorders in particular. Specifically, the criterion related to the commission of "*illegal acts (...) to finance gambling*" was eliminated, prompting debates among clinicians and researchers regarding its relevance (Petry et al., 2013; Substance Abuse and Mental Health Services Administration, 2016). Moreover, the dichotomous classification of substance abuse and dependence as separate disorders was discarded and replaced instead by indicators or levels of severity. Consequently, in the present case, gambling disorder could be considered mild (meeting 4-5 diagnostic criteria), moderate (meeting 6-7 criteria) or severe (meeting 8-9 criteria; Hasin et al., 2013; Petry et al., 2013). Finally, an additional change in the wording of the criteria compared to previous versions mandates explicit acknowledgment that symptoms must be recurrent over one year (Petry et al., 2013). Unsurprisingly, this alteration has had profound implications for societal perceptions of problem gambling since 2013 and for quantifying the prevalence of gambling.

Prevalence and state-of-the-art

The prevalence rates of problem and pathological gambling vary according to different sources of information, influenced by factors such as the year of data collection, methodological approaches, the types of analyses conducted, and the instruments used to assess the severity of the disorder. Despite this variability, it is possible to obtain a general idea of the global presence of problem and disordered gambling across various societies and cultures.

Currently, the estimated average prevalence of adult problem and pathological gamblers worldwide is 1.29% (with predictive values ranging from 0 to 4.17%). For individuals classified as at-risk and moderate-risk gamblers, the mean prevalence rate is 2.43%. These figures, obtained from studies published between 2016-2022, represent a slight deviation from the conclusions drawn from the most recent systematic review, which evaluated prevalence studies published between 2000 and 2015 across five continents (Calado & Griffiths, 2016). According to that review, between 0.1 and 5.8% of individuals met diagnostic criteria for pathological gambling in the year preceding the survey, while between 0.7% and 6.5% were projected to meet such criteria during their lifetime. In Europe, prevalence rates ranged from 0.1 to 3.4% during that period.

In Spain, the most recent national, statewide prevalence study conducted in 2022 indicates that 0.97% of gamblers meet the diagnostic criteria for gambling disorder (Secades-Villa et al., 2023). The current prevalence rate is, therefore, slightly higher than the 0.72% reported by Chóliz et al. (2021), whose data were collected in 2015, a period when online gambling was less widespread than it is today.

In this regard, various reports suggest a projected slight increase in prevalence at the state or global level over the coming years (Observatorio Español de las Drogas y las Adicciones, 2022, 2023). While concerning, this prediction is not surprising. Presently, gambling disorder is already recognized as an escalating mental health problem, accompanied by an increasing social and healthcare burden (Wardle et al., 2018).

The rising impact of gambling on societies (physical and virtual) is attributed, in part, to several factors. Notably, the transformation of the gambling world, propelled by gambling operators, appears to be driving a shift in its sociodemographic and behavioral landscape (Calado et al. 2017). In this regard, the omnipresence of gambling in leisure culture, the emergence of new and increasingly accessible forms of gambling, and the unprecedented proliferation of advertising on television and social networks targeting particularly vulnerable groups all appear to directly influence and compromise gamblers' betting behaviors (López-González, Estévez, & Griffiths, 2017).

Specifically, the transformation in gambling marketing is significantly related to the situational and structural characteristics of the product and the techniques employed to promote it (López-González, Estévez, & Griffiths, 2017). Situational factors include convenience, ease, and rapid accessibility (e.g., betting from home via mobile devices) and uninterrupted betting opportunities (e.g., competitions accessible 24 hours a day). Additionally, the implementation of various payment methods (e.g., electronic transfers and credit cards) and the option to maintain privacy and anonymity (thereby avoiding the social stigma traditionally associated with gambling) are significant factors. Structural factors, on the other hand, refer to the inherent features of the gambling activity (see **Section 3** of the **Introduction** for a more extensive analysis). These factors cover several aspects, such as the opportunity to increase betting frequency or engage in parallel betting (e.g., combined bets, accumulators, and placing wagers on events of short duration that favor faster reward mechanisms). Moreover, the option to engage in in-play or contextual betting (e.g., placing bets before and during a soccer match or on specific outcomes during the course of an event) or make use of functionalities such as *cash-out* (e.g. enabling the withdrawal of bets before the conclusion of an event) have helped shape the evolution of gambling markets (e.g. Newall, Russell & Hing, 2021; Clark & Zack, 2023).

Of special interest among the structural factors are the predetermined designs of certain gambling devices that generate *near-miss events.* These events, such as loss situations perceived as close to success by the player (e.g., obtaining a "cherry-cherry-lemon" sequence in a slot machine; Foxall & Sigurdsson, 2012; Pisklak, Yong, & Spetch, 2019), are known to encourage loss-chasing, create the illusion of an imminent win, and trigger cognitive biases or fallacies associated with gambling (Clark et al., 2014; Amazue et al., 2021; Banerjee et al., 2023; for an exception, see Stange & Dixon, 2020)

These cognitive biases, which are also exploited by marketing strategies in the gambling industry (López-González, Estévez, & Griffiths, 2017), could play an important role in the maintenance of gambling behavior. However, despite their association with problem gambling, neither their etiology nor their specific contribution to such behavior is clearly understood. Put simply, there is currently insufficient evidence to conclusively establish whether these biases emerge as a consequence of repeated engagement in gambling or whether they represent a predisposing factor for developing a problematic relationship with gambling.

Dysfunctional cognitions about gambling

Gambling-related cognitions are one of the distinctive factors inherent to problem gambling. These cognitions not only contribute to the diversity seen among individuals with gambling disorders but also differentiate them from those dealing with substance-related addictive disorders (Toneatto, 1999; Wareham & Potenza, 2010).

The term “cognitive distortions” or “cognitive biases” refers to irrational ways of thinking that promote or perpetuate dysfunctional behaviors in general (Fortune & Goodie, 2012), interfering with optimal decision-making and judgment. Specifically within the context of gambling, these are often referred to as "gambling fallacies" or "gambling-related cognitive distortions" (although these terms may be used interchangeably, a distinction can be seen in Leonard, Williams & Voke, 2015). They include false perceptions, thoughts, or beliefs regarding gambling outcomes or their correlation with one's behavior or other environmental events (Goodie & Fotune, 2013). These cognitions are expressed as affirmations about the gambler’s ability to predict or control chance-based outcomes or as misinterpretations or illogical decision-making that encourage continued participation in gambling despite losses or other negative consequences (Hodgins, Stea & Grant, 2011; Ledgerwood et al., 2019; Shaw et al., 2022; Philander & Gainsbury, 2023).

Types of distorted cognitions and implications

In recent decades, numerous authors have attempted to identify and classify cognitions associated with gambling (Griffiths, 1994; Pinke, 2002; Toneatto et al., 1997; Steenbergh et al., 2002). These efforts have resulted in the emergence of three primary areas of interest.

First, many gamblers hold unreasonably high expectations regarding personal probability of success, surpassing what might be justified based on objective probability (Langer, 1975). They tend to overestimate their degree of control over the outcomes of events, often attributing it to their perceived skill, ability, or knowledge (Ladouceur et al., 1984; Steenbergh et al., 2002; Toneatto et al., 1997). Second, some gamblers believe they can accurately predict outcomes by relying on internal or external salient cues (for example, intuitions, feelings, hunches, weather phenomena; Toneatto, 1997; Joukhador, Blaszczynski, & Maccallum, 2004; Armstrong, Rockloff, & Browne, 2020; McInnes, Hodgins, & Holub, 2013) or due to an inadequate understanding of probability and randomness (for example, the gambler's fallacy, the hot-hand fallacy, or false contingencies; Griffiths, 1994; Raylu & Oei, 2004; Toneatto, 1997). Finally, many players tend to exhibit an interpretive bias, attributing their successes to their own skill while attributing losses to external factors (Gilovich, 1983; Toneatto, 1997). This tendency may motivate them to persist in gambling activity despite continued losses.

In 2004, Raylu and Oei developed and validated the *Gambling Related Cognitions Scale* (GRCS), one of the most widely used questionnaires for assessing cognitive distortions in gambling. The GRCS is composed of five subscales or dimensions: (1) *interpretative bias* (IB), which refers to the reformulation of gambling outcomes in a way that encourages further gambling; (2) *illusion of control* (IC), which involves the belief that an individual can influence gambling outcomes through skill or the use of rituals or charms; (3) *predictive control* (PC), which refers to the belief that gambling outcomes can be predicted; (4) *perceived inability to stop gambling* (IS), which concerns beliefs about the powerlessness to control gambling urges; and (5) *gambling-related expectancies* (GE), which include any anticipated benefits from gambling (Goodie y Fortune, 2013; Raylu y Oei, 2004). The first three dimensions largely correspond to the three areas mentioned earlier and are similar to the categories identified by other researchers (Griffiths, 1994; Langer, 1975; Toneatto, 1997; Walker, 1992). However, IS and GE have their origins in instruments used to measure cognitions related to substance use and are not strictly considered cognitive biases or distortions. Nonetheless, their presence can also influence gambling behavior. Expectations — whether monetary or non-monetary (e.g., to feel better or escape from problems) — can serve as instrumental motives for gambling. At the same time, the perceived inability to stop reflects metacognition concerning one's ability to control their gambling behavior (Walters y Contri, 1998; Oei y Raylu, 2004; Oei y Burrow, 2000; Devos et al., 2020).

The PC dimension includes the "gambler's fallacy" and the "hot-hand fallacy" (Clark & Wohl, 2022). The former, also referred to as the Monte Carlo fallacy, revolves around the belief that, in random events, the streak or repetition of a specific outcome will be balanced by a tendency toward the opposite outcome (Ayton & Fischer, 2004; Oskarsson et al., 2009). For instance, if a coin toss results in "heads" four times in a row, it is considered more likely that the next toss come up "tails.” Similarly, after experiencing a series of losses, individuals may expect a winning event to occur soon, a phenomenon known as "negative recency." This perception may contribute to behaviors such as chasing losses since, after a series of monetary losses, one would expect that profit would be "on the way” (Clark, 2017). Conversely, and in line with the "positive recency" phenomenon, the "hot-hand fallacy" concerns the belief that if someone has been repeatedly successful in an activity or task (e.g., "being on a roll"), this streak is more likely to continue over time (Ayton &

Fischer, 2004; Croson & Sundali, 2005). For instance, if a person wins several hands in a row while playing poker, they may be perceived as "hot," and therefore, their winning streak is expected to persist in subsequent games.

Similarly, the IC dimension includes two other types of beliefs: superstitions related to the effectiveness of certain rituals or charms in enhancing the chances of winning and an exaggerated perception of one's ability to predict or influence gambling outcomes ("illusion of mastery"; Clark & Wohl, 2022; Langer, 1975). The conviction that one's actions can sway chance-based events can incentivize gambling for multiple reasons. Interestingly, an extensive body of research has shown that this bias does not arise solely from the act of making a choice itself but rather reflects pre-existing (illusory) beliefs. These beliefs tend to consider certain options as being more effective despite all options being functionally identical in reality (e.g. Klusowski et al., 2021; Goodman & Irwin, 2006; Ejova & Ohtsuka, 2019).

These distorted cognitions, along with others, exist to varying degrees in all gamblers, and their prevalence is positively correlated with the severity of problem gambling. They are considered key determinants in the etiology, development, and perpetuation of problematic or pathological gambling behaviors (Raylu & Oei, 2004; Michalczuk et al., 2011; Raylu et al., 2016; Goodie, Fortune & Shotwell, 2019; see Fortune & Goodie, 2012 for a review). It is, therefore, no coincidence that the situational and structural aspects of gambling have evolved to facilitate or enhance these cognitive distortions. Likewise, gambling-related cognitive biases are commonly targeted in commercial strategies (Landreat et al., 2009; Romo et al., 2016; Parke et al., 2016; Guillou et al., 2019; Billieux et al., 2011; López-Gónzalez, Estevez & Griffiths, 2017).

Gambling-related cognitions, along with other components, such as craving management or relapse prevention (Rash & Petry, 2014), serve as therapeutic targets in Cognitive-Behavioral Therapy (CBT; e.g. Menchon et al., 2018; Yakovenko & Hodgins, 2014; Chrétien et al., 2017). CBT, recommended by most clinical guidelines (Nathan & Gorman, 2015), is regarded as the approach with the strongest empirical support for treating gambling disorders, demonstrating its relative efficacy in reducing cognitive biases, gambling frequency, and the overall severity of gambling disorders in the short and medium term (Potenza et al., 2019; Grant & Odlaug, 2012; Cowlishaw et al., 2012; Yakovenko & Hodgins, 2014). However, CBT is not without limitations, including a decrease in long-term success and high rates of relapse and dropout. Additionally, studies that have focused solely on treating gambling-related cognitive biases have shown relatively low efficacy. In other words, it seems that prioritizing treatment for gambling-related maladaptive cognitions may not confer a therapeutic advantage (Toneatto & Gunaratne, 2009, Mallorquí-Bagué et al., 2020; Challet-Bouju et al., 2017). At this point, it seems reasonable to ask what role cognitive distortions play in problem gambling.

What role do cognitive biases play in gambling disorder?

Despite the clear link between problem gambling and the presence of dysfunctional cognitions about gambling, there remains a lack of consensus among experts in the discipline regarding the causal relationship between these variables. In both the scientific literature and general discourse, two different approaches have been proposed to explain this relationship, each offering an alternative account.

On the one hand, some researchers suggest that certain individuals may possess a heightened susceptibility to biases in general. This means that some people are inherently more prone to biases and errors, which could make them more vulnerable to developing gambling problems. These biases manifest specifically through distorted beliefs during gambling activities, which may stem from underlying cognitive differences or alterations that are not specific to the gambling domain but are present before and independent of gambling interactions. Conversely, others argue that biases related to gambling are highly specific to the game and do not necessarily reflect a general tendency toward biases.

On the other hand, and somewhat distinct from the previous viewpoint, some studies suggest that cognitive distortions associated with gambling could either cause or result from problem gambling. One perspective posits that cognitive biases are part of the root causes of problem gambling, essentially driving the manifestation of problematic gambling behavior and fueling the gambling activity itself. Alternatively, another proposal suggests that these biases emerge as a consequence of the escalation of gambling into compulsive behavior, essentially being driven by the gambling activity. This perspective opens up a third possibility, offering a bidirectional viewpoint. This perspective suggests that while cognitive biases may play a causal role, they alone are insufficient to fully explain gambling problems. In this scenario, cognitive distortions are both fueled by gambling itself and contribute to its exacerbation and perpetuation.

Cognitive distortions as a cause of gambling problems

The misperception of chance and probability forms the foundation of distorted cognitions associated with gambling (Fortune & Goodie, 2013). Consequently, if cognitive biases play a significant role in the development of problem gambling, training in abstract and probabilistic reasoning skills, coupled with preserved general cognitive functioning, could potentially protect individuals from developing gambling-related issues. Conversely, deficits in general domain intelligence or poor mathematical and probabilistic reasoning might facilitate the emergence of cognitive biases, thus increasing the likelihood of problem gambling (e.g. Orgaz, Estévez, & Matute, 2013; Lambos & Delfabbro, 2012; Donati et al., 2018).

To test these hypotheses, preventive and treatment interventions have been implemented to enhance these cognitive abilities (Donati & Chiesi, 2014; Ladouceur et al., 1999; Donati et al., 2018; Williams & Connolly, 2006), with researchers also exploring the associations between these variables more generally (Donati et al., 2018; Xue et al., 2012; Donati et al., 2014; Lambos & Delfabbro, 2012; Yakovenko et al., 2016). Although the evidence regarding the involvement of general domain or probabilistic reasoning in distorted gambling cognitions is somewhat limited, some indications support and refute this proposition.

Studies focusing on interventions conducted with non-gamblers have yielded mixed results. In certain instances, interventions targeting probabilistic reasoning have demonstrated a notable, albeit modest, impact on mitigating gambling-related biases (Donati & Chiesi, 2014; Donati et al., 2018) and reducing long-term gambling frequency (Donati et al., 2018). Conversely, another study revealed that while enhancing knowledge of probability and mathematics strengthened resistance to gambling fallacies, this improvement did not necessarily correlate with decreased gambling behavior (Williams & Connolly, 2006). In contrast, a cognitive treatment aimed exclusively at addressing misperceptions about perceived chance in five pathological gamblers yielded clinically significant reductions in the urge to gamble and gambling severity (Ladouceur et al., 1999).

The second group of studies, which sought to investigate the interconnections between the previously mentioned variables, also produced contradictory findings.

Regarding the role of cognitive distortions, results have suggested two distinct relationships with problem gambling. On the one hand, the presence of cognitive distortions appears to predict future gambling involvement more strongly than the reverse relationship (Yakovenko et al., 2016). On the other hand, one study indicated that cognitive distortions acted as a mediating factor in the association between the gambler's fallacy and superstitious beliefs about problem gambling behavior (although problem gambling was not directly correlated with these distortions; Donati et al., 2018). Concerning reasoning abilities, research has indicated that higher scores in fluid intelligence correlate with greater probabilistic reasoning ability, which, in turn, is associated with making more advantageous decisions in risky situations involving information about winnings, losses, and probabilities (Donati et al., 2014). Put simply, it seems that it is necessary for probabilistic reasoning ability to act as a mediator for intelligence to impact adaptive decision-making. Conversely, a study involving students demonstrated a positive correlation between using the gambler's fallacy during a task and higher cognitive abilities, such as intelligence and executive function (Xue et al., 2012). Similarly, another study found that pathological gamblers exhibited significantly more cognitive biases compared to other groups. However, this difference was not attributed to a lack of understanding of the probabilities of the gambling event or a deficit in numerical ability (Lambos & Delfabbro, 2012).

In summary, the scientific literature presents arguments for and against the proposition outlined in this section. However, the presence of mixed results prevents us from definitively implicating or discounting the role of probabilistic or domain-general reasoning in developing cognitive manifestations related to gambling and their contribution to the etiology of problem gambling.

Cognitive distortions as a consequence of gambling

The alternative proposal to the above suggests that gambling-related biases emerge and manifest as a consequence of the emotional and motivational dynamics inherent to problem gambling. To date, no study has directly addressed this possibility. However, this proposition has arisen from discussions surrounding the inconsistent findings of previous studies and observations of the sometimes paradoxical relationships between emotional regulation mechanisms and gambling-related cognitive biases (e.g. Ruiz de Lara, Navas & Perales, 2019; Buen & Flack, 2021; Jara-Rizzo et al., 2019).

Broadly speaking, most players are likely to experience more monetary losses than gains (e.g. Fiorillo et al., 2003). These losses and the problems stemming from them can lead to negative emotional states or, at the very least, ambivalent feelings (Rodda et al., 2018; Palomäki, Laakasuo, & Salmela, 2013).

Consequently, several studies have sought to clarify how players adapt to the emotional impact of these losses. In this regard, gambling-related cognitions may play a role in regulating emotions derived from gambling outcomes by potentially attenuating the emotional response to losses and other negative consequences while intensifying the emotional experience associated with gains (Navas et al., 2019).

For instance, amplifying expectations about gambling may assist the gambler in mentally offsetting losses and other adverse consequences experienced thus far with the perceived future benefits of gambling, whether monetary or otherwise. This could include playing to alleviate negative emotions, experiencing excitement, avoiding boredom, or gaining social approval from peers, all of which could hinder the impact that these negative consequences might otherwise have on the potential abandonment or reduction of gambling behavior(Raylu & Oei, 2004; Ladouceur et al., 2003). Conversely, interpretive bias enables the re-attribution of internal or external factors to gambling outcomes. By reframing gambling outcomes, individuals may attribute gains to their own ability or skill while attributing losses to bad luck or other circumstantial factors (Raylu & Oei, 2004; Rothbaum, Weisz, & Snyder, 1982).

The gambler's or hot hand fallacy (presented in a previous subsection) represents a type of predictive control that could also catalyze these adjustment processes. Despite being seemingly contradictory, both types of beliefs can coexist in the player's worldview as a function of various factors (i.e., the player's need to rationalize game outcomes). On the one hand, players may expect a streak to persist (positive recency or hot hand belief) when the sequence of events is perceived to be influenced by a human or a non-random device. Conversely, they may predict a streak to end (negative recency or gambler's fallacy) when the events are generated by a random, inanimate mechanism (Aton & Fischer, 2004; Clark, 2017; for a reply to this approach, see Tyszka et ak., 2008). The perceived intentionality of the causal agent underlying the sequence tends to trigger the hot hand belief, whereas the absence of intentionality favors the emergence of the gambler's fallacy (Caruso et al., 2010). However, motivated reasoning can also play a role in shaping these beliefs and attributions. Motivation to witness a specific outcome can influence the adoption of one reasoning strategy over another, depending on how it aligns with desired goals. The desire for a streak to continue or cease could lead to illusory predictions supported by either the gambler's fallacy or the hot hand belief (Braga et al., 2016).

As evident from this discussion, regardless of the outcome, the utilization of gambling-related cognitions serves to rationalize continued gambling behavior, whether prompted by losses or reinforced by gains. The proposition that biases and other gambling-related beliefs stem from the affective dynamics induced by problematic gambling itself implies that these cognitions serve as a form of self-deception mechanism, enabling individuals to diminish the impact of gambling consequences and persist in gambling. In essence, at problematic levels of severity, the desire to gamble fuels the inclination to distort reality to accommodate this desire while protecting one's self-image, which may be threatened by a more realistic perception of losses and a lack of self-control. This proposal is not novel and aligns with motivated reasoning models, which suggest that motivation involves the use of re-elaboration mechanisms, utilizing biases to validate pre-existing and desired expectations (Kunda, 1990).

Moreover, such domain-specific motivated reasoning could apply to gambling and may not be linked to domain-general intelligence or intellectual processes but rather to affective processes (Navas et al., 2019).

Cognitive distortions as both cause and consequence of gambling

These two perspectives —that cognitive distortions are a cause or consequence of the exacerbation of gambling problems — are not necessarily incompatible. A first step in reconciling these two views is to consider the role of cognitive distortions across various phases of the process of onset and progression of gambling problems.

First, it is apparent that some cognitive distortions related to gambling are essentially general distortions applied specifically within the gambling context. For instance, the gambler's fallacy can be seen as an application of the "law of small numbers" within the gambling context (Navarrete, Santamaría, & Froimovitch, 2015). These generalized tendencies, prevalent within the population yet subject to individual variations, may predispose individuals to engage in gambling activities at non-clinical levels. This is evident in the widespread exploitation of these biases in gambling product advertising and the subsequent impact of such advertising on gambling behavior (Lopez-Gonzalez, Estévez & Griffiths, 2018, 2019, 2020).

Second, the design of gambling products is inherently geared towards reinforcing these cognitive distortions (including, for example, illusion of control and “near-miss” events; Billieux et al., 2012; Ruiz de Lara & Perales, 2020; Lopez-Gonzalez, Estévez & Griffiths, 2020; Ndukaihe & Awo, 2003; Jacobsen et al., 2007; Chase & Clark, 2010; Clark et al., 2009). Increased exposure to and persistence in gambling are essential prerequisites for the central structural characteristics of gambling to exert their addictive effect, ultimately transforming recreational or instrumental gambling into a compulsive activity. Consequently, at a more advanced stage, when gambling behavior is in the process of becoming entrenched and chronic, individuals may resort to the use of cognitive distortions as a means of coping with the adverse consequences of gambling and the accompanying emotions.

Another integrative approach to understanding the mixed results in gambling research relates to the heterogeneous nature of gambling disorder. Many studies in the field have concentrated on a singular form of gambling or have grouped different types of gamblers into a unified sample, neglecting their distinctions (Bonnaire et al., 2013). However, several models suggest the presence of diverse types or profiles of gamblers (e.g. Blaszczynski & Nower, 2002; Navas et al., 2017), each exhibiting a preference for distinct forms of gambling and following different paths in the development of gambling problems.

For instance, the Pathways Model identifies distinct subtypes of gamblers, including conditioned gamblers, emotionally vulnerable gamblers, and an impulsive/antisocial gambler subtype (Blaszczynski & Nower, 2002). Conditioned gamblers are predisposed to gambling-related issues through sustained exposure to the structural elements of gambling. Emotionally vulnerable gamblers, already susceptible to anxiety or depression, turn to gambling as a coping mechanism to alleviate negative affect, seeking an escape from reality. The third group exhibits pre-existing risk factors such as high impulsivity and an elevated susceptibility to developing psychopathological disorders associated with externalizing behaviors.

The Gambling Space Model (GSM; Navas et al., 2017) refines the Pathways Model into a dimensional framework, encompassing the abovementioned subtypes while introducing a fourth subtype characterized by appetitive motives for gambling. This subtype shows a heightened sensitivity to the hedonically positive rewards of gambling and holds strong self-justifying cognitive distortions. These gamblers employ sophisticated reasoning strategies to rationalize excessive gambling behavior and reinterpret its adverse consequences. Notably, this profile tends to be associated with younger age, higher educational attainment on average, and a marked preference for skill-based games (e.g. poker and sport betting, primarily; Griffiths et al., 2009; Odlaug et al., 2011; Myrseth et al., 2010). This type of gambler is becoming increasingly prevalent in the overall incidence of problem gambling (Valenciano-Mendoza et al., 2023; MacKay et al., 2014; Griffiths et al., 2009; Wood & Williams, 2011). Independent evidence suggests that gamblers favoring skill-based games, as opposed to games of pure chance (e.g. slots, lottery), tend to display more pronounced cognitive distortions Myrseth et al., 2010; Mallorquí-Bagué et al., 2020; Navas et al., 2017**b**). This profile departs from the stereotypical portrayal of the pathological gambler characterized by executive functioning deficits (Verdejo-García & Manning, 2015) and lower educational levels (e.g. Abbott, 2020; Hing et al., 2015). In essence, certain gamblers may develop cognitive distortions as a consequence of lower intellectual functioning or general cognitive impairment, leading to the development of gambling problems. Conversely, others with preserved cognitive function and average to high intellectual capabilities may develop gambling issues due to extensive exposure to gambling, employing motivated reasoning to distort reality and eliminate cognitive dissonance stemming from gambling losses, debts, or other adverse consequences.

In any case, and based on this literature, we cannot conclusively establish that cognitive biases have an exclusively cognitive origin. If cognitive factors alone are insufficient to explain gambling problems, it suggests that the inclination to interpret gambling consequences with bias may arise from the gambling problems themselves. Consequently, it seems that the core elements underlying gambling issues may be associated with factors of a different nature.

The nature and development of compulsivity in gambling

The fundamental basis of problem gambling relates to the loss of control over gambling behavior. However, it is evident from the preceding discussion that cognitive biases related to gambling are not solely responsible for this loss of control. Instead, these biases may result from motivational mechanisms driven by the need to integrate problems associated with gambling into an individual's personality.

In other words, these biases operate by masking the inability to keep gambling under control and, therefore, the capacity to respond to its associated negative consequences. This creates an illusion where continued problematic behavior appears as a deliberate and logical decision aligned with the individual's personal beliefs and expectations. This illusion serves as a kind of "cover-up" that hides the true nature of the problem, serving as an ego-protective mechanism that traps the gambler in a cycle where the perceived control over gambling reinforces the persistent behavior.

Therefore, a deep exploration of these aspects is crucial to fully grasp the complexity of problematic gambling and the underlying mechanisms of its origin and perpetuation. Identifying the processes that explain the onset of this destructive cycle involves drawing from various hypotheses that, despite their differences, agree on their general approach to this question. Current evidence, which has primarily emerged from the study of substance use disorders, appears to point to a shift in behavioral control from goal-driven to compulsive or habit-based modes of behavior.

From goal-directed behaviors to automatic behaviors

Loss of control over drug use is a key feature of substance use disorders. Although the clinical phenomenon of addiction is well documented, and significant neurobiological evidence has been accumulated, there remains an urgent need to understand the specific mechanisms underlying the development and maintenance of this condition (Doñamayor et al., 2022; Belin et al., 2013). To this end, several proposals have emerged in recent years in the form of etiological models of addictive behavior, highlighting the importance of dissociating problematic behavior from instrumental goals (Vandaele & Ahmed, 2020; Robinson & Berridge, 2003).

In this context, substance use is often conceptualized as a learned behavior (Everitt y Robbins, 2005, 2016; Diederen & Fletcher, 2021) that is initially motivated by seeking pleasure or avoiding discomfort (Robinson y Berridge, 2008). Repeated use over time makes this behavior automated, triggered by environmental cues, and executed irrespective of the anticipated outcome (Doñamayor et al., 2022; Perales et al., 2020). Various theories have been proposed within this framework to explain this transition, which are frequently interconnected and partially overlap (Vandaele & Ahmed, 2020; Lüscher, Robbins, & Everitt, 2020). While these theories agree that the loss of control over addictive behavior is associated with a shift between two modes of behavioral control, they differ in their characterization of these modes of control and their explanations of how this transition occurs (Robinson & Berridge, 2003; Gillan et al., 2016).

The theory of habit formation: from goal-directed to habitual behaviors

The theory of habit formation represents one of the most extensively developed approaches in the recent scientific literature. This model distinguishes between goal-directed and habitual behaviors, positioning them at opposing ends of a spectrum governed by the balance between two competing learning systems or modes of control (Perales et al., 2020; Balleine & O'Doherty, 2010; Dolan & Dayan, 2013). The general thesis proposed by various proponents of this theoretical framework asserts that the core of the addictive process—specifically, the loss of control over addictive behavior—arises from the gradual dominance of habitual behaviors over those that are goal-directed (Vandaele & Ahmed, 2020; Belin et al., 2013). In simpler terms, prolonged substance abuse leads to the predominance of habit-based control over goal-directed control according to this model (Everitt & Robbins, 2016).

Under the goal-directed control mode, behavior is regulated by knowledge of the relationship between actions and their consequences (Belin et al., 2013). Thus, individuals can adjust their actions according to changes in instrumental contingencies in a deliberate, conscious, and flexible manner (Perales et al., 2020; Doñamayor et al., 2022). However, this *modus operandi* places greater demands on cognitive resources, implying, in the words of Vandaele y Ahmed (2022) and Dolan y Dayan (2013), the construction of a decision tree that considers all possible states and actions, allowing individuals to navigate this "cognitive map" by estimating the long-term value of each potential outcome. Furthermore, the outcomes of the chosen behaviors are continually monitored to assess changes in their causal relationships and utility value (Perales et al., 2020; Doñamayor et al., 2022). This ongoing evaluation updates their motivational value, refreshing the information within the "cognitive map," ideally *ad infinitum.*

Habits, on the other hand, are typically defined by the absence of goal-directed behavior (Vandaele y Ahmed, 2020). They involve automatic and highly efficient actions, achieved at the expense of behavioral flexibility. Under habit-based control, individuals repeat actions reinforced during the learning phase without necessarily considering the specific characteristics of the outcome (Doñamayor et al., 2022). Essentially, habitual behaviors have their origins in the pursuit of a goal, which, after repeated practice, become detached from their original purpose. Instead, they are triggered by cues or stimuli associated with the goal, often disregarding the immediate consequences of the behavior itself (Everitt y Robbins, 2005, 2016; Vandaele y Ahmed, 2020; Kruglanski y Szumoska, 2020).

Moreover, the transition between the two modes of behavioral control is supported by neurobiological evidence indicating neural reorganization at both intrastriatal and corticostriatal levels (Everitt & Robbins, 2005; Sjoerds et al., 2013; Knowlton & Patterson, 2016). Specifically, it is proposed that the progressive formation of habitual behavior involves a shift in control from interactions between the medial prefrontal cortex and dorsomedial striatum (involved in goal-directed control) to regions such as the dorsolateral striatum and potentially motor cortical areas (Belleine & O'Doherty, 2009; Everitt & Robbins, 2016). Additionally, within the striatum, there is a suggested shift in striatal-nigrostriatal dopaminergic pathways from ventromedial to dorsolateral regions so that processes controlled by the former would eventually be directed by the latter (Everit & Robbins, 2005, 2016). However, it is worth noting that some authors regard this evidence as limited (Vandahele & Ahmed, 2020).

Habit theory, until recently, has been a well-established model with substantial empirical support. The conceptual evolution of this approach has been extensively documented in the scientific literature over the years (a historical evolution of the constructs presented here can be found in Dolan and Dayan, 2013). This literature has been complemented by laboratory experiments aimed at studying and distinguishing between goal-directed and habitual control. Paradigms such as contingency degradation, reward devaluation, and sequential decision-making tasks (conducted in animal and human studies) have provided a substantial body of experimental evidence regarding the characterization and transition between these two presumed modes of behavioral control (Balleine y O'Doherty, 2010; Balleine y Dickinson, 1998; Everitt y Robbins, 2016; Doñamayor et al., 2020; Vandaele y Ahmed, 2020). Nevertheless, this evidence has also played a role in challenging the foundations of habit theory, with a significant number of authors presenting compelling arguments that question the validity of this model (e.g. Hogarth, 2018; Heather, 2017; Kruglanski & Szumowska, 2020). While the aim of this introduction is not to delve deeply into these arguments, it is useful to touch on some of them to provide an overview of the current state of this field of study.

Some authors argue that substance use behaviors may not solely be driven by habitual behaviors but also involve complex goal-directed behaviors (Heather, 2017). For instance, the sequence of behaviors involved in obtaining funds, purchasing a substance, and consuming it often necessitates using flexible and planned strategies. These actions are typically motivated by the anticipation of substance effects and require careful consideration of potential consequences, both positive and negative. The traditional view of habit-based versus goal-directed control suggests that these should not be regarded as completely distinct or independent systems; instead, they likely exist on a continuum. In this regard, substance use behaviors could be influenced by either system or a combination of both, depending on individual characteristics and contextual factors (Vandaele y Ahmed, 2020).

Other authors point out that habits are, in fact, inherently goal-directed, further blurring the boundary between the two types of behavior (Kruglanski y Szumowska, 2020; Wood y Neal, 2007; Hogarth, 2018). On the one hand, habitual behaviors, far from being disconnected from the original goals, are sensitive to changes in reward value and are sufficiently flexible to become associated with new goals. Various empirical studies provide evidence to support the notion that in different situations (e.g., when the goal originally mediated by the habitual behavior loses its value, is associated with an unpleasant experience, or a more attractive reward is presented), the individual stops, abandons, or modifies the habitual behavior (Hogarth, 2018; Hommel, 2019; Kruglanski & Szumowska, 2020). On the other hand, habitual behavior is sensitive to the expectation of achieving a desired goal. When the intensity of this expectation decreases below a certain threshold, the associated response is interrupted, although it seems that on some occasions, this interruption (extinction of the behavior) may take time to occur. This especially seems to be the case, especially in paradigms in which, during the learning phase, the acquisition trials were partially reinforced, which in turn would make it difficult to determine whether the probability of achieving the goal has significantly decreased (Kruglanski & Szumowska, 2020). Finally, other arguments put forward by various authors suggest that habits do not emerge when individuals are presented with a choice between different reinforcers (a scenario closer to real-world contexts; e.g. Pelloux, Murray, & Everitt, 2015), that goal-directed behaviors could, in fact, be automatic (e.g. Moors, Boddez, & De Houwer, 2017), or that a unitary model of control might be more appropriate, criticizing the binary conceptualization of this theoretical proposal (Hommel & Wiers, 2017).

Finally, some authors have raised an interesting point that is consistent with the criticisms presented here (Sjoerds et al., 2014; though see also Belin et al., 2013). Although the habit construct, by definition, is presented as being theoretically unrelated to goal desirability, the question arises as to whether habits are truly devoid of motivation or if motivation continues to play a significant role in habitual behavior. The notion that habitual behavior is solely explained by stimulus-response contingencies is considered overly simplistic, particularly for more complex human habits that may be intertwined with motivational factors. In this regard, it is proposed that a habit is not a unitary construct; rather, different types could co-exist. In particular, simple habits are triggered by direct motor schemas without being modulated by impulses, thoughts, or feelings — essentially "pure" stimulus-response contingencies (e.g., checking a cell phone reflexively upon noticing a vibration without any genuine interest in the notification). Motivational habits, on the other hand, are driven by underlying motivational or emotional impulses (e.g., accessing a specific social network app constantly) and appear to be goal-directed (e.g., relieving boredom, actively seeking comments or 'likes' even though no notifications have been received), although the behavioral sequence triggered in reaction to emotional or motivational stimuli resembles simple habits in many respects. This type of habit likely plays a more relevant role in addictive behaviors. For instance, other motivational mechanisms related to substance use, such as attentional and approach bias, could implicitly drive motivational habits, contributing to, for example, persistent substance use.

In broad terms, this habitual pattern could be comparable to compulsive behavior, characterized by repeated responses to a negative emotional state despite resulting in undesirable consequences. Interestingly, compulsive behavior is considered the counterpart of the goal-directed mode in another model that, similar to habit formation theory, seeks to explain the loss of behavioral control.

The incentive sensitization theory: from goal-directed behavior to compulsive craving

The incentive sensitization theory incorporates several of the previously discussed criticisms and insights into its etiological model of addictive behaviors. Similar to habit formation theory, the incentive sensitization theory was developed to determine (i) the factors that cause the transition from occasional drug use to addiction, (ii) the brain changes involved in this transition, and (iii) what characterizes addictive behavior. Additionally, it puts forward important hypotheses concerning (iv) what characteristics make certain individuals particularly susceptible or vulnerable to this transition. Finally, (v) the theory assigns a determinant role to *craving* or the intense desire to consume the addictive substance (Robinson & Berridge, 1993, 2008).

The general thesis of this approach states that repeated use of potentially addictive drugs, in certain individuals in specific contexts, can lead to an intensified "craving" triggered by the anticipation of the rewarding effects of that use and the associated cues (Robinson y Berridge, 2008; Anselme & Robinson, 2019). According to this model, incentive sensitization is the critical mechanism underlying the transition to addictive behavior, characterized by the compulsive seeking of rewards associated with substance consumption, ultimately resulting in a loss of behavioral control (Warlow et al., 2020; Robinson & Berridge, 1993). According to this model, the specific sequential process involved in the shift from recreational drug use to compulsive behavior can be divided into the following three distinct phases:

In the initial phase, consumption of a potentially addictive substance leads to feelings of pleasure or euphoria in the individual (Robinson & Berridge, 2008). These rewarding properties of the substance reinforce the consumption behavior, motivating the individual to repeat the experience. In other words, the initiation of repeated substance consumption is triggered by the anticipation of the hedonic value associated with the substance based on previous pleasurable experiences (Sjoerds et al., 2014). During this first phase, therefore, the behavior is directed towards the goal of experiencing pleasurable sensations and does not necessarily indicate loss of control. However, over time, the individual continues to seek positive reinforcement through substance use, and the pattern of consumption becomes more frequent and regular. This consistent consumption establishes operant associative learning processes based on the formation of strong links between the use of the substance and its hedonic effects (Anselme & Robinson, 2019).

At this point, it is important to clarify certain concepts before proceeding further. First, there is a distinction between the pleasurable effect of a substance (the "liking" of its effects on the organism) and the desire to consume it (the "wanting" of the substance; Nguyen, Naffziger & Berridge, 2021; Berridge & Robinson, 2016; Anselme & Robinson, 2016; Berridge, 2019). While pleasure and desire have long been thought to be two sides of the same coin, research has established that "liking" and "wanting" are distinct psychological and neurobiological constructs (Anselme & Robinson, 2019). This characterization of reward is important for understanding the model (Berridge, Robinson & Aldridge, 2009). Additionally, the concept of "sensitization" is significant in this context. Sensitization is defined as the opposite process of "habituation" (for alternative definitions, see Robinson & Berridge, 2003). Whereas habituation refers to a decrease in an organism's response to a stimulus repeatedly presented, sensitization involves a "hyper-reactivity" to the stimulus, characterized by an increase in the magnitude or frequency at which the individual emits a response when it is presented (Eisenstein et al., 2012; Domjan, 2007). In the context of this theory, this definition extends to a neural response in the presence of a specific stimulus.

Continuing with this process, repeated exposure to the substance initiates the transition phase of the behavior, marking the beginning of the second part of the process. Prolonged and continued use of the substance leads to significant changes in brain circuits responsible for regulating the perceived importance or relevance of stimuli (Robinson & Berridge, 2008). Specifically, a phenomenon occurs where the dopaminergic neurons of the subcortical circuits involved in this process become hypersensitive or "sensitized," resulting in a gradual increase in the expectation of the effects of the substance (Robinson & Berridge, 2000; Berridge, 2007, 2012). The critical aspect here is that the component subject to sensitization and mediated by dopamine is not the subjective pleasure of consumption ("liking") but the motivation to consume the substance itself (i.e.," wanting" or craving it; Wise, 2004; Berridge, Venier & Robinson, 1989; Robinson & Berridge, 2000). This sensitization process confers increased salience to the substance and the environmental and internal cues associated with its use — a concept referred to as "incentive salience" (Robinson & Berridge, 1993; 2000).

Specifically, salience refers to the capacity of a stimulus to capture attention and motivate an individual's behavior (Parvaz et al., 2021; Berridge & Kringelbach, 2015; Robinson & Berridge, 2008). Those stimuli that acquire incentive salience are assigned inordinate importance and can dominate the thoughts, feelings, and behavior of the individual experiencing it (Trinity & Robinson, 2018; Robinson & Berridge, 2008). In this third and final phase of the process, the addictive cycle becomes firmly established. As sensitization to the cues associated with the substance becomes generalized, the mere presence of these cues can trigger an irrepressible and pathological desire to consume the drug, ultimately leading to compulsive drug-seeking and drug-taking behavior (Anselme & Robinson, 2019; Robinson & Berridge, 2008).

In summary, incentive sensitization results in an attentional bias towards stimuli associated with the substance and a pathological desire to consume it. Additionally, despite this sensitization of the "wanting" systems, the pleasure or "liking" associated with the reward may be reduced or remain unchanged, prompting individuals to intensify their consumption in an attempt to achieve the initial levels of pleasure they experienced. In other words, individuals crave the substance more and more even though it becomes less pleasurable over time. Importantly, the negative consequences of substance abuse often disrupt functional life. Nonetheless, these consequences do not appear to attenuate compulsive behavior or redirect motivation despite the fact that they outweigh, by far, any perceived "benefits" of consumption (Anselme & Robinson, 2019; Robinson & Berridge, 1993; 2008).

Finally, it is worth noting that the process of incentive sensitization leading to compulsive substance use behavior has been extensively studied from a detailed neurobiological perspective, providing insights into the physiological mechanisms underlying behavioral transitions in addiction. Specifically, research suggests that the mere pairing of a cue with a reward is insufficient for effective learning to occur. In addition to the contiguous co-occurrence of events, there is a need for a perceived discrepancy between the expected value of a reward and the actual reward obtained (Pascale, Anthony & Schultz, 2001). This discrepancy, known as reward prediction error (RPE), is encoded by midbrain dopaminergic neurons, which play a pivotal role in motivation and reward-based learning processes (Keiflin & Janak, 2015; Schultz, 2016; Linnet, 2020).

Under normal conditions, the RPE serves as a mechanism that facilitates learning from experiences (Diederen & Fletcher, 2020; Schultz, 2016). For instance, when consuming a more pleasurable food than expected, a positive RPE is generated, accompanied by an increased release of dopamine in the brain regions involved in reward processing (Diederen & Fletcher, 2020). Conversely, when an anticipated reward does not materialize, the activity of these neurons is reduced below baseline (Schultz, 2016; Kwon et al., 2017; Keiflin & Janak, 2015). Based on these experiences, the mechanism adjusts expectations of future events, which results in a decrease in the error signal and, thus, the discrepancy. Consequently, the activation of dopaminergic neurons encoding the RPE progressively decreases as the predictability of the reward increases (i.e., as the error signal decreases), leading to habituation processes (Keiflin & Janak, 2015). Moreover, these neurons have a characteristic feature that is of special interest. During the process of associative learning, the activation of these neurons shifts from the reception of reward to predictive signals, intensifying the response to anticipatory or cue stimuli while diminishing reactivity to the reward itself (Enomoto et al., 2010; Schultz, Dayan & Montague, 1997; Sebastian, Bradford & Uchida, 2012; Matsumoto & Hikosaka, 2009). This enhanced efficiency in computing the RPE, "recalibrating" the prediction of future rewards, facilitates more flexible behavioral adaptation, and optimizes decision-making.

However, research has demonstrated that the consumption of potentially addictive substances enhances normal learning processes by triggering a significant release of dopamine, effectively "hacking" the typical functioning of RPE. This disruption abolishes habituation and sustains an elevated response to the drug over time (Schultz, 2016; García-García, Zeighami, & Dagher, 2017). These substances appear to exert direct and indirect pharmacological effects on dopamine activation and release, distinct from those of natural rewards (Keiflin & Janak, 2015), contributing to system sensitization. Specifically, drugs supra-physiologically elevate extracellular dopamine levels. Consequently, persistent positive prediction errors occur due to the substances' direct impact on dopaminergic neurons (Redish, 2004). Therefore, even though an individual may anticipate the heightened reward from these substances, the brain continues to react as if the reward were unexpected. Moreover, sensitization predominantly affects neurons in brain regions associated with desire or craving for the reward (wanting) rather than in liking hotspots involved in habituation processes (Berridge, Robinson, & Aldridge, 2009).

Furthermore, as learning progresses, and as described above, the dopaminergic neural response shifts from the reward itself to internal cues (e.g., internal states that trigger reward prediction; Wassum, Ostlund & Maidment, 2012) or external cues (e.g., contexts where the substance has been previously consumed or that indicate reward availability; Roitman et al., 2004) associated with the reward. This transition is believed to explain the incentive salience of these cues and why these can trigger such intense cravings, regardless of whether or not the drug itself is present. Ultimately, this process initiates a vicious cycle in which (1) the substance abuse and sensitization of incentive systems are mutually reinforcing, (2) this reinforcement is maintained over time regardless of continued substance use or the establishment of a period of abstinence, and (3) this results in increased automatic and compulsive control of behavior triggered by substance-related incentive stimuli (Rømer Thomsen et al., 2014; Nguyen, Naffziger, & Berridge, 2021).

Implications of the etiological models presented

The bulk of the literature reviewed is broadly consistent in describing the events underlying the loss of behavioral control in addiction. On the one hand, it is suggested that addictive behavior emerges from a shift between two modes of behavioral control, namely goal-directed to compulsive or habitual, depending on the specific framework. Furthermore, different perspectives agree that once this behavioral transition has occurred, individuals become increasingly compelled to seek and use the drug, even though this behavior no longer aligns with their primary objectives that initially triggered consumption and despite the negative consequences it may hold for their lives and life goals. Finally, it is not just the substance itself but also the cues associated with the substance that play a critical role in triggering drug seeking and use.

Broadly speaking, despite their differences, the proposals presented here appear to be on the right track in characterizing the control models that explain disordered behavior based on current evidence. For instance, a recent consensus study using the Delphi methodology aimed to identify several key processes relevant to understanding addiction was conducted by Yücel et al. (2019). Some of these processes relate to various aspects of vulnerability to addictive disorders, such as abnormal reward valuation or altered expectancy learning. However, the study identified two fundamental aspects crucial to the chronic nature of addiction: the development of rigid habits and compulsivity. In this review, habits are operationalized as "Sequential, repetitive, motor or cognitive behaviors elicited by external or internal triggers that, once initiated, can go to completion without constant conscious oversight" (p. 1102), whereas compulsivity would be defined similarly to habits, with the difference of being "associated with negative outcome expectancy that contributes to the experience of being 'forced' or 'compelled' to act despite negative consequences" (p. 1103).

In this regard, it seems that both the habit formation theory and the incentive sensitization theory, although diverging in some respects, could have some validity. However, in recent years, empirical evidence seems to have tilted the balance in favor of the second theory, particularly with regard to motivation as a determining factor in associative learning and in the transition of behavior (Anselme, 2015).

On the one hand, while learning processes are important in shaping behavior during the early stages of substance use, it appears that they alone are not sufficient to render the behavior compulsive (Robinson & Berridge, 2023). In other words, while substance use can promote the learning of strong automated stimulus-response habits, these habits, however deeply ingrained, do not inevitably lead to compulsive behavior (Robinson & Berridge, 2008). This perspective aligns with the incentive sensitization theory, which emphasizes that motivation plays a crucial role in Pavlovian conditioning (Anselme, 2015). According to this theory, incentive motivation—defined as the internal drive that compels an organism to seek a reward—plays a more significant role in controlling the conditioned response than predictive learning (Berridge, 2012).

In this context, some authors have extended the habit model in an effort to incorporate the motivational aspects of addiction (Güell & Nuñez, 2014) and reconcile both approaches. For example, Sjoerds et al. (2014) proposed in their opinion article that motivation plays a pivotal role in the culmination of the addictive process. They introduced the concept of "motivational habits" (in contrast to "motor habits"). Motivational habits are conceptualized similarly to incentive motivation, representing compulsive behavior driven by the desire for a rewarding goal (Güell & Nuñez, 2014; Sjoerds et al., 2014). Similarly, Belin et al. (2013) speaks of "incentive habits" in what appears to be an attempt to reconcile the two proposals. “Incentive habits” would be defined as a "pathological coupling of drug-influenced motivational states and a rigid stimulus-response habit system" (Belin-Rauscent, 2013, p. 565). According to this proposal, substance addiction would be described as "a compulsive incentive habit, which results from the progressive subversion by addictive drugs of striatum-dependent instrumental and Pavlovian learning mechanisms that are normally involved in the control over behavior by natural reinforcers" (Belin & Everitt, 2010, p. 571).

Finally, and despite these varying theoretical propositions, several conclusions can be drawn: (1) as a concept, it is clear that learned habits alone do not fully explain the incentive motivation (i.e., the strong motivational pull) of rewards and their associated cues, something that appears to be inherent to the development of addiction; (2) additionally, habit learning does not fully account for the compulsive nature of addictive behavior, as motivational compulsion can be misinterpreted as automatic functioning. Strong stimulus-response associations, no matter how overlearned or pharmacologically potent, do not alone explain the compulsive nature of addictive behavior; (3) substance-seeking and substance-taking behaviors are often flexible and directed toward implicit and explicit goals; (4) repeated use of potentially addictive drugs in specific individuals and contexts induces neurophysiological changes that enhance the desire for substances and their associated cues, regardless of the pleasure/reinforcement they provide, their attenuation, or the negative consequences of their use; and (5) the compulsivity inherent to addictive behavior tends to persist despite periods of abstinence, contributing to the cycle of relapse (e.g. Anselme & Robinson, 2019; Robinson & Berridge, 2003).

In short, if potentially addictive drugs are ultimately the fundamental and destabilizing element that triggers the transition to addictive behavior, then it is essential to ask what causes this same process in gambling addiction.

The intermittent nature of rewards and the role of uncertainty: from recreational gambling to gambling addiction

Based on the discussion so far, it is evident that addiction is inherent to the properties of certain chemical substances due to their pharmacological capacity to sensitize the dopaminergic system and alter its response to rewards through various pathways. This sensitization leads, on the one hand, to the attribution of salience to incentive cues and, on the other hand, heightened reactivity of the "wanting" system towards rewards and these cues. Taken together, these processes play a fundamental role in the shift from goal-directed behavior to addictive behavior. In the absence of direct modulation of brain pathways by exogenous chemicals, one might ask the question of what endows gambling and its associated cues with incentive salience or what triggers the behavioral transition outlined in previous sections.

The short answer to this question seems to point to the characteristics of the random-ratio reinforcement schedules inherent to gambling. The longer explanation seems to lie in the uncertainty triggered by these schedules (Navas et al., 2019; Delfabbro et al., 2023; Robinson et al., 2014) and in other elements that enhance the subjective perception of reward variability (Clark & Zack, 2023; Anselme & Robinson, 2019). In particular, it has been suggested that uncertainty about reward can initiate processes that promote incentive salience, ultimately facilitating the transition from recreational to compulsive gambling, resulting in the onset of gambling disorder.

The evolutionary pathway towards compulsive gambling behavior can be understood from three different perspectives: (1) random-ratio reinforcement schedules as a source of uncertainty, (2) the structural characteristics of gambling that further enhance the variability of reward inherent to these schedules, and (3) the incidence of comorbidities with substance use, which may lead to cross-sensitization processes.

Randomized ratio reinforcement schedules: the source of uncertainty

Intermittent reinforcement schedules deliver reinforcement only after a few occurrences of the behavior (as opposed to continuous reinforcement schedules, in which a reinforcer is administered each time the behavior is performed e.g. Tarbox & Tarbox, 2017). In other words, a specific response produces a specific outcome, but only a few times or not each time the response occurs. There are various types of intermittent reinforcement schedules. Fixed-ratio (FR) schedules determine how many occurrences of the response are required for reinforcement to be delivered, whereas in variable-ratio (VR) schedules, an average number of responses is required before reinforcement is delivered. For instance, in a VR4 schedule, the reinforcer is delivered after an average of 4 responses across all trials (e.g., sometimes the response will need to be performed 4 times, sometimes 1, and sometimes 8, with the total average number of responses required always being 4). Behaviors reinforced using variable ratio schedules show greater resistance to extinction, as the organism has experienced a history of trials in which the reward is not always delivered in a predictable manner. However, under this schedule, trials are not independent of each other with respect to the reward since the probability of receiving a reinforcer increases with each successive trial; that is, if, after one response, the behavior is not reinforced, the probability that it will be reinforced on the next trial increases (Humphrey & Richard, 2014).

Gambling games, which are often regarded as VR schedules, function rather like a third type of intermittent reinforcement schedule, known as random ratio schedules (RR; Haw, 2008). Unlike VR schedules, in an RR schedule, each response has an equal probability of being paired with reinforcement, regardless of what has occurred on previous trials. For instance, in an RR4 schedule, in which each response has a 25% chance of being followed by a reinforcer, the number of unreinforced responses could range from 1 to an indefinitely larger number since the number of responses required for the delivery of the reinforcer does not respond to a fixed, preset average, but changes randomly after each reward is delivered (Humphrey & Richard, 2014).

It seems that this additional degree of unpredictability and randomness of reward inherent to random-ratio schedules could be highly effective in eliciting high response rates and triggering compulsive behaviors that are much more resistant to extinction (Perales et al., 2020; Haw et al., 2008). Traditionally, learning models have proposed that the stronger the predictive value of a conditioned stimulus with respect to its outcome (e.g., reward), the more likely the individual would be to respond to that stimulus. However, several studies have revealed that contexts of uncertainty, i.e., those where conditioned stimuli unreliably predict the delivery of a reward, have the capacity to enhance incentive motivation and increase responding (compared to contexts where the reward is delivered with 100% probability; Anselme, Robinson, & Berridge, 2013; Robinson, Bonmariage, & Samaha, 2023; Robinson et al., 2014). In other words, and although seemingly counterintuitive, uncertainty appears to act as a mechanism or driving force that enhances the motivation to respond to those stimuli whose association with the occurrence of a reward is uncertain (Robinson et al., 2014; Anselme, 2015). This phenomenon, observed in gambling due to its structural characteristics, suggests that uncertain or weak predictors can sometimes enhance incentive motivation and even sensitize reward pathways in some cases (Linnet et al., 2010; Robinson et al., 2015).

The motivational effects of uncertainty can be explained by the incentive hope hypothesis (see Anselme (2015, 2016) for a more detailed account of this hypothesis). In short, incentive hope is described as an evolutionary adaptive mechanism aimed at enhancing perseverance in the search for resources essential for survival, such as food, particularly during times of scarcity or unpredictability (Anselme & Güntürkün, 2018). Under such conditions, there is a heightened motivation to dedicate time and effort to searching for and consuming these resources, compared to circumstances under which these resources are more readily obtainable (i.e., “just in case”; Anselme & Robinson, 2019). Moreover, uncertainty directly enhances the motivational value of cues that predict the attainment of rewards (Ostlund & Marshall, 2021). In this regard, it appears that weak cues or predictors of high-value rewards can elicit a higher level of cue tracking than more reliable predictors of small rewards (Robinson et al., 2014; Anselme, Robinson & Berridge, 2013). Finally, it has been suggested that rewards obtained under conditions of uncertainty are perceived as more attractive, and this heightened attractiveness (or increased incentive value) could also sensitize brain mechanisms to the same extent as potentially addictive substances (Robinson et al., 2014; Anselme, Robinson & Berridge, 2013).

The effect of uncertainty on incentive salience and sensitization can also be explained at the molecular level. Uncertainty about reward, similar to potentially addictive drugs, can serve as a constant source of RPE (Navas et al., 2019). As previously explained, surprising or unexpected rewards elicit strong increases in activation of midbrain dopaminergic neurons, leading to increased dopamine release and heightened RPE. One might anticipate, therefore, that as learning increases and prediction improves, prediction error and dopaminergic activation in response to the attainment of rewards in gambling would decrease. However, gambling activities are designed to maintain high and variable uncertainty thresholds, which sustain the activation of dopaminergic neurons (Fiorillo et al., 2003; Linnet et al., 2012). Furthermore, studies have shown that pathological gamblers exhibit significantly greater dopamine release than healthy controls in response to monetary losses (Linnet et al., 2010).

If these findings are confirmed, gambling environments could be considered an ideal setting for disrupting RPE and promoting maladaptive learning. Given the inherent uncertainty in gambling and that loss events often outweigh gains (Fiorillo et al., 2003), gambling environments could readily foster a sustained release of dopamine. This might, in turn, trigger intense positive RPE, endowing both gambling activities and various associated stimuli with incentive salience.

For instance, audiovisual elements such as bright lights and exciting sounds figure centrally in the dynamics of gambling activities (Winstanley & Hynes, 2021). Despite having low predictive value, these elements serve as cues signaling the potential for obtaining a payout or prize, thereby capturing the player's attention and increasing the likelihood that they will engage in actions to pursue monetary rewards. In this case, the effect of the uncertainty inherent to the reward structure of gambling games is transmitted to these sensory cues. As a result, these cues acquire incentive salience and become powerful motivators for the player (Robinson et al., 2014). The strong attraction of these cues can override the player's own realistic assessment of their chances of winning.

To study more precisely how incentive salience is attributed to the predictive cues of uncertain (non-pharmacological) rewards, studies have been conducted in laboratory settings with animal populations, employing automatic conditioning or "autoshaping" paradigms (Flagel et al., 2006; Robinson & Flagel, 2009; Meyer et al., 2012, some of which specifically mimic gambling environments (Robinson et al., 2014). These experiments allow researchers to manipulate varying levels of uncertainty in terms of the probability, location, and magnitude of rewards, and their results can provide valuable insights into the mechanisms underlying gambling behavior.

On the one hand, it seems that cues signaling the delivery of larger rewards with a lower probability trigger higher levels of tracking compared to those signaling smaller rewards with complete reliability (Robinson et al., 2014; according to Anselme, Robinson & Berridge, 2013). On the other hand, it appears that initial exposure to a stimulus generating high uncertainty maintains the motivational impact of such a stimulus over time, even if its predictive value of reward objectively changes. Finally, uncertainty appears to be capable of endowing even initially unnoticed cues (discrete conditioned stimuli) with incentive salience, turning them into motivational magnets that can divert the attention of rats from the location of a reward (Robinson et al., 2014). This generalized attribution of incentive salience to distal cues could explain how gamblers are drawn to and captivated by gambling-related cues, ranging from the audiovisual elements of casinos to the features of advertising campaigns. Furthermore, the decision to persist with gambling despite losses and various negative life consequences may mirror how animals choose "risky" levers over "safe" levers based on reward probability and magnitude, even if the former choice places them in situations that might be perceived as dangerous. This behavior might be explained on the basis of Fiorillo et al. (2003) findings, which could offer a physiological account of the "loss chasing" phenomenon (e.g. Zhang & Clark, 2020).

Taken together, the presented studies suggest that a key aspect of gambling disorder involves the release of dopamine linked to an altered RPE resulting from a context filled with unpredictable reinforcers. Uncertainty is a central element in gambling and could be its most representative structural feature, while the presence of reward variability is also a notable characteristic of gambling environments. The combination of both these elements is likely to maximize their impact on gamblers' behavior (Linnet et al., 2012).

Potentiators, facilitators, and mediators of uncertainty

We have observed how uncertainty, inherent in random ratio schedules, plays a critical role in attributing incentive salience to gambling-associated cues via drug-like effects on mesolimbic and mesocortical dopaminergic signaling. Moreover, uncertainty ensures that the delivery of a reinforcer is always a surprising event, potentially evoking an RPE and contributing to aberrant learning processes and compulsive gambling behaviors in certain individuals (Zack, George & Clark, 2020). Gambling devices and gambling games *per se* have multiple sources of reward variability, which can complement each other hierarchically and horizontally (Clark & Zack, 2023). This reward variability means that the reinforcement obtained from an action may not always be the same or delivered in the same manner and could differ in terms of quality, quantity, timing, or any combination of these or other factors. This variability significantly enhances the impact of uncertainty (Linnet et al., 2012; Takahashi et al., 2017; Robinson et al., 2014). Aside from the player's subjective uncertainty about receiving a reinforcer, there is "added uncertainty" concerning the incentive value and characteristics of the reward and the implications of these factors for the dynamics of gambling. Therefore, variability further favors incentive sensitization and increases the number of incentives derived from various "versions" of the final reinforcer. It might be argued that the effects of reward variability could strengthen compulsive gambling behaviors and addiction by increasing the number of cues capable of driving gambling behavior, thus heightening the risk of losing control over gambling activities.

In this regard, certain authors have identified various sources of variability and have examined their roles in modern gambling products, along with their potential implications for the development of addictive gambling behavior (Zack, George & Clark, 2020; Clark & Zack, 2023).

One primary source of reward variability is variable or random ratio schedules. While players are assumed to have the intuition that reinforcement will be obtained on a given trial, the specific number of trials or target responses required to obtain that reinforcement is never the same (Clark y Zack, 2023).

Another notable source of variability stems from the magnitude and characteristics of the reward (e.g. the size of the monetary payout in gambling games; Zack, George & Clark, 2020; Clark & Zack, 2023). On the one hand, we have already seen how the magnitude of a reinforcer has direct implications for how cues that signal its (probable) presence are tracked and approached, regardless of their predictive value (Robinson et al., 2014). On the other hand, it is well documented that RPE not only responds to changes in reward value but also alterations in the traits or sensory characteristics of the reward (even if its perceived value remains constant; Takahashi et al., 2017). Gambling games typically offer a wide range of win sizes, in quantitative terms, along with qualitatively different versions of rewarding stimuli. For instance, in modern slot machines, winning different monetary prizes may be accompanied by distinct audio-visual stimuli (e.g. lights, sounds; Zack, George & Clark, 2020), allowing each of them to acquire incentive salience independently. Moreover, each version of the rewarding stimulus can also evoke an RPE independently (Diederen & Fletcher, 2020; Takahashi et al., 2017).

Bonus games are an example of the wide range of rewarding stimuli that can be offered, whether as substitutes for monetary prizes or additional rewards (Parke & Griffiths, 2006; Rockloff, Hyoun & Hodgins, 2019; Taylor, Macaskill & Hunt, 2016). These free games allow players to win extra prizes without requiring further financial investment or wagers (e.g. Thorne, Justus & Li, 2016). During a bonus game, the magnitude of the reward also varies, and the unique (in-game) features of such games are highlighted through distinctive icons and sounds, often presented in an enlarged format compared to those featured in "standard" gameplay (Clark & Zack, 2023). Moreover, players may interpret access to a bonus game as a reward in itself, even though participating in these games does not guarantee a specific monetary gain.

Bonus games fall under the category of "simultaneous" or "concurrent" schedules, representing another source of gaming variability (Clark & Zack, 2023). In other words, the opportunity to access multiple games or sub-games within the main game itself or the ability to place several bets simultaneously enables multiple reinforcement schedules (typically variable or random ratio) to operate concurrently. For instance, sports betting provides players with a wide array of prediction options that they can engage in simultaneously. These options include pre-match bets (e.g., predicting match outcomes or winners of various events, including the option to combine multiple bets into one), live or in-game bets (e.g., placing real-time bets on the outcomes of ongoing matches or events, with odds adjusted by operators as events unfold), and prop bets (e.g., bets on specific events such as the first team to score or the number of yellow cards received by the away team), among many others and combinations (e.g. Newall, Russell & Hing, 2021; Nelson et al., 2021; Hing et al., 2015). This array of possibilities multiplies the uncertainty experienced by the player due to the numerous potential outcomes, often with the resolution of one bet depending on the outcome of previous bets. Furthermore, placing multiple bets means that they are resolved over different time frames (Clark & Zack, 2023), adding another layer of complexity and variability to the gambling experience.

Temporal variability represents another source of reward variability, and in the context of gambling, this refers to the time elapsed between the action of placing a bet (the response) and the resolution of the bet (the payoff). In terms of uncertainty, this refers to the unpredictability concerning when the outcome will be resolved in one way or another (Clark & Zack, 2023). For instance, if placing a proposition bet on which team will score first in a soccer match, uncertainty persists until the event occurs (or not) and will vary with each prediction made. In certain slot machines, players can deliberately slow down the reels or extend gameplay through bonus features, contributing to increased temporal variability. Interestingly, alterations in the timing of uncertainty, particularly increased temporal variability, have been shown to affect RPE and dopamine release (Daw, Courville & Touretzky, 2006; Starkweather et al., 2017). Moreover, the resolution of uncertainty itself can be regarded as a type of reward of some value, endowing it with a certain “attractiveness” even if the desired outcome is not achieved (Clark & Zack, 2023; Zack, George & Clark, 2020).

Taken together, the effect of uncertainty and its modulation by various sources of reward variability, enhanced by the structural framework of gambling, seems to provide the perfect environment for altering the learning processes associated with gambling addiction. Incentive sensitization, driven by repetitive associative processes, increases due to the high frequency of these events in gambling contexts (Clark y Zack, 2023). The layering of different rewards and sources of uncertainty, operating concurrently and across different time frames, may serve to (1) boost the incentive salience of stimuli associated with both monetary and other types of rewards and (2) increase the ability of conditioned stimuli increasingly distal to the reward to influence the desire to gamble. Moreover, it is possible that (3) exposure to a multitude of incentives may eventually obscure the perception of alternative reinforcers linked to more adaptive behaviors.

Other processes involved in the attribution of incentive salience to gambling and their key features

Finally, other processes that influence the attribution of incentive salience and which are of particular interest in this context include the state factor (Zack, George & Clark, 2020) and the phenomenon of cross-sensitization (Anselme & Robinson, 2019).

Cross-sensitization refers to the phenomenon where sensitization to one substance or experience enhances dopaminergic reactivity or sensitization to other substances, experiences, or stimuli (Hellberg, Russell & Robinson, 2018). This means that sensitization of neural pathways associated with the "desire" or "want" for a specific reward could facilitate the attribution of incentive salience to other rewards. Research has demonstrated the occurrence of cross-sensitization between different types of drugs (e.g. Wuo-Silva et al., 2011; Liu, Morgan & Roberts, 2007; Carr, Ferrario & Robinson, 2020), between stress and drugs (e.g. Booij et al., 2016; Cruz et al., 2012), and between drugs and gambling (e.g. Zack et al., 2014; Boileau et al., 2013). This phenomenon can explain the frequent comorbidity observed between gambling disorder and substance use (Grant & Chamberlain, 2020; Lorains, Cowlishaw & Thomas, 2011; Maccallum & Blaszczynski, 2002). Additionally, it could shed light on how persistent involvement in a specific gambling behavior (e.g. sport betting) can open the door for a gambler to explore other, different gambling games (e.g. casino games). In other words, the incentive salience acquired through exposure to gambling paraphernalia may increase the propensity to seek out and engage with other types of games or gambling activities (Robinson et al., 2015; Redish, 2004).

Finally, cross-sensitization between stress and problem gambling has been proposed. Exposure to response omission events during gambling can recurrently activate stress neurocircuitry and enhance the effects of intermittent reinforcement schedules on the sensitization of dopaminergic neurons (Zack, George & Clark, 2020; Biback & Zack, 2015).

A stress state factor could thus contribute to the attribution of incentive salience to gambling and its associated cues. State factors influence incentive motivation toward a stimulus or reward, whether pharmacological or natural (e.g., a cue signaling water availability is more salient when thirsty than when satiated with water; Anselme & Robinson, 2019). Similarly, continuing to gamble despite financial losses resulting from gambling may be driven by a motivation to recoup lost money or to alleviate stress caused by the situation (Zack, George & Clark, 2020).

In conclusion, it does not seem unreasonable to suppose that the interaction between state factors and cross-sensitization, along with any other factors that might increase exposure to gambling or its characteristics (e.g. uncertainty or reward variability), facilitates the transition from recreational gambling to compulsive and/or addictive gambling behavior. For instance, early significant winnings associated with the development of problem gambling could serve as a pathway to initiating gambling behavior (Turner et al., 2008; Haw et al., 2008), although some laboratory studies have failed to support this notion (see Mentzoni et al., 2012; Weatherly, Sauter & King, 2004; Kassinove & Schare, 2001). Early wins are surprising events that could, therefore, evoke intense positive RPEs, altering dopaminergic release and initiating incentive sensitization. They also appear to have a particularly powerful effect on behavior established by intermittent reinforcement schedules (Navas et al., 2019). Subsequently, over time, most gamblers experience a greater number of losses than gains in absolute terms. Accumulating large debts can further perpetuate gambling behavior as individuals seek large rewards (also associated with gambling as incentives) to compensate for losses and alleviate the stress triggered by financial setbacks, thus preventing, for example, the extinction of gambling behavior (Zhang & Clark, 2020; Linnet et al., 2010; Zack, George & Clark, 2020).

Gamblers not only continue to gamble (despite its negative consequences) for these reasons. The continuous incentive sensitization of gambling and its cues can trigger increasingly intense peaks of desire, making the pursuit of rewards almost irresistible and extending to many other stimuli, even those that are temporally and spatially distant from gambling itself. Avoiding these triggering stimuli of the irrepressible desire to (want to) gamble is challenging, especially when internal stimuli such as memories, physical sensations, or thoughts are involved. This intense desire — and the central axis of the incentive sensitization theory and compulsive behavior — is known in the specialized literature as "*craving."*

Craving as a driver of compulsive behavior

In behavioral terms, incentive stimuli appear to share three primary characteristics (Meyer et al., 2012; Perales et al., 2020). First, they promote an attentional focus or bias toward themselves, serving as cues indicating the availability of a reward (Berridge & Aldridge, 2009; Ciccarelli et al., 2016). This attentional capture (observed in humans) is believed to be a remnant of autoshaping in animals (e.g. Anselme & Robinson, 2020; Krank et al., 2007). Second, this sequestration of attentional resources is often accompanied by approach behaviors, where individuals move closer to the stimuli or the reward with which they are associated (e.g. Anselme & Robinson, 2020). Third, exposure to cues that have acquired salience triggers an intense affective state characterized by an overwhelming desire for the reward, even if this desire is not matched by the hedonic value derived from the reward (e.g. Berridge & Robinson, 2016), and the persistent pursuit of the reward leads to negative consequences (e.g. Zhang & Clark, 2020). These three characteristics—attentional bias, approach behaviors, and intense desire—form a multifaceted craving response associated with incentive stimuli in behavioral contexts (Perales et al., 2020).

Craving plays a crucial role in substance use disorders and gambling disorders (Mallorquí-Bague et al. 2023) and is thought to represent the ultimate outcome of the aberrant learning processes described in this chapter. In general terms, craving has been defined as an irrepressible urge, impulse, or desire to engage in behavior aimed at obtaining a reward (e.g., gambling or substance use), leading to a loss of control over that behavior despite attempts to resist it (Vafaie & Kober, 2022; Skinner & Aubin, 2010). However, there is currently no clear consensus on the mechanisms underlying craving, although various hypotheses and theories (such as the incentive sensitization theory) have proposed their own models framed around motivational, psychobiological, cognitive, or learning factors to explain the phenomenon (e.g. Koob, 2020; Brand et al., 2016; Redish et al., 2008; Tiffany, 1999; Robinson & Berridge, 1993). Furthermore, the affective nature of craving remains unclear, that is, whether craving represents a negative/aversive emotional or a positive/appetitive emotional state (Wilson, 2022).

In one sense, craving may explain the persistence of addictive behavior through negative reinforcement, operationalized as the avoidance or escape from unpleasant sensations resulting from an aversive state (Koob & Volkow, 2010; Havermans, 2013; Baker et al., 2004). This discomfort can be triggered by stress, physiological symptoms, or stimuli previously associated with the object of addiction, such as incentives (Vafaie & Kober, 2022). While it has been suggested that this negative state resembles or is mediated by withdrawal syndrome (Baker et al., 1986), craving persists and may even increase after extended periods of reward deprivation (Pickens et al., 2011). This possibility is consistent with the capacity of incentive stimuli to provoke craving and drive addictive behavior aimed at alleviating that craving, even following long periods of abstinence (Nicolas et al., 2019; Kawa & Robinson, 2019; Stewart, 2008).

Alternatively, craving can be conceptualized as a state predominantly characterized by positive affect (Wilson et al., 2022). In this regard, cues that trigger craving would acquire some of the properties of the desired reward, generating a state of anticipation that is appetitive in nature (Mansueto et al., 2019; Cornil et al., 2017). According to IS theory, craving represents an appetitive state because the “desire” to obtain the reward underpins the increased incentive value and attractiveness of cues associated with that reward (e.g. Robinson y Berridge, 1993, 2001). In contrast, the Elaborated Intrusion Theory (EIT) proposes that craving arises from a combination of intrusive and elaborate thoughts related to the reward (Kavanagh, Andrade & May, 2005). These intrusive thoughts and mental images evoke feelings of pleasure and interfere with behavioral control (May et al., 2004).

In any case, the appetitive and aversive components of craving need not be mutually exclusive (Wilson, 2022). Some proposals have even postulated a dual-affect model, suggesting the co-existence of a positive and a negative affect craving network (Baker et al., 1987). It is possible that, depending on the type of addiction, the profile of the individual, or even the context, the emotional nature of craving may take on a different emotional valence (Sayette et al., 2016). There seems to be less doubt about the emotional or affective nature of craving. In this regard, it has been proposed that craving control can be considered a form of emotional regulation (Giuliani & Berkman, 2015).

In summary, we have observed that substance abuse or persistent gambling, in some individuals and due to specific circumstances, can lead to the development of addictive processes. Moreover, addictive behavior would be underpinned by motivational habits, compulsive behaviors, or erratic patterns of behavior. In turn, this behavioral pattern is characterized by a heightened salience of gambling or associated cues, a tendency to approach these cues, and an irrepressible desire for their use or consumption, all of which are constituent features of the construct known as craving.

Thus, craving appears to be the core element driving the loss of behavioral control in gambling and, therefore, plays a central role in learned compulsivity. Moreover, it serves as a focal point where several theoretical and empirical contributions presented in this chapter converge. First, craving allows for the integration of habit formation models and incentive sensitization theory. On one hand, craving is an affective state triggered automatically by internal and external cues, while on the other hand, engaging in addictive behavior is reinforced by the relief of this craving. Second, craving represents the primary mechanism underlying the motivation to continue gambling despite the negative consequences. In this regard, it acts as the fuel needed for the individual to employ motivated reasoning and ego-protective emotional regulation strategies that serve to mask the loss of control over gambling. Third, craving manifests as an affective state triggered by predominantly automatic associations, suggesting, therefore, that its frequency and magnitude should be governed by emotional regulation mechanisms of a similar nature (i.e., automatic, implicit, and incidental). However, as already stated, not all individuals who engage in gambling develop disordered behavior or become addicted. Therefore, it remains to be determined what makes certain individuals more or less vulnerable to developing cravings. Consistent with the conceptualization of craving as an affective construct, one proposal is that failures in emotional regulation mechanisms serve as the key that unlocks the door to the entire addictive process.

The role of emotion (dys)regulation in (loss of) craving control

Emotions play a critical role in human cognition and behavior, emerging as physiological-affective reactions to significant events or stimuli in our surroundings (Keltner & Gross, 1999; Cole, 2014; Gendolla, 2000). Rather than being fleeting responses, they serve the purpose of adapting the organism to the demands of the environment to facilitate survival (Phan et al., 2015; Keltner & Gross, 2010; Kopp & Neufeld, 2003; Turner, 2000; Scherer, 1984). Instead of merely reacting, emotions prepare organisms to engage with the environment by motivating specific actions to modify or maintain it to achieve a more functional life (Bose, Pontier & Treur, 2010; Gendolla, 2000). Additionally, emotions guide organisms toward external cues that signal opportunities to fulfill essential needs or motivationally significant desires (Inzlicht, Bartholow & Hirsh, 2015).

However, emotions can also lead to dysfunctional affective states and responses, resulting in maladaptive behaviors (Gross, 2015; Parrot, 2001; Watson, 2000). This often happens when affective experiences persist for too long, are excessively intense or variable, occur too frequently, or are inappropriate for the situation (Stanton & Watson, 2014). Fortunately, through biological and cultural evolution, organisms have developed tools to regulate these abnormal affective experiences (Aldao, Nolen-Hoeksema y Schweizer, 2010; Al-Shawaf & Lewis, 2020).

Although not classified as an emotion *per se*, craving exhibits characteristics of an affect-laden state and shares similarities with dysfunctional emotional experiences (Hofmann & Kotabe, 2013; Franken, 2003). Therefore, regulating craving can be viewed as a form of emotional regulation (Giuliani y Berkman, 2015; Kober & Mell, 2015; Ruisoto & Contador, 2019). Effectively managing craving could assist in controlling potentially problematic behaviors, whereas unsuccessful regulation might lead to heightened craving intensity and increased difficulty in resisting urges (Kober et al., 2010; Silvers et al., 2014).

Emotional regulation and dysregulation

Defining emotional regulation precisely is not a simple task. In the absence of a unifying approach, it continues to be considered a multidimensional umbrella construct that lacks consensus in the scientific and therapeutic communities regarding its definition and operationalization (Vine, 2023; Nardelli, 2023; Velotti et al., 2021; Gross, 2015; Cole, 2014; Campos et al., 2011). However, despite the ongoing debate, it is still possible to approach the concept in a relatively rigorous manner.

Emotional regulation generally refers to an individual's capacity to influence their own experience and expression of emotions (Gross, Richards & John, 2006; Bose, Pontier & Treur, 2010; Aldao, Nolen-Hoeksema & Schweizer, 2010). This includes managing moods, affective responses, or impulse control, as these are behaviors and responses resulting from emotional experiences (Gross, 1998, 2015). Technically, emotional regulation can be defined as the processes, mechanisms, or strategies used to modulate the valence, intensity, or duration of emotions in a flexible manner. The goal is to respond effectively to self-imposed demands or those arising from the environment (Rogier & Velotti, 2018; D'Agostino et al., 2017; Gross, 2014, 2015).

Similarly, emotional dysregulation refers to the inflexible or maladaptive use of strategies for managing emotions, difficulties in implementing appropriate strategies, and/or deficits in the expected functioning of processes or mechanisms involved in controlling the expression and modulation of emotions (Buen & Flack, 2022; Estévez et al., 2020; Sancho et al., 2019; D'Agostino et al., 2017). This definition is an approximation since the concept of emotional dysregulation — like emotional regulation — is still evolving and lacks a consensus definition (For an extensive review of the concept of emotional dysregulation, see Thompson et al., 2019, and D'Agostino et al., 2017). Nonetheless, significant efforts have been made to clarify its scope (e.g. Gratz & Roemer, 2004).

Types of emotional regulation and their classification

Emotional regulation mechanisms operate across various stages of the emotional cycle, spanning from the phases before becoming consciously aware of an emotion to its behavioral expression (Oschner & Gross, 2005). In this regard, distinct regulation mechanisms have been suggested to come into play at different stages of the emotion generation process (Gross, 1998; Yang et al., 2015; Berkman & Lieberman, 2009). These mechanisms require varying levels of supervision, cognitive resources, and conscious monitoring to effectively carry out their functions (Kopp & Neufeld, 2003; Etkin, Büchel & Gross, 2015; Jara-Rizzo et al., 2019).

Given the diverse nature of these mechanisms, multilevel approaches have proposed classifying types of emotional regulation based on whether the modulation of emotions is driven by conscious or non-conscious motives (explicit vs. implicit emotion regulation; Braunstein, Gross & Ochsner, 2017; Gyurak, Gross, & Etkin, 2011) and whether it occurs automatically or requires the intervention of cognitive control (spanning from more automatic to more controlled; Braunstein, Gross & Ochsner, 2017). Some authors have further distinguished between intentional and incidental emotional regulation, which broadly reconciles these two characterizations (Payer et al., 2014; Berkman & Lieberman, 2009). Intentional emotional regulation strategies involve consciously recognizing and evaluating the nature of experienced emotions, understanding their potential impact, and deciding whether to moderate or intensify emotions to appropriately respond to a given situation. These strategies are goal-oriented behaviors (Berkman & Lieberman, 2009; Ochsner et al., 2002). On the other hand, incidental emotional regulation relies on associative learning mechanisms and facilitates gradual adjustments of emotional responses to changing circumstances. This type of regulation is automatically triggered based on learned associations (Payer et al., 2014; Berkman & Lieberman, 2009.

Given the existence of different dual and multilevel approaches, some authors have emphasized the need to develop a comprehensive theoretical framework. This approach should unify and integrate the diverse strategies and mechanisms underlying the various forms of emotional regulation so that we can understand their functioning within an integrative framework (Raio et al., 2016; Etkin, Büchel & Gross, 2015, 2016).

The selected framework is rooted in recent computational theories that leverage advancements in artificial intelligence to develop models of reinforcement learning (RL). These models are used to simulate and understand how organisms learn from interactions with their environment and make decisions to maximize rewards (O'Doherty, Cockburn & Pauli, 2016; Doya, 2008; Dayan & Niv, 2008; Bose, Pontier & Treur, 2010). These computational models recognize two fundamental approaches describing how individuals orient their behaviors toward achieving goals or responding efficiently to the environment: model-based and model-free control (Dayan & Berridge, 2014; Tanaka et al., 2015; Von et al., 2014; Gläscher et al., 2010; Dayan & Niv, 2008). This dichotomous framework resembles the division between the different modes of behavioral control discussed earlier (e.g., goal-directed vs. habitual). However, it represents a theoretical evolution of these concepts (Dolan y Dayan, 2013; Dayan & Berridge, 2014; O'Doherty, Cockburn & Pauli, 2016), offering greater conceptual clarity and precision in algorithmic and computational modeling, allowing for the formulation of concrete hypotheses about the interaction, coexistence, and competition between the two modes of control (Doya et al., 2002; Dayan & Niv, 2008).

Model-based control is characterized by decision-making based on the anticipation and evaluation of the actions' future consequences, both proximate and distal (Dayan & Berridge, 2014). This approach entails creating a mental representation or model of the environment, which includes the causal relationships between available actions and their potential consequences.

Consequently, by leveraging this internal cognitive model or map, individuals can prospectively evaluate the consequences of performing certain actions (Von et al., 2014; Dayan & Niv, 2008; Dayan & Berridge, 2014). This process relies on prior knowledge of these relationships, which are continually updated through various interactions with the environment (Dayan & Niv, 2008. Although this is a flexible type of control that adapts well to environmental changes and goals, it places greater demands on cognitive resources (Daw, Niv & Dayan, 2005; Dayan & Niv, 2008).

In contrast, model-free control relies on learned associations between actions and their immediate outcomes, operating without the need to construct an explicit model of the environment (Dayan & Berridge, 2014; Dayan & Niv, 2008). Instead, it utilizes "cached" or stored values that “summarize” the history of rewards and punishments associated with specific actions. These values are reinforced based on predictive error signals, serving as direct references for decision-making that enable rapid responses without the complex processing required for simulating or predicting potential outcomes of actions (Von et al., 2014; Gläscher et al., 2010; Dayan & Berridge, 2014; Daw, Niv & Dayan, 2005; Lucantonio et al., 2014). Such simplicity and efficiency are advantageous, facilitating the formation of automatic habits and behaviors at low cognitive cost. However, this strategy exhibits notable inflexibility since the stored values do not rapidly adjust to changes in outcome desirability. Consequently, decisions are more strongly influenced by past experiences rather than anticipations of future consequences. This limitation restricts the adaptability of model-free control to new environmental changes or demands (Daw, Niv & Dayan, 2005; Dayan & Niv, 2008).

Based on the distinction between these two systems or modes of behavioral control, Etkin, Büchel, and Gross (2015) introduced a new conceptual framework that views emotional regulation as a series of decisions aimed at achieving a desired emotional state. This framework proposes two pathways of emotional regulation: model-based emotional regulation and model-free emotional regulation. It is clear that the incidental/model-free and intentional/model-based conceptualizations coexist in the scientific literature and, to some extent, overlap. For the sake of clarity, we will adopt the computational terminology when discussing these pathways.

Following this approach, model-based emotional regulation involves implementing an internal model of personal goals to guide regulation (Lee, Shimojo, & O'Doherty, 2014; Daw, Niv, & Dayan, 2005). This would be the case, for instance, in strategies such as cognitive reappraisal that require deliberately altering the meaning of an emotional state (Bramson, Toni & Roelofs, 2023; Goldin et al., 2008; Ochsner et al., 2002). This form of regulation entails becoming aware of the emotion and either modifying aspects of the stimulus that provokes it or modifying its consequences for the individual, with the aim of changing its emotional valence or the intensity experienced (Etkin, Büchel y Gross, 2015).

Model-free emotional regulation relies on associative learning processes and operates automatically, that is, with little or no intentional control by the individual (Lee, Shimojo, & O'Doherty, 2014; Etking, Büchel, & Gross, 2015). This implies that the emotional regulation processes occur before the individual becomes fully aware of the emotion being regulated (Roelofs, Bramson & Toni, 2023). The underlying mechanisms involve predictive error signals, similar to what occurs in phenomena such as extinction (Silvers, 2020; Lee, Shimojo, & O'Doherty, 2014).

Additionally, these two types of regulation can be dissociated at the brain level (Etkin, Büchel y Gross, 2015. Model-free regulation depends on the modulation of the ventral anterior cingulate and ventromedial prefrontal cortex, which are linked to emotional reactivity. In contrast, model-based emotional regulation relies on activity in the frontoparietal regions and motor areas, which are responsible for generating internal models that help determine the suitability of regulatory actions to execute (or not) a specific behavior. Moreover, it has been proposed that these systems could communicate bidirectionally and operate simultaneously (Etkin, Büchel y Gross, 2015; Daw et al., 2011). Alternatively, there may be a form of "arbitration" mechanism that determines which system controls behavior based on the specific situation or context (Lee, Shimojo, & O'Doherty, 2014).

Emotional dysregulation is believed to play a fundamental role in the development of problem or disordered gambling behaviors (Velotti et al., 2021; Buen & Flack, 2021; Piccoli et al., 2020; Williams et al., 2011). In this regard, it has been proposed that various mechanisms of emotional regulation contribute differently to addictive behavior. Specifically, the distinct roles of these mechanisms are identified as (1) the alteration of model-free regulation of emotions triggered by contexts or cues directly related to gambling, (2) the generalized alteration of model-free regulation, and (3) the alteration of model-based regulation (Navas et al., 2019).

Model-free emotional dysregulation in gambling disorder

As discussed earlier, model-free emotional regulation is driven by associative learning processes (Dayan & Berridge, 2014; Roelofs, Bramson, & Toni, 2023), which operate automatically with minimal or no conscious control by the individual (Dayan & Berridge, 2014). This inherent nature poses challenges for studying these mechanisms, as they are "hidden" behaviors that operate largely outside of conscious awareness or supervision. Consequently, individuals often have difficulty self-reporting or articulating these processes (Berkman & Lieberman, 2009), which presents practical challenges, such as the lack of specific measurement tools designed to assess this type of regulation.

Fortunately, the underlying incidental processes of model-free emotional regulation can be inferred and studied through well-known learning phenomena (Delgado et al., 2008). These phenomena, including reversal learning, reinforcer revaluation, and extinction (Salice & Salmela, 2022; Hartley & Phelps, 2010; Braunstein, Gross & Oschner, 2017), represent strategies initiated by implicit goals to modify affect and are implemented through automatic (or somewhat controlled, in the case of reversal learning; Braunstein, Gross & Oschner, 2017) processes. Therefore, these phenomena serve as candidate experimental paradigms for designing studies aimed at unraveling the mechanisms of model-free emotional regulation without relying solely on individuals' self-reports of such processes (Braunstein, Gross & Oschner, 2017).

Reinforcer revaluation and extinction are both examples of learning processes where the affective value of a stimulus changes due to modifications in the associated rewards or punishments. In reinforcer revaluation, a stimulus originally linked to a specific outcome (such as a significant reward) now signals a different outcome (e.g., a reduced reward). In extinction, a stimulus that previously predicted a positive punishment (e.g., an electric shock) no longer does so (Hartley & Phelps, 2010; Delgado et al., 2008). In the case of reversal learning, the scenario is slightly different. In a basic reversal-learning task, an individual or animal learns associations between two stimuli, where one (A) is linked to a reward and the other (B) to a punishment or no reinforcement/punishment at all. After learning these associations, the contingencies are unexpectedly reversed between either the two cues or stimuli (Schiller & Delgado, 2010). These phenomena are considered examples of model-free emotional regulation for several reasons. Firstly, they demonstrate how emotional responses can be altered without explicit or apparent conscious effort to regulate those emotions. Secondly, emotional regulation in these cases is not driven by an explicit goal. Lastly, the modification of emotional responses occurs through mechanisms that operate automatically, at least in reinforcer revaluation and extinction (Hartley & Phelps, 2010; Braunstein, Gross & Oschner, 2017). In reversal learning, updating the affective values of stimuli represents a form of implicit regulation, although it may not be fully automatic and can involve some level of control in some cases (Braunstein, Gross & Oschner, 2017).

The empirical support for the involvement of associative processes in model-free emotional regulation comes from studies correlating emotional regulation in everyday contexts (measured through self-report or direct observation) with learning phenomena observed in experimental laboratory tasks employing paradigms such as reinforcer revaluation, extinction, and reversal learning (e.g. Graham & Milad, 2017; Milad et al., 2013; Silver, 2020; Quail, Morris & Balleine, 2017; Hinojosa-Aguayo & González, 2019; Yang et al., 2015; Oschner & Gross, 2005). Interestingly (and relevant to this work), these experimental paradigms have been utilized to investigate model-free emotional regulation in individuals with gambling disorders or problem gambling. However, the number of studies in this area is limited.

Regarding reversal learning in the context of gambling research, most studies indicate that individuals with pathological or severe gambling tendencies exhibit signs of learning inflexibility compared to recreational gamblers or healthy controls. This inflexibility is often characterized by fewer correct responses, increased perseveration (repeated responses despite changing contingencies), or slower acquisition of new learning. While the majority of studies support these findings (Jara-Rizzo et al., 2020; Perandrés et al., 2021; Boog et al., 2014), two studies did not find significant differences between groups in terms of reversal learning performance (Torres et al., 2013; Verdejo-García et al., 2015). However, the former did establish a relationship between gambling intensity (e.g., higher amounts of money wagered per unit of time) and increased reversal cost. It is important to note that despite these findings, the primary focus of many of these investigations was not specifically aimed at determining how reversal learning deficits may explain or relate to emotional dysregulation issues in gambling.

Research is even more limited regarding the study of extinction processes in laboratory tasks involving gamblers. Only one study (Quintero et al., 2020) has investigated the relationship between an indirect measure of emotional dysregulation (specifically, negative urgency; see the following subsection for a more detailed discussion of the implications of this measure) and resistance to extinction of conditioned emotional associations in gamblers with varying levels of gambling severity. In this study, the authors found that the measure of emotional dysregulation predicted (1) resistance to extinction and (2) higher levels of craving, which in turn predicted greater gambling severity (i.e., more severe gambling-related symptoms). However, craving did not predict performance on the behavioral extinction task.

The significance of these findings lies in the association between extinction difficulties and players' scores on negative urgency, which has been considered a proxy for generalized model-free emotional dysregulation of behavior.

Generalized model-free emotional dysregulation in gambling disorder

As mentioned earlier, the rationale behind studying model-free emotional regulation in laboratory tasks stems from the challenges of assessing it directly with specific instruments or questionnaires. The mechanisms underlying this type of regulation are not fully accessible through self-observation, making it difficult to report on these processes accurately and thus develop precise evaluation tools. Consequently, some researchers suggest evaluating disruptions in model-free emotional regulation indirectly through their expression in the form of emotional impulsivity (Lynam et al., 2006; Cyders & Smith, 2008).

Impulsivity refers to deficits in cognitive processes related to controlling, planning, and anticipating behavior. Broadly speaking, it entails a tendency to react hastily and thoughtlessly to internal or external stimuli, often without considering the potential negative consequences of those reactions (Brewer & Potenza, 2008). Impulsivity is multidimensional in nature and can manifest as impulsive choice, impulsive action, or trait impulsivity, depending on the context in which it is assessed (MacKillop et al., 2016; Kristen et al., 2015; Grant & Chamberlain, 2014; DeYoung, 2011). Emotional impulsivity, a specific aspect, is derived from multidimensional models of impulsivity that distinguish between emotional and cognitive impulsivity (Knezevic-Budisin et al., 2015; Verdejo-García et al., 2009; Whiteside et al., 2005). The UPPS-P model of impulsivity is one such model, identifying five facets of impulsivity, three of which—sensation seeking, positive urgency, and negative urgency—have been linked to emotional impulsivity (Lynam et al., 2006).

The study of emotional impulsivity, particularly negative urgency, has garnered significant interest in recent years (Halcomb, Argyriou & Cyders, 2019; Zorrilla & Koob, 2019; Um et al., 2019). Negative urgency is characterized by a tendency to act impulsively or lose control in response to intense negative emotions, suggesting it could serve as an indicator of emotional regulation difficulties (Cyders & Smith, 2008; Whiteside et al., 2005). Consequently, negative urgency has been proposed as a psychometric measure reflecting behavioral manifestations of model-free emotional dysregulation (Navas et al., 2019; Jara-Rizzo et al., 2019; Quintero, Navas & Perales, 2020; Ruiz de Lara, Navas & Perales, 2019). Support for this proposal ranges from theoretical assumptions to empirical evidence obtained through cross-sectional studies.

The main rationale for this proposal stems from research indicating that negative urgency is a transdiagnostic factor and a critical vulnerability marker for disorders where impaired emotional regulation is a recognized causal factor.

This includes addictive disorders and other externalizing disorders, such as gambling disorders (Beauchaine, Zisner & Sauder, 2017; Johnson, Carver & Joormann, 2013; Johnson et al., 2017; Settles et al., 2012; Billieux et al., 2010). Negative urgency and emotional impulsivity, more broadly, have been linked to higher rates of comorbidity between gambling disorder and other externalizing psychopathologies (Savvidou et al., 2017).

More specifically, in gambling, negative urgency serves as an indicator that is linked to the complexity and severity of the symptoms associated with gambling disorder (Billieux et al., 2012; MacLaren et al., 2011). Etiological models of gambling disorder identify a specific phenotype of gamblers with high impulsivity and externalizing problems (Blaszczynski y Nower, 2002). The inability to adequately regulate emotions could precipitate the loss of behavioral control and the tendency to engage in rash and reckless behaviors during intense emotional states. Current etiological models propose that this type of gambler is characterized by having impaired model-free emotional regulation mechanisms, which are necessary for limiting the conditioning processes underlying gambling behavior and thus preventing generalized model-free emotional dysregulation (Navas et al., 2019). In this context, generalized emotional dysregulation would be defined as the inability to manage intrusive thoughts and the expression of behaviors triggered by particularly intense (generally negative) emotions. This dysregulation is considered a vulnerability mechanism not only for gambling disorders in particular but also for addictive processes in general (Jara-Rizzo et al., 2019; Stone, 2023).

In summary, the general disruption of model-free emotional regulation could underlie the complications observed in certain gamblers, who are also characterized by comorbidity and externalizing behavioral issues, setting them apart from other phenotypes. Evidence suggests a strong connection between impulsivity driven by negative affect and dysregulation. The loss of control in gambling behaviors may result from impulsive urges to escape negative mood states triggered by monetary losses or from the subjective experience of craving.

Model-based emotional dysregulation in gambling disorder

While emotional regulation can involve automatic processes, much of the research in this field has primarily focused on studying model-based emotional regulation processes. Model-based emotional regulation entails learned responses or strategies that are intentional and goal-directed, that is, the individual aims to reduce (or increase) their affective experiences and is aware that this regulation is taking place (Berkman & Lieberman, 2009).

In contrast to model-free emotional regulation, model-based emotional regulation is explicit, lending itself to the possibility of being studied from at least three different perspectives: (1) through self-reports and psychometric instruments, and (2) through laboratory tasks, which allow the recording of (3) different psychophysiological measures.

Research conducted through self-report or psychometric instruments often focuses on assessing dispositional or trait emotion regulation (Koval et al., 2022). This approach provides insights into individuals' habitual and stable tendencies to influence their emotions and how they are likely to respond emotionally across different situations (Aldao, Nolen-Hoeksema, & Schweizer, 2010). Various validated scales and questionnaires are commonly utilized for this purpose, targeting specific regulation deficits or strategies (e.g. Gross & John, 2003; Garnefski y Kraaij, 2007; Gratz & Roemer, 2004; Rassin, 2003). Two widely recognized questionnaires used in this context are the Emotional Regulation Questionnaire (ERQ; Gross & John, 2003) and the Cognitive Emotion Regulation Questionnaire (CERQ; Garnefski & Kraaij, 2007). The former primarily assesses the tendency to use strategies such as reappraisal and suppression of emotional expression, while the latter concentrates on assessing cognitive regulatory strategies. Reappraisal involves modifying emotions by reevaluating internal events or experiences, essentially adopting a new perspective on the meaning of an emotional situation (Clark, 2022; Gross & John, 2003). On the other hand, suppression entails attempting to conceal, inhibit, or forcibly reduce the behavioral expression of experienced emotions (Cutuli, 2014; Butler et al., 2003; Gross & John, 2003). Reappraisal is considered effective in reducing reactivity to negative emotional experiences (Mansson et al., 2023; Velotti et al., 2022). In contrast, suppression is viewed as a counterproductive strategy that may lead to increased emotional arousal and perpetuate unpleasant or maladaptive emotions over time (Williams et al., 2011; Marchica et al., 2019; Velotti et al., 2022).

The majority of research investigating how problem and disordered gamblers regulate their emotions, relying on self-report measures, focuses on two primary strategies: reappraisal and expressive suppression. The findings regarding the impact of these strategies on problem gambling are mixed. Overall, systematic reviews and meta-analyses (Marchica et al., 2019; Neophytou et al., 2023; Velotti et al., 2021) suggest that reappraisal is associated with a decreased risk of problem gambling (Bonnaire et al., 2022;

Rogier et al., 2019, 2021; Pace et al., 2015), whereas expressive suppression is linked to an increased risk (Bonnaire et al., 2022; Rogier et al., 2019, 2021; Navas et al., 2017). However, some studies contradict these relationships or fail to find strong evidence supporting them (Barrault et al., 2017; Barrault et al., 2018; Mestre-Bach et al., 2021; Williams et al., 2011). In addition to these findings, other studies have identified positive associations between negative urgency—a tendency to act rashly under intense negative emotions—and expressive suppression (Navas et al., 2017; Jara-Rizzo et al., 2019).

While the study of dispositional emotional regulation strategies is extensive, it is important to recognize that the ability and tendency to influence emotions are distinct issues (e.g. Silvers & Moreira, 2019; Berkman & Lieberman, 2009). Research conducted through laboratory tasks provides a valuable opportunity to gather behavioral data and simultaneously record various neuroimaging or psychophysiological measures during the execution of regulation strategies. These measures may include electroencephalographic (EEG) recordings, skin conductance, cardiac variability, or facial electromyography. By assessing performance and success in emotion regulation tasks alongside these physiological recordings, researchers can delve deeper into the underlying mechanisms of model-based emotional regulation.

To this end, researchers have developed specific laboratory tasks primarily aimed at examining performance on cognitive reappraisal (e.g. Phan et al., 2015; Bastiaansen et al., 2018; Giles et al., 2017; Deak et al., 2018; Goldin et al., 2008; Contreras-Rodriguez et al., 2020) and expressive suppression (e.g. Goldin et al., 2008; Desatnik et al., 2017; Challet-Bouju et al., 2020). The task format is similar for both strategies. Participants are presented with a series of images depicting varying emotional content (e.g., images with negative valence compared to neutral valence). During these tasks, participants are instructed to apply the designated emotional regulation technique while viewing the images, with the goal of mitigating their emotional impact. The effectiveness of each technique is evaluated by comparing it to control conditions in which the participants either experience the emotions generated by the images without attempting to alter their effect or are exposed to images with neutral levels of valence and emotional arousal. Consequently, the efficiency of the chosen strategy is measured by comparing the subjective evaluations of the emotional distress induced by the images in the different scenarios (for some illustrative examples, see Phan et al., 2015; Goldin et al.,2008; Deak et al., 2017).

While there is a lack of research specifically examining the ability of problem gamblers to suppress emotions (with only one study involving non-pathological gamblers; Challet-Bouju et al., 2020), there are two noteworthy studies that have investigated the success of gamblers in using cognitive reappraisal as an emotion regulation strategy (Navas et al., 2017; Picó-Pérez et al., 2022). These studies are particularly interesting and complementary as they involved the same sample of participants but employed different analytical approaches. One finding from these studies was that there were no discernible differences in task performance between a group of pathological gamblers and a group of healthy controls when using cognitive reappraisal. However, neuroimaging results revealed intriguing insights. Specifically, it was observed that negative urgency—a tendency to act rashly under negative emotions—was positively correlated with increased activation in frontal brain regions during negative emotion regulation among pathological gamblers. Additionally, these individuals exhibited an overactivation of cognitive control areas during reappraisal compared to the control group. This heightened activation may suggest that pathological gamblers require greater cognitive resources to manage their emotions effectively and perform comparably to the control group, thus incurring a higher cognitive cost during emotional regulation tasks.

Implications of the three types of emotional regulation on gambling, craving, and cognitive biases

While there have been relatively few studies exploring emotional regulation mechanisms in gamblers, the findings have been somewhat contradictory. However, it is possible to construct a tentative general interpretation based on these results.

First, evidence from research on model-based emotional (dys)regulation processes can be viewed in conjunction with data obtained from various approaches to studying these mechanisms. Despite some inconsistent findings, the overall evidence suggests a tendency among problem gamblers to preferentially use dispositional maladaptive regulation strategies, such as suppression, over adaptive strategies, such as reappraisal. This tendency is, in turn, associated with the presence of negative urgency. Cognitive reappraisal, characterized by a constructive reinterpretation of negative emotional situations, can play a protective role against the development of problematic gambling behaviors. It facilitates the management of gambling urges (e.g., craving) by reducing the impact of intense negative emotions, thereby mitigating the adverse subjective experiences (e.g., stress, anxiety) associated with gambling.

Conversely, expressive suppression may exacerbate gambling problems by perpetuating a cycle where emotions are not effectively processed. This can intensify generalized emotional dysregulation, potentially leading individuals to use gambling as a coping mechanism to manage overwhelming emotions.

One plausible hypothesis suggests that individuals who tend to suppress cognitive reappraisal may do so due to the perceived cognitive effort required by these strategies (Navas et al., 2017). Rather than addressing emotions at their root (e.g., by directly reframing events to alter their emotional impact), these individuals may choose more accessible palliative measures, such as inhibiting the outward behavioral expression of their emotional responses.

However, it is known that a subset of players has an intact ability to employ intentional emotional regulation strategies effectively. For these players, emotional regulation could play a complex role in sustaining disordered gambling behavior. This particular group of gamblers might utilize such techniques to alleviate cognitive dissonance resulting from a loss of control over their gambling habits, reducing the emotional impact of negative consequences and fostering illusory reasoning that perpetuates problematic behavior. In this context, cognitive biases related to gambling would serve as a crucial tool for aligning outcomes with pre-existing beliefs about one's behavior, masking losses, or attributing financial setbacks to external factors beyond the gambler's control.

Second, studies investigating model-free emotional regulation mechanisms have yielded relatively consistent results. Most studies point to specific signs of learning inflexibility or increased perseveration among pathological gamblers compared to non-problematic gamblers in tasks such as probabilistic reversal learning. Generally, poor reversal learning involves excessive focus on cues previously associated with reward. This attentional bias is indicative of incentive salience and the affective response of craving, suggesting that model-free emotional dysregulation is a vulnerability factor influencing its manifestation or control. Similarly, and as discussed earlier in this chapter, alterations in extinction mechanisms could be triggered by incentive motivation linked to the uncertainty inherent to gambling devices. Although in the study by Quintero et al. (2020), craving was not directly associated with resistance to extinction, it was found to correlate with higher scores on negative urgency (indicative of generalized model-free emotional dysregulation). Craving was found to be a necessary condition (i.e., a mediating variable) for model-free emotional dysregulation to indirectly affect the severity of problem gambling symptoms.

CHAPTER II:

Justification, Objectives, and Hypotheses

Overview and Rationale

The characterization of pathological gambling as an addictive disorder represents a significant advancement in both practical and theoretical terms, following decades of empirical research. This development has led to the recognition of a new diagnostic category (i.e., behavioral addiction), which is presumed to be a fundamental, albeit possibly insufficient, first step. Gambling disorder still necessitates improvements in prevention and treatment strategies. The achievement of this objective is contingent upon a more profound comprehension of the individual variations among those who engage in problematic gambling, as well as the precise tailoring of interventions to these distinctions. This entails three key elements: (1) the identification of risk factors and vulnerability markers, (2) an understanding of the underlying mechanisms that precipitate the loss of control over gambling, while considering how these mechanisms respond to, are activated by, or are intensified in relation to other triggering factors (i.e., structural properties of gambling games), and (3) the determination of how this set of elements fits the variability of existing gambler profiles.

To date, research in the field of behavioral addictions, in general, and gambling addiction, in particular, has exhibited a marked extensional character, along with a pronounced inclination to adhere to the confirmatory approach (Griffiths, 2017; Kardefelt-Winther et al., 2017). It is accurate to state that the categorization of pathological gambling as an addictive phenomenon was based on established parallels with substance addictions, as well as the majority of diagnostic criteria (see Introduction). Consequently, research has primarily focused on confirming these similarities, particularly in their clinical manifestations, rather than or with less emphasis on etiological factors.

Perhaps the approach that most representatively implements both extensional and confirmatory perspectives is the Components Model of Addiction. According to this model, the way to determine if a behavior is “addictive” is by comparing it to the clinical criteria of other established substance addictions (Griffiths, 2005). Following this assertion, the model proposes that all addictions consist of basic components whose presence is imperative for them to be considered as such; that is, “a behavior should not be classed as an addiction unless there is endorsement and empirical and/or clinical verification of six specific components,” namely, “salience, mood modification, tolerance, withdrawal, conflict, and relapse” (p. 180, Griffiths, 2019). While this approach has been supported and promoted by numerous authors, framing new addictions within a familiar diagnostic framework and expanding the field of study with significant contributions, it also creates a scenario with several drawbacks. Although these drawbacks largely pertain to the field of behavioral addictions in general (see Billieux et al., 2019; Castro-Calvo et al., 2022; Billieux et al., 2015; Brevers et al., 2022; see Griffiths, 2019 for a rebuttal to various criticisms), they also have important implications for the specific field of interest in this thesis (Tseng et al., 2023), as they compromise the ultimate goal of gambling research, which is to provide knowledge for more effective, evidence-based interventions and intervention strategies.

Achieving this goal involves distinguishing an addictive behavior from one that is not. Currently, labeling a pathological condition requires only the sum of a series of components or criteria. An operationalization of these based solely on the presence of specific clinical manifestations can lead to evaluations that are sufficiently lax to result in phenomena of over-pathologization. It is possible that some gamblers fit several operationalizations of the components mentioned in the previous paragraph, and yet (1) the severity of their symptoms does not conform to a disorder condition, or (2) they reflect peripheral characteristics (not necessarily indicative of pathology) rather than central characteristics (with more diagnostic validity; Billieux et al., 2019). In the DSM-5, the severity of gambling disorder is also based on the number of diagnostic criteria the potential patient meets. Consequently, two gamblers who meet completely different criteria can be diagnosed with the same label, without consideration of the relevance of the factors contributing to their individual differences. The presence of certain criteria/components may depend on the individual etiological path that a particular gambler has followed. This is of paramount importance in order to establish flexible and effective therapeutic strategies that are tailored to the specific phenotype of problematic gamblers.

Furthermore, reducing the similarities of addictions to six basic components can be a double-edged sword. On one hand, its parsimony cannot be denied. However, this necessarily entails the exclusion of other "components" that may be fundamental in gambling addiction (e.g., compulsivity, craving, or the presence of cognitive distortions; Kim & Hodgins, 2018). Consequently, the confirmatory approach may hinder the identification of additional crucial elements related with problematic gambling; whether currently present or anticipated in the future (this is exemplified by potential structural alterations in gambling devices driven by emerging technological advancements).

In light of the aforementioned considerations, we believe that it is essential to overcome the epistemological inertia that has brought us to this point. While it has contributed significantly to this field, it limits its ultimate goal, which is to provide effective therapies to affected patients and prevention strategies to individuals potentially vulnerable to losing control over gambling behavior. We propose an intentional or transdiagnostic approach to studying gambling addiction, with a focus on the underlying processes to adequately operationalize the signs, symptoms, and behaviors in the gambling population. This approach allows us to trace a causal history of the addictive phenomenon, based on its etiology and the diverse mechanisms that sustain it (Sussman, 2017). We posit that defining and addressing gambling addiction through its fundamental causes will facilitate the identification of specific causal processes, thereby enabling a deeper understanding and more effective intervention for this disorder.

Background and General Objectives

The previous chapter introduced several constructs that, while fundamental to the maintenance and development of problem gambling, are not yet part of direct diagnostic criteria for gambling disorder. First, the construct of gambling-related cognitions was introduced, along with its relationship to problem gambling and various hypotheses regarding the etiology of these distortions. Secondly, the transition from goal-directed behavior to compulsive behavior was discussed as a fundamental core of the addictive process, describing the processes and elements it encompasses according to some of the most studied scientific models in substance use disorders and its relevance to problem gambling. In addition, the concept of craving was introduced as a potential fundamental driver of learned compulsivity. Finally, different mechanisms of emotional regulation were described. The dysfunctional use of these mechanisms, deficits, or problems in their functioning could potentially underlie the other behaviors previously described. Furthermore, various implications of their role in problem gambling were presented based on existing empirical data.

Building on this foundation, the present thesis set out with the original objective of elucidating the role of model-free and model-based emotional regulation processes in the severity of gambling symptoms in general, and in the other constructs in particular. This objective was pursued through two empirical studies (**Studies IV** and **V**). However, there were some gaps in the research that were considered to be directly related to the original objective of this thesis and needed to be addressed. To this end, a study was conducted to confirm or refute the relationship between general domain cognitive processes and gambling-related cognitive biases (**Study I**), and two studies were undertaken to deepen the characterization of learned compulsivity in behavioral addictions (**Studies II** and **III**).

The overarching objective of these studies was (1) to delve into the etiological particularities of gambling disorder from a transdiagnostic perspective, (2) to provide new diagnostic tools and psychophysiological markers to this field of study, (3) to construct a hypothetical causal narrative of the chain of processes that lead from recreational gambling activity to compulsive gambling activity, and (4) to open or rule out new lines of research based on the results of our work and their fit within the current literature. More specifically, each of these studies, divided into four sections or chapters, aimed to achieve several more specific objectives, as will be described in detail below.

Chapter III: Justification, Objectives, and Hypotheses

As previously stated in the Introduction section, the link between distorted cognitions and gambling problems is evident. Nevertheless, the etiological nature of these cognitions remains unclear. Given that empirical results from various studies show inconsistent and sometimes contradictory findings, interpretations of these results are also inconsistent. The heterogeneity of the studies and populations examined makes it challenging to ascertain whether inconsistencies are attributable to mere statistical issues or to a multitude of unconsidered factors that influence the manifestation of these cognitions (e.g., type of gambler, level of severity, etc.). Resolving this debate in the literature is crucial, as it has a direct impact on addressing an element that is particularly important and idiosyncratic in gambling behavior.

In this context, a number of potential explanations are currently under discussion. One hypothesis is that gambling-related cognitive distortions result from general cognitive impairments, such as deficient abstract (fluid intelligence) or probabilistic reasoning. If this is the case, then faulty reasoning would facilitate the manifestation of distortions, which in turn would lead to problematic gambling. An alternative hypothesis is that gambling itself is the catalyst for these cognitive distortions. These distortions would result from mere continuous exposure to the consequences of gambling and its structural properties, which would be directly related to its severity.

Chapter III directly addresses these potential explanations to add evidence to this area of disordered gambling research. This chapter presents an investigation (**Study I**) examining the controversial association between abstract (fluid intelligence) and probabilistic reasoning abilities and gambling-related cognitive distortions in two samples: a non-problematic gambler sample and a sample of gamblers diagnosed with gambling disorder. Therefore, the objectives of this chapter are to directly clarify:

- The relationship between general domain reasoning abilities (abstract and probabilistic) and gambling-related distortions.
- The relationship between general domain reasoning abilities and the severity of problematic gambling.
- The relationship between gambling-related cognitive distortions and the severity of problematic gambling.

Although it is expected that participants with disordered gambling will exhibit higher gambling-related cognitions and perhaps a slight disadvantage in tests evaluating abstract and probabilistic reasoning abilities, the hypotheses remain open. This is due to the substantial amount of contradictory findings in the literature regarding the links between these variables. For this reason, and in line with the absence of specific predictions, Bayesian methodology is used to estimate the support for the existence or non-existence of such an association.

Chapter IV: Justification, Objectives, and Hypotheses

The prevailing models of substance addiction highlight the idea that the transition from initially goal-directed behaviors to compulsive behavior constitutes the core of addiction. However, the precise characterization of compulsivity, as well as its operationalization and etiology in the context of non-substance addictions, remains inadequately specified. Similarly, there are no instruments that allow for the evaluation of compulsivity as characterized throughout the introduction of this work. This presents a challenge for the research and treatment of both recognized and potential behavioral addictions.

Chapter IV consists of two independent but closely related studies that attempt to address this issue. The first of these studies (**Study II**) is a systematic review, whose main objective is to delve into the conceptualization and operationalization of compulsivity in the context of behavioral addictions. To achieve this purpose, this study is developed through three specific objectives:

- Identify items sensitive to the construct of compulsivity in psychometric instruments used in behavioral addiction research.
- Analyze the content of these items to establish potential operationalizations of the construct of compulsivity and differentiate them.
- Evaluate these operationalizations to identify potential delimitation issues in each of them.
- Use the information obtained for the development of a future scale that measures compulsivity in any behavioral domain, including gambling addiction and other potential behavioral addictions.

We anticipate that the resulting scale will be multidimensional. However, it is possible that the factorial composition of compulsivity may not entirely correspond with the set of previously established operationalizations.

In this sense, the first study serves to lay the groundwork for the second study of the chapter (**Study III**), whose main objective is to develop and validate a compulsivity scale in two domains of potentially addictive behaviors: gambling and video gaming. To this end, a 90-item scale encompassing six different operationalization proposals of compulsivity (emerging from the previous study) was administered to two convenience samples of individuals with a high degree of involvement in gambling and video gaming activities. Specifically, the objectives of the study were:

- Uncover the factorial structure of the 90-item set.
- Examine whether compulsivity can be measured across different behavioral domains (gambling and video gaming), and explore the potential difference in the nature of compulsivity between the two chosen domains.
- Examine the relationship between compulsivity and other variables of interest related to gambling.
- Construct a shortened version of the scale to facilitate its use in future research.

With regard to the first objective, the hypotheses remain open. For the second objective, it is predicted that compulsivity will have a stronger association with gambling-related problems than with video gaming, and therefore, (third objective, and third prediction), the correlations between scale scores and other gambling-related variables will be higher in the gambling sample than in the video gaming sample. A more comprehensive elaboration of this last prediction can be found in **Study III**.

Chapter IV: Justification, Objectives, and Hypotheses

The Gambling Space Model (GSM; Navas et al., 2017) is an etiological model of gambling that emerged from previous projects to which this doctoral thesis is related. This model places central importance on the different mechanisms of emotional regulation in the course, severity, and prognosis of gambling disorder. Notably, it assigns different implications to the alteration of these mechanisms, which would have distinct impacts on various gambling complications and could be specific to different gambler profiles.

Chapters V and **VI** aim to elucidate the role of model-free (**Study IV**) and model-based (**Study V**) emotional regulation processes in the symptoms of problematic gambling. Additionally, they also aim to establish a triadic association between behavioral markers of emotional regulation in laboratory experimental tasks, psychometric indicators related to emotional regulation of theoretical and clinical importance, and psychophysiological markers.

Specifically, in **Chapter V** (**Study IV**), the performance in a Pavlovian acquisition-extinction task is investigated in a sample of regular community gamblers, both with subclinical and clinical levels of gambling severity. This task allows the analysis of how neutral stimuli acquire affective salience and how the presence of clinical correlates of problematic gambling might be associated with difficulty in extinguishing such salience.

This study has several objectives. Firstly, it aims to replicate and extend a previous study (Quintero et al., 2020) to further explore the mechanisms of incidental emotional regulation linked to cues and generalized incidental dysregulation in problematic gambling. In the aforementioned study, negative urgency was found to be associated with slower extinction of conditioned stimuli with emotional content. In this context, the additional objectives are:

- To replicate the findings of the aforementioned article and extend them to positive urgency.
- To clarify the role of model-free emotional dysregulation in the development of craving and gambling problems. In other words, to corroborate the link between the extinction rate of predictive responses

and individual differences in psychometric markers of emotional regulation and other gambling-related behaviors.

- To confirm that the selected laboratory task can serve as a model-free emotional regulation paradigm useful for deepening the study of gambling problems.
- To find electrophysiological markers of the changes that occur in the processing of the conditioned stimulus throughout extinction.

Regarding the hypotheses of this study, it is expected to replicate the findings of Quintero et al. (2020). Specifically, we anticipate greater resistance to extinction in gamblers showing signs of model-free emotional dysregulation, measured through negative urgency, and a positive correlation between this and measures of craving and gambling severity. The effects of positive urgency on extinction and its relationship with craving and problematic gambling severity remain open, although expected predictions can be found in the study itself.

Chapter VI: Justification, Objectives, and Hypotheses

Similarly, **Chapter VI** presents a study that aims to delve into the basic mechanisms of intentional emotional (dys)regulation in a sample of community gamblers through a cognitive reappraisal task. The objectives of this study are:

- To explore possible differences in the success of emotional regulation execution during the cognitive reappraisal task.
- To identify psychometric markers of potential clinical interest associated with better or worse performance in a cognitive reappraisal task.
- To test the utility of other potential psychophysiological markers of interest by recording heart rate variability (HRV) during the task execution. This peripheral marker seems useful for measuring the cognitive effort involved in controlled emotional regulation.

Based on a previous study already presented in the introduction (Navas et al., 2017), we do not expect differences in the success of implementing cognitive reappraisal among gamblers with different levels of severity. However, we do expect that the execution of model-based emotional regulation (reappraisal) will result in a more pronounced increase in mental load (as measured through HRV) in those gamblers exhibiting higher levels of gambling severity, other related factors, or with lower or higher scores on measures of dispositional emotional regulation, both adaptive (reappraisal) and maladaptive (suppression), respectively.

Other hypotheses concerning the relationship between changes in HRV and other gambling-related measures (such as several indices of the cognitive reappraisal task itself) can be found in the study. In any case, due to the contradictory results regarding the relationship between measures of dispositional emotional regulation and the severity of gambling symptoms, and since this is the first study using HRV to explore these processes, we will proceed in the same manner as in **Study I**; that is, using Bayesian methodology to assess the strength of the evidence supporting or refuting the obtained data.

CHAPTER III:

Study I

Gambling-specific cognitions are not associated with either abstract or probabilistic reasoning: a dual frequentist-Bayesian analysis of individuals with and without gambling disorder

The content of this chapter has been published as:

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Abstract

Background: Distorted gambling-related cognitions are tightly related to gambling problems, and are one of the main targets of treatment for disordered gambling, but their etiology remains uncertain. Although folk wisdom and some theoretical approaches have linked them to lower domain-general reasoning abilities, evidence regarding that relationship remains unconvincing. *Method*: In the present cross-sectional study, the relationship between probabilistic/abstract reasoning, as measured by the Berlin Numeracy Test (BNT), and the Matrices Test, respectively, and the five dimensions of the Gambling-Related Cognitions Scale (GRCS), was tested in a sample of 77 patients with gambling disorder and 58 individuals without gambling problems. *Results and interpretation*: Neither BNT nor matrices scores were significantly related to gambling-related cognitions, according to frequentist (MANCOVA/ANCOVA) analyses, performed both considering and disregarding group (patients, non-patients) in the models. Correlation Bayesian analyses (bidirectional BF_{10}) largely supported the null hypothesis, i.e. the absence of relationships between the measures of interest. This pattern or results reinforces the idea that distorted cognitions do not originate in a general lack of understanding of probability or low fluid intelligence, but probably result from motivated reasoning.

Introduction

Gambling is a leisure activity, practised non-problematically by a large share of the population, but that can generate substantial harm to the community (Shannon et al., 2017). The severity of potentially problematic gambling lies on a continuum in which gambling disorder is placed at its highest end (Shaffer and Martin, 2011; Rai et al., 2014). However, from a public health perspective, gambling-related harms go beyond the individual, and are not exclusively driven by the severity of disordered gambling (Wardle et al., 2019).

Understanding the factors that foster gambling involvement is thus important at the individual, social, and policy levels, regardless of clinical status. And, among these factors, distorted gambling-related cognitions play a central role (Fortune and Goodie, 2012; Lindberg et al., 2014a; Goodie et al., 2019; Brooks et al., 2020). These cognitions are frequently targeted by commercial advertising (Lopez-Gonzalez et al., 2018), and are among the main therapeutic targets in cognitive-behavioral therapy of gambling disorder (Rash and Petry, 2014; Choi et al., 2017; Menchon et al., 2018). Indeed, they are present to some degree in virtually all gamblers, play a key role in maintaining gambling behavior [see (Goodie and Fortune, 2013), for a review], and their strength varies as a function of severity (Emond and Marmurek, 2010; Del Prete et al., 2017; Jara-Rizzo et al., 2019) and is modulated by the effectiveness of therapy (Breen et al., 2001; Doiron and Nicki, 2007; Toneatto and Gunaratne, 2009; Donati et al., 2018).

The most comprehensive and widely used model of gambling-related cognitions [the Gambling-Related Cognitions Scale, GRCS (Raylu and Oei, 2004)], encompasses five different domains, namely, inability to stop, expectancies, predictive control, illusion of control, and interpretative bias. The first two are common dysfunctional (but not necessarily “erroneous”) beliefs present in a range of potentially addictive behavior patterns. Specifically, inability to stop refers to a lack of self-efficacy in controlling gambling behavior and overcoming urges, and expectancies allude to expected outcomes than can work as motives to gamble, such as winnings or curbing negative affect. The other three can be strictly considered cognitive biases at making causal inferences. Illusion of control and predictive control are beliefs about the possibility to control and predict gambling outcomes, respectively. Interpretative bias is the tendency to attribute positive and negative gambling outcomes to internal and external causes, respectively, that is, to reformulate wins as due to skills, and losses as due to bad luck (Oei and Burrow, 2000; Oei and Raylu, 2004).

There are at least two mechanisms by means of which better domain-general reasoning abilities could protect individuals from distorted gambling cognitions, and thus, indirectly, from developing gambling problems. The first one is more specific: given the evident overlap between poor understanding of probability and randomness, and causal biases (Gilovich et al., 1985; Ladouceur et al., 1996; Clark, 2017), it seems reasonable to assume that people with lower scores in probabilistic reasoning will transfer that disadvantage to gambling activities, where, as mentioned earlier, causal misattribution plays a key role. Or the other way round, good domain-general probabilistic reasoning could potentially prevent the development of at least some types of distorted gambling-related cognitions.

The second mechanism is more general, and regards the potential role of general fluid intelligence and abstract reasoning. These two largely overlapping constructs refer to the capacity to think logically, solve novel problems and operate abstract symbols with minimal dependence on previously acquired knowledge (Carpenter et al., 1990; Santarnecchi et al., 2017; Gómez-Veiga et al., 2018). Gambling devices and the rules under which they operate can be mathematically complex and opaque, so, in principle, fluid intelligence could contribute to a better understanding of how gambling devices work, and thus to override cognitive biases (Evans and Over, 2010). Complementarily, fluid intelligence could foster a more reflective reasoning style (Barrouillet, 2011), and thus preclude the tendency to rely on the device-triggered intuitions and heuristics from which gambling-related cognitions seem to originate.

Nonetheless, the possibility that gambling-related cognitions (and specifically gambling-related biases) could be disconnected from general reasoning abilities has also been theoretically articulated. In some previous work, it has been shown that dysfunctional gambling-related cognitions, and especially gambling-related causal biases and misattributions, as measured by the GRCS, are more prevalent in individuals playing skill-based games, who, in turn, tend to be younger and better educated, relative to individuals who mostly practice pure chance games (Griffiths et al., 2009; Myrseth et al., 2010; Wood and Williams, 2011). In the context of the Gambling Space Model [GSM, (Jara-Rizzo et al., 2019; Navas et al., 2019; Ruiz de Lara et al., 2019)], more dysfunctional cognitions and stronger gambling-related biases are not hypothesized to originate in weaker domain-general reasoning processes, but in domain-specific motivated reasoning. This kind of reasoning (Kunda, 1990) is driven by ego-protection, that is, it is used by the individual to disguise the real (and potentially ego-damaging) reasons that drive gambling, to make gambling more acceptable, and to reappraise aversive gambling outcomes. In other words, the underpinnings of gambling cognitions would not be mainly intellectual, but affective (Navas et al., 2016, 2017b).

A brief review of the literature on the link between domain-general reasoning and gambling cognitions

Studies on domain-general reasoning skills in gamblers fall into three broad categories. In the first one, intelligence or domain-general reasoning is recorded only for control purposes, in case-control designs with problematic vs. non-problematic gambling (so that domain-general reasoning measures were not the main variables of interest). This category is heterogeneous and the studies in it do not systematically report associations between domain-general reasoning and gambling cognitions. With regard to the association between domain general reasoning and gambling disorder symptoms or diagnosis, results are mixed: in some studies, the group with disordered or problematic gambling obtained lower scores than controls in domain-general reasoning constructs (Martínez-Pina et al., 1991; Toplak et al., 2007; Forbush et al., 2008), whereas, in others, the groups did not show significant differences (Brevers et al., 2012). It is important to take into account, however, that in part of these studies, domain-general reasoning scores were intentionally matched across groups (groups were sampled a priori to show no differences in general reasoning ability), so the absence of differences in reasoning abilities between groups is not always informative. For that reason, studies in which matching in general reasoning measures was forced are not included in this review.

Table 1. Characteristics and summary of results of the revised studies on the relationship between domain-general reasoning abilities and gambling symptoms' severity.

Study	*N*	Participants	Severity index	Domain-general reasoning task	Main findings regarding severity/diagnosis of gambling disorder and domain-general reasoning
Brevers et al. (2012) *	100	27 PG 38 PrG 35 HC	SOGS	WAIS Vocabulary and WAIS Block Design	PGs, PrGs and controls were similar in estimated IQ. Groups were not intendedly matched in IQ *a priori*
Delfabbro, Lhan, & Grabosky (2006) †	926	Approximately, 5% of the sample were PrG. The rest were non-PrG	DSM-IV-J criteria for PG in children and VGS	Five questions about understanding of odds and probabilistic concepts	Little evidence that PrGs had a poorer understanding of the objective odds of gambling activities. PrGs were more accurate than non-PrG on one question concerning binary odds
Fernandez-Montalvo, Echeburúa, & Báez (1999) †	69	69 PG	SOGS	Raven's Standard Progressive Matrices	Non-significant negative correlation between fluid intelligence and SOGS
Forbush et al. (2008) *	59	25 PG 34 HC	SOGS	WAIS Letter-Number Sequencing and WAIS Picture Completion	PGs performed significantly worse than controls on the two WAIS subtests
Hodgins et al. (2012) †	136	60 PrG 76 non-PrG	CPGI (frequency). PGSI and CIDI (severity)	WASI Vocabulary and WASI Matrix reasoning	PrGs performed significantly worse than non-PrGs on intelligence subtests
Kaare, Mottus, & Konstabel (2009) †	75	33 PG 42 NG	SOGS (compared with DSM-IV criteria for PG)	Raven's Standard Progressive Matrices	PGs had significantly lower total scores than controls in fluid intelligence. Low cognitive ability was among the main predictors of pathological gambling, they but remained non-correlated with gambling-related irrational beliefs
Lambos & Delfabbro (2007) †	135	44 PG 46 RG 45 IG	SOGS	Numerical Reasoning Ability and five questions about understanding of odds	There was no significant difference between the groups for their knowledge of gambling odds. PGs and RGs had significantly lower total scores than IGs for numerical reasoning ability
Martinez-Pina et al. (1991) *	172	57 PG 115 HC	SOGS	WAIS	Intelligence was lower in PGs than in controls
Primi, Morsanyi, Donati, Galli, & Chiesi (2017) †	822	822 students	SOGS	Advanced Progressive Matrices and PRS	Significantly positive correlation between SOGS and fluid intelligence, and significantly negative correlation between SOGS and probabilistic reasoning
Rai et al. (2014) †	7461	36 PrG 4557 non-PrG 2234 NG	DSM-IV diagnostic criteria for PG	NART Verbal IQ	PrGs had a significantly lower estimated verbal IQ than non-PrGs and non-gamblers. The odds of PrG nearly doubled with each 1SD drop in IQ
Templer, Kaiser, & Siscoe (1993) †	136	136 men convicted	SOGS	Raven's Standard Progressive Matrices	Higher gambling scores were associated with more unfavorable scores on fluid intelligence
Toplak, Liu, Macpherson, Toneatto, & Stanovich (2007) *	107	24 PG 26 risk non-PG 57 non-PrG	SOGS and DSM-IV diagnostic criteria	WAIS-R Vocabulary and WAIS-R Block Design	PGs and subclinical gamblers tended to have significantly lower WAIS-R scores than non-PrGs

Abbreviations: PG = Individuals with pathological gambling, PrG = Individuals with problem gambling, IG = Infrequent gamblers, RG = Regular Gamblers, HC = Healthy controls, NG = Non-gambling individuals, SOGS = South Oask Gambling Screen, CPGI = Canadian Problem Gambling Index, VGS = Victorian Gambling Screen, PGSI = Problem Gambling Severity Index, WAIS = Wechsler Adult Intelligence Scale, WASI = Wechsler Abbreviated Scale of Intelligence, PRS = Probabilistic Reasoning Scale, NART = National Adult Reading Test. * Studies in which domain-general reasoning was recorded only for control purposes, in between-participants designs with problematic vs non-problematic gambling. † Studies intendedly investigating the associations between gambling severity (or presence of gambling disorder/problem gambling) and domain-general reasoning (see subsection "*A brief review of the literature on the link between domain-general reasoning and gambling cognitions*" in the Introduction). None of the studies from our research team is included in this table, due to partial sample overlapping with the present one.

A second category of studies has intentionally investigated the putative associations between gambling severity (or presence of gambling disorder/problem gambling) and domain-general reasoning (Templer et al., 1993; Fernández-Montalvo et al., 1999; Delfabbro et al., 2006; Lambos and Delfabbro, 2007; Kaare et al., 2009; Hodgins et al., 2012; Rai et al., 2014; Primi et al., 2017) in broad community or convenience samples, using regression or correlation techniques. These show that individuals with low domain-general reasoning abilities show more severe gambling problems or are in a higher risk of presenting disordered or problematic gambling, with few exceptions [(Fernández-Montalvo et al., 1999); in Primi et al. (2017), gambling problems' severity was found to correlate positively with fluid intelligence, but negatively with probabilistic reasoning]. Again, however, gambling-specific cognitions were not central variables of interest. With the exception of Lambos and Delfabbro (2007), the moderating role of gambling-related cognitions in the association between general reasoning and gambling problems was not assessed either.

Studies of these two categories, primarily or supplementarily estimating the association between domain-general reasoning abilities and presence or severity of gambling problems, are summarized in **Table 1.**

A third category of studies, more directly relevant to the aims of the present study, has directly investigated whether gambling-related cognitions are underpinned in some way by domain-general reasoning processes. Most of the studies in this category are also observational or correlational, but they do straightforwardly focus on the relationship between domain-general and gambling-related reasoning. For instance, using a card-guessing task, Xue et al. (2012a) found that students with higher cognitive abilities (intelligence and executive function) were more prone to show the gambler's fallacy. i.e., the erroneous belief that streaks of bad luck are bound to end in a win. In a similar vein, Perales et al. (2017) found gamblers with stronger biases to perform better than gamblers with weaker biases on non-gambling related causal learning tasks [for a different, although compatible, result, see Orgaz et al. (2013)]. The abovementioned study by Lambos and Delfabbro (2007), beyond the association between gambling problems and general understanding of odds, also found such a measure of odds understanding to be unpredictive of gambling-related irrational beliefs. However, in a recent study by Delfabbro et al. (2020), participants who reported greater illusory control in non-gambling-related everyday tasks (in a self-report questionnaire) scored higher on standardized measures of gambling-specific illusory control.

To our knowledge, only one study in this last category has directly intervened on general-domain reasoning abilities in an attempt to reduce gambling-related biases. Donati et al. (2018) showed that a preventive intervention to modify erroneous cognitions by shaping probabilistic and superstitious thinking in adolescents, reduced their erroneous gambling-related cognitions, suggesting that gambling-related cognitions could related to domain-general reasoning.

Present study

The present study is aimed at directly testing the association between domain-general reasoning abilities and gambling cognitions, in two samples of (a) individuals from the community who present a detectable level of gambling but do not present gambling problems (henceforth, individuals with non-problematic gambling, NPG), and (b) treatment-seeking patients with gambling disorder (PGD).

Reasoning abilities (i.e., the independent variables in our study) were assessed using the matrices task of the WAIS-IV intelligence scale (Wechsler, 2008), and the Berlin Numeracy Test [BNT (Cokely et al., 2012)], for abstract and probabilistic reasoning, respectively, mirroring the two mechanisms described earlier. These two measures have good validity and reliability. The BNT is a sound index of probabilistic reasoning in practice (Cokely et al., 2018), namely individuals' easiness to deal with basic probabilistic operations from real-life problems (Lipkus and Peters, 2009; Cokely et al., 2012). The matrix reasoning subtest of the WAIS-IV assesses non-verbal perceptual reasoning abilities, and is considered to be a reliable measure of fluid intelligence (Bugg et al., 2006; Wechsler, 2008; Stephenson and Halpern, 2013; Gignac, 2014; Green et al., 2017; Kim and Park, 2018). This mostly overlaps with the g-factor (Spearman, 1927; Tranel et al., 2008; Jaeggi et al., 2010).

On the side of dependent measures, gambling-related cognitions were assessed using the GRCS, described earlier. Complementarily, severity of potentially disordered gambling was assessed with the South Oaks Gambling Screen [SOGS, Spanish version (Echeburúa et al., 1994)].

In view of the evidence briefly reviewed earlier, we expect participants in the PGD sample to present a small-to-moderate disadvantage in the matrices and BNT tests, and much stronger dysfunctional/distorted gambling-related cognitions, relative to participants in the NGD sample. Yet, our main hypotheses, specifically regarding the relationships between BNT/matrices scores and gambling-related cognitions, remain open. Firstly, across samples, we will estimate the independent contribution of domain-general reasoning scores to the five domains of gambling-related cognition. Secondly, associations (or their absence) between reasoning and gambling-related cognitions will be tested in the two samples separately. Support for the existence (H1) or inexistence (H0) of such links will be assessed using Bayes factors.

Materials and methods

Participants

The study sample comprised 135 participants, divided in 77 treatment-seeking patients with gambling disorder (PGD) and 58 participants with non-problematic gambling involvement (NPG). Characteristics of the two samples are reported in **Table 2**. Participants in the PGD group had a diagnosis of gambling disorder, as established by their therapist based on DSM5 criteria, and they had abstained from gambling for 15 days or more. The NPG group consisted of individuals with different degrees of involvement in gambling activities (with the minimum being "having ever gambled"). A specific exclusion criterion for NPG was presenting a gambling pattern severe enough to be classified as a disordered gambler [i.e., ≥5 in SOGS; (Stinchfield, 2002)]. The rest of exclusion criteria were similar for both groups, i.e., having ever been diagnosed or treated for any psychopathology (beyond gambling disorder in the case of PGD), and any history of neurological disease or brain trauma causing unconsciousness for 10 min or longer. Common exclusion criteria were assessed with a semi-structured interview.

Table 2. Descriptive statistics of all measured variables, and Bayes factors (based on the non-parametric Mann-Whitney statistic for quantitative variables and a Bayesian contingency table test for gender) and *p*-values (Welch's t-tests for quantitative variables, and χ^2-test for gender) for the differences between samples (patients with gambling disorder vs individuals with non-problematic gambling).

	Sample	Mean	SD	Min.	Max.	BF_{10}	p
Gender	*PGD*	2F/75M				0.60	0.733
	NGD	1F/57M					
Age	*PGD*	36.18	11.42	19	61	0.29	0.142
	NGD	33.62	8.75	20	61		
Education ys.	*PGD*	12.34	3.92	5	24	0.95	0.064
	NGD	13.48	3.19	7	20		
Matrices	*PGD*	97.08	16.31	65	130	3.79	0.008
	NGD	104.31	14.61	75	140		
BNT	*PGD*	0.82	0.96	0	3	1.64	0.011
	NGD	1.26	1.00	0	3		
Expectancy	*PGD*	3.95	1.68	1	7	> 100	<0.001
	NGD	1.49	0.71	1	4		
Inability to stop	*PGD*	4.26	1.66	1	7	> 100	<0.001
	NGD	1.19	0.51	1	4		
Control illusion	*PGD*	2.59	1.40	1	7	> 100	<0.001
	NGD	1.25	0.52	1	4		
Predictive control	*PGD*	3.75	1.53	1	7	> 100	<0.001
	NGD	1.48	0.64	1	4		
Interpretative bias	*PGD*	4.75	1.79	1	7	> 100	<0.001
	NGD	1.50	0.86	1	5		
SOGS	*PGD*	10.35	2.99	3	17	> 100	<0.001
	NGD	0.62	0.93	0	3		

PGD patients with gambling disorder, *NGD* no problem gamblers, *SD* standard deviation

Procedure

Patients with gambling disorder were recruited from different associations of rehabilitated gamblers in Andalucía (Spain), whereas NPG were recruited using convenience and snowball sampling methods among researchers' and patients' acquaintances, and using advertisements.

All participants were recruited across different phases of a more ambitious multi-stage research project (GBrain, and GBrain-2, see section "Funding"), with the different stages having slightly different aims and assessment protocols (with some measures being common to all phases and others present in only some of them). The participants included in the present study were the ones from all the phases of the project that were assessed with both the Matrices test for abstract reasoning, and the BNT for probabilistic reasoning (i.e., the two main independent variables involved in the hypotheses articulated earlier).

Across phases, PGD and NPG participants were sampled from similar social milieus, and groups were intendedly matched in sociodemographics, including gender, age and education years (but not psychological/cognitive characteristics; please see complementary information about matching in the section "Preliminary Analyses").

In all phases, the protocol consisted of a set of questionnaires and neuropsychological tasks, administered in a quasi-randomized order, in a single session that lasted approximately 2 h. Some participants were invited to participate in an extra session in a different day, in which psychophysiological or neuroimaging measures were recorded. There is thus some overlap between the current sample and the one in other studies of our research group: Megías et al. (2018), 33.3%; Navas et al. (2016, 2017b), 60%; Perales et al. (2017), 47.4%; Perandrés-Gómez et al. (2020), 97%; Ruiz de Lara et al. (2018), 34.1%; and Navas et al. (2017a), 52.6%.

Participants were debriefed about study aims and signed an informed consent prior to their participation, and received a €10/hour compensation. In the case of patients, the compensation was paid via an authorized relative. The study was approved by the Ethic Committee of the University of Granada and complied with the Helsinki Declaration.

Instruments

Matrix Reasoning Task [WAIS-IV (Wechsler, 2008)]

This instrument consists of 26 sequences of geometric figures, with each one following a unique organizational pattern, and a blank cell. Participants are asked to guess the underlying logic in the sequence, and to fill the blank cell with the option that best fits among the five possible alternatives. This is a standardized task that has excellent psychometric properties and is adapted for Spanish populations (Wechsler, 2012).

Berlin Numeracy Test [BNT (Cokely et al., 2012)]

This is a paper-and-pencil test in which participants are asked to answer 4 different questions on probability in ascending order of difficulty [e.g., Imagine we are throwing a five-sided die 50 times. On average, out of these 50 throws, how many times would this five-sided die show an odd number (1, 3 or 5)?]. A final score of numeracy skills is calculated as the sum of correct answers.

Gambling-Related Cognitions Scale [GRCS; Raylu and Oei, 2004; Spanish version: Del Prete et al., 2017)]

This is a self-reported measure of gambling-related cognition based on Raylu and Oei′s model. It consists of 23 items to be answered using a five-point Likert scale that assess five cognitive distortions: inability to stop gambling (e.g., My desire to gamble is so overpowering), gambling expectancies (e.g., Gambling makes things seem better), predictive control (e.g., Losses when gambling, are bound to be followed by a series of wins), illusion of control (e.g., I have specific rituals and behaviors that increase my chances of winning), and interpretative bias (e.g., Relating my winnings to my skill and ability makes me continue gambling). Given that individuals in the PGD group had been in therapy for some time (from 15 days to 6 months), these participants were specifically instructed to refer their answers to the GRCS items to the time when they initiated treatment [see also (Navas et al., 2017a)].

This scale has shown good psychometric properties (Del Prete et al., 2017). In the present study, internal consistency values (Cronbach's α) were 0.866, 0.914, 0.709, 0.826, and 0.920 for gambling expectancies, inability to stop, illusion of control, predictive control and interpretive bias, respectively, and 0.963 for the total scale.

South Oaks Gambling Screen [SOGS (Lesieur and Blume, 1987); Spanish Version (Echeburúa et al., 1994)]

This instrument was used to assess disordered gambling symptoms' severity. The Spanish version has shown good psychometric properties. For this study, SOGS showed an excellent level of internal consistency (Cronbach's α = 0.929).

Statistical analyses

Descriptive statistics are provided for age, education years, gender composition, WAIS-IV matrices scores, BNT scores, SOGS total severity scores, and the five dimensions of the GRCS questionnaire (gambling expectancies, inability to stop, control illusion, predictive control, and interpretative bias). For quantitative or quasi-quantitative variables, these descriptives include mean, standard deviation, and maximum and minimum values. These descriptives are complemented with Bayesian and frequentist tests to check for differences between participants showing non-problematic gambling involvement (NPG) and patients with gambling disorder (PGD). Scores in the five dimensions of the GRCS are submitted to a first multivariate analysis of covariance (MANCOVA), with group (sample: PGD, NPG) as a between-participant factor, and WAIS-IV matrices score as a continuous predictor. These are followed by GRCS dimension-by-dimension analyses of covariance (ANCOVA), with the same independent variables. The same analyses will be performed with BNT (instead of matrices) scores as continuous predictor.

Given the nature of the dependent variables involved, these analyses are likely to be affected by two limitations: (a) violation of homogeneity of covariance matrices and multivariate normality assumptions, and (b) the unsuitability of null-hypothesis significance testing (NHST) to provide evidence in favor of the null hypothesis. In view of that, non-parametric correlations (Kendall's τ) will be computed for correlations of each GRCS subscore with matrices and BNT scores. These correlations will be interpreted using bidirectional Bayes factors (BF10) instead of NHST.

Regarding these statistical analyses, there are two important points that require further consideration. First, we did not use stratified sampling (or any other method to ensure populational representativity; see section “Limitations and Final Remarks”), but the sampling strategy and the inclusion/exclusion criteria were very similar for the two groups, and we did not force matching on psychological/cognitive variables [please see Perandrés-Gómez et al. (2020), for a discussion on the consequences of IQ non-matching in cross-sectional analyses of a sample largely overlapping with the present one]. Using convenience samples of gamblers with and without gambling problems is quite a standard practice in correlational research in the field (Barrada et al., 2019). Still, and in order to surpass the problems that this sample composition may cause, we ran analyses with the whole sample, while controlling for group (first part of the section “Main Analyses”), with the whole sample without controlling for group (Supplementary Materials), and with the two groups separately (second part of the section “Main Analyses”). As detailed below, results were robust across statistical approaches.

And second, please note that frequentist tests are aimed at checking for statistical significance of effects (i.e., whether the observed test statistic is extreme enough for the null hypothesis to be rejected), so null results can be explained as resulting from either the absence of an effect or the lack of power of the test. That implies that frequentist tests cannot distinguish between evidence of absence and absence of evidence (Altman and Bland, 1995). In the present study, however, we are as much interested on the possible inexistence of certain relations as we are in their existence. Bayesian tests expressed in the form of Bayes factors (BF10) are aimed at comparing two models of the world, one in which the effect of interest is zero, and another one in which it is non-zero (with a given probability density distribution over the populational effect size). These two models representing the null and the alternative hypothesis are treated symmetrically, in such a way that BF10 < 1 is interpreted as supporting the null, whereas BF10 > 1 is interpreted as supporting the alternative. The arbitrary thresholds to consider evidence in favor of one or the other substantial enough vary across reference guidelines, so BFs will be interpreted here as strictly continuous measures of evidence (Dienes, 2014). For a discussion on equivalence tests and Bayes factors as tools to establish evidence for the null, see Lakens et al. (2020). Data and reproducible analysis files are fully available in the OSF framework.

Results

Preliminary analyses

Table 2 shows group means, maximum, and minimum values, and standard deviations for age, education years, matrices, BNT, SOGS severity, and GRCS dimensions scores; proportions for gender; as well as Bayes factors and p-values for differences between groups in all variables. Detailed distributions for all these variables across groups are reported in the Supplementary Materials.

As expected, the two groups differed in SOGS and GRCS scores, and were closely matched in gender composition and mean age. Although education years was also controlled across phases of the project, the pooling of samples across phases made the difference between groups in this variable to get close to the significance threshold ($p = 0.064$), and to yield a virtually uninformative BF (BF10 ≈1).

The two groups, however, differed in both Matrices and BNT scores. In other words, differences in reasoning abilities remained in spite of control of sociodemographic variables. Actually, a MANCOVA with BNT and matrices scores as dependent variables, group as independent variable, and sociodemographics (age, gender, and education years) as covariates yielded significant effects for both the multivariate effect (Wilks' $\lambda = 0.910$, $p = 0.002$), and the univariate effects [$F(1, 130) = 8.109$, $p = 0.005$; and $F(1, 130) = 8.335$, $p = 0.005$, for matrices and BNT scores, respectively]. In other words, despite sociodemographic matching, general reasoning scores remained associated with GD, which is in line with the abovementioned evidence of links between reasoning abilities and risk of being diagnosed with GD.

Table 3. Results of separate ANCOVAs for GRCS dimensions as dependent variables, and Group and continuous predictors (left: WAIS matrices, right: BNT) as independent variables.

		WAIS matrices			*BNT*		
IV	***DV***	***MSE***	***F (1, 132)***	***p***	***MSE***	***F (1, 132)***	***p***
Group	*EXP*	1.836	108.850	< 0.001	1.812	110.305	< 0.001
	IS	1.707	182.762	< 0.001	1.691	184.538	< 0.001
	CI	1.245	47.697	< 0.001	1.239	47.950	< 0.001
	PC	1.517	112.572	< 0.001	1.506	113.375	< 0.001
	IB	2.160	161.027	< 0.001	2.119	164.100	< 0.001
Covariate	*EXP*	1.836	0.234	0.629	1.812	2.001	0.160
(Matrices/BNT)	*IS*	1.707	0.006	0.938	1.691	1.289	0.258
	CI	1.245	0.072	0.789	1.239	0.772	0.381
	PC	1.517	0.085	0.772	1.506	1.027	0.313
	IB	2.160	0.124	0.725	2.119	2.645	0.106

Abbreviations: IV: Independent variable; *DV*: Dependent Variable; *EXP*: Gambling Expectancies, *IS*: Inability to Stop, *CI*: Control Illusion, *PC*: Predictive Control, *IB*: Interpretative Bias, *BNT*: Berlin Numeracy Test

Main analyses

The MANCOVA with group as between-participants factor, matrices score as continuous predictor, and GRCS subscores as dependent variables, yielded a significant effect for group, Wilks' $\lambda = 0.378$, $F(5, 128) = 42.181$, $p = 0.001$, but not for the matrices score, Wilks' $\lambda = 0.991$, $F(5, 128) = 0.231$, $p = 0.948$. Table 3 (left panel) shows the results of separate ANCOVAs for the five GRCS dimensions. In accordance with the global MANCOVA, all dependent variables showed significant effects of group, but not of matrices score.

Similarly, the MANCOVA with group as between-participants factor, BNT score as continuous covariate, and GRCS subscores as dependent variables yielded a significant effect for group, Wilks' $\lambda = 0.374$, $F(5, 128) = 42.884$, $p < 0.001$, but not for the BNT score, Wilks' $\lambda = 0.977$, $F(5, 128) = 0.607$, $p = 0.695$. **Table 3** (right panel) shows the results of separate ANCOVAs for the five GRCS dimensions. In accordance with the global MANCOVA, all dependent variables showed significant effects of group, but not of BNT score.

The Box's test [$\chi2$ (15) = 201, $p < 0.001$], and the Shapiro-Wilks' test [$W = 0.875$, $p < 0.001$], showed clear violations of the homogeneity of covariance matrices and multivariate normality assumptions, respectively. In view of that, we computed non-parametric correlations (Kendall's τ) between reasoning abilities and GRCS dimensions for the two groups separately, and interpreted the evidence portrayed by them using bidirectional Bayes factors (BF10), computed with the default settings in JASP software (JASP Team, 2019).

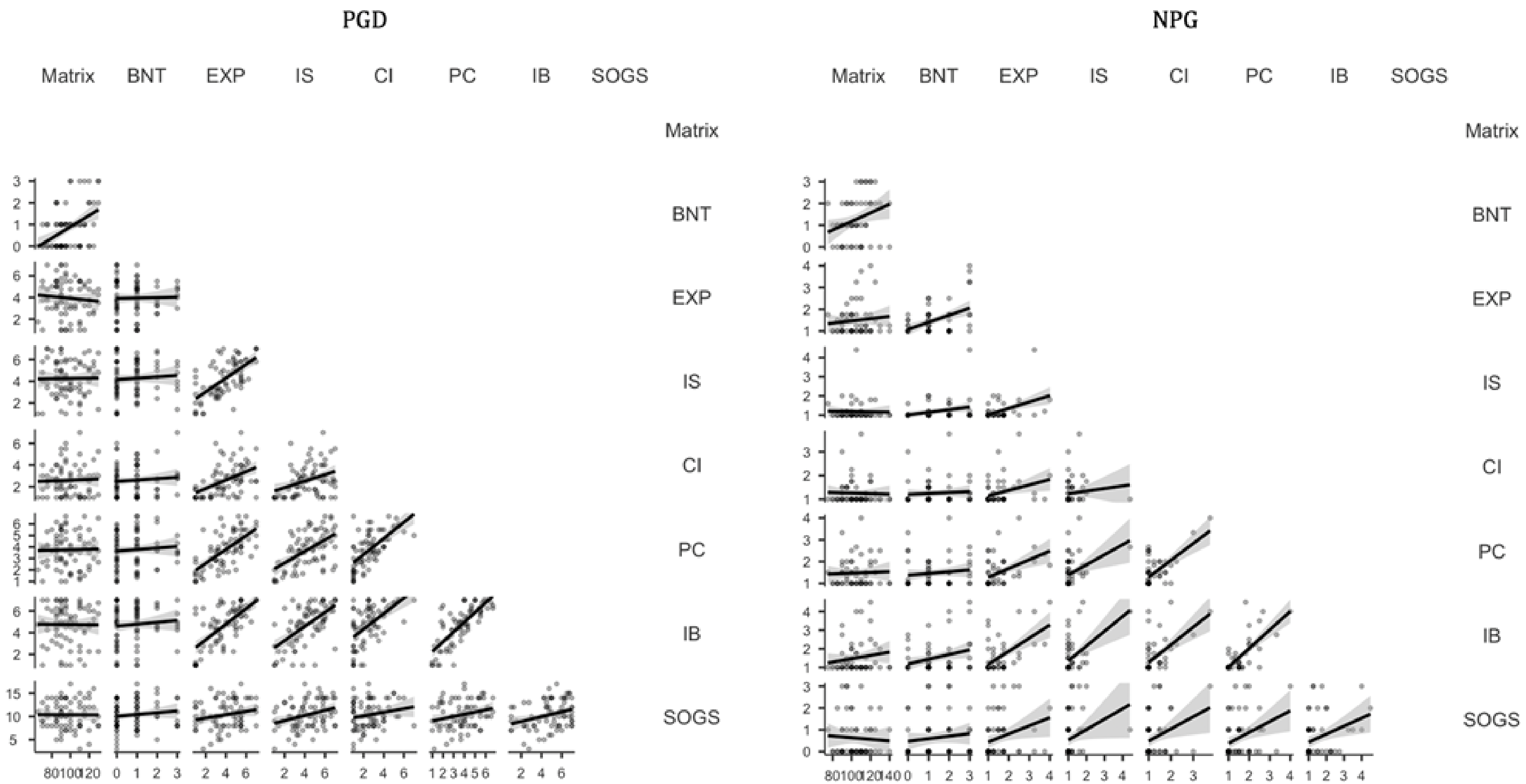
Figure 1 and **Table 4** show the results of these analyses for the PGD and the NPG group, respectively.

Table 4. Bayesian correlation tests (bidirectional Bayes factors for Kendall's τ) between variables of interests in PGD and NPG samples.

		Age	*Education*	*Matrices*	*BNT*	*EXP*	*IS*	*CI*	*PC*	*IB*
PGD										
Education	τ	-0.31								
	BF_{10}	> 100								
Matrices		-0.07	0.40							
		0.22	> 100							
BNT		-0.27	0.41	0.34						
		48.47	> 100	> 100						
EXP		-0.03	-0.04	-0.08	-0.02					
		0.16	0.18	0.27	0.15					
IS		0.00	-0.09	-0.02	0.07	0.46				
		0.15	0.28	0.16	0.22	> 100				
CI		-0.08	-0.04	0.00	0.05	0.38	0.27			
		0.24	0.16	0.15	0.19	> 100	67.17			
PC		-0.14	0.05	0.00	0.07	0.49	0.40	0.51		
		0.71	0.18	0.15	0.22	> 100	> 100	> 100		
IB		-0.10	0.00	-0.02	0.05	0.50	0.47	0.42	0.61	
		0.35	0.15	0.16	0.18	> 100	> 100	> 100	> 100	
SOGS		-0.06	-0.05	0.00	0.11	0.13	0.22	0.11	0.18	0.22
		0.20	0.19	0.15	0.38	0.53	7.59	0.42	1.93	6.83
NPG										
Education	τ	-0.18								
	BF_{10}	1.20								
Matrices		0.23	0.11							
		4.24	0.36							
BNT		0.05	0.29	0.25						
		0.19	26.54	7.42						
EXP		-0.10	0.05	0.05	0.27					
		0.30	0.19	0.20	15.04					
IS		0.03	0.03	-0.04	0.22	0.35				
		0.18	0.18	0.19	3.42	> 100				
CI		0.03	-0.04	-0.02	0.12	0.33	0.32			
		0.18	0.19	0.18	0.39	> 100	76.20			
PC		-0.16	0.07	0.02	0.13	0.44	0.38	0.40		
		0.82	0.23	0.17	0.49	> 100	> 100	> 100		
IB		-0.13	0.08	0.11	0.19	0.42	0.37	0.55	0.62	
		0.48	0.24	0.35	1.64	> 100	> 100	> 100	> 100	
SOGS		-0.02	-0.15	-0.03	0.16	0.36	0.37	0.21	0.30	0.32
		0.17	0.69	0.18	0.76	> 100	> 100	2.36	45.14	81.42

Abbreviations: EXP: Gambling Expectancies, *IS*: Inability to Stop, *CI*: Control Illusion, *PC*: Predictive Control, *IB*: Interpretative Bias, *BNT*: Berlin Numeracy Test, *SOGS*: Gambling symptoms' severity

Figure 1. Graphic depiction of the correlation matrix for all variables of interest across groups (*PGD*: patients with gambling disorder; *NPG*: Individuals in non-problematic gambling; *Matrix*: WAIS matrices scores, *BNT*: Berlin Numeracy Test, *EXP*: Gambling Expectancies, *IS*: Inability to Stop, *CI*: Control Illusion, *PC*: Predictive Control, *IB*: Interpretative Bias, *SOGS*: Gambling severity).



As expected, in both groups, substantial correlations were found between the different subdimensions of GRCS. In the NPG group, the SOGS score correlated positively with all GRCS dimensions, with the strength of evidence for H1 ranging from BF10 = 2.36 to BF10 > 100. Correlations between SOGS and GRCS were weaker in the PGD group, with only three BFs above 1, i.e., for inability to stop (BF10 = 7.59), interpretative bias (BF10 = 6.83), and predictive control (BF10 = 1.93, anecdotal) . BNT and matrices also correlated positively between them, and with education years, and negatively with age.

Most importantly, BFs for correlation coefficients between reasoning abilities (matrices and BNT) and GRCS scores mostly provided moderate (BF10 < 0.33) evidence in favor of the null hypothesis. The only exceptions (i.e., BF10 > 1) were the BF10 = 15.04, Kendall's τ = 0.27 between BNT and gambling expectancies, the BF10 = 3.41, Kendall's τ = 0.22 between BNT and inability to stop, and the BF10 = 1.64 (anecdotal), Kendall's τ = 0.19 between BNT and interpretative bias, in the NPG group. In other words, there is some weak evidence of a direct link between BNT and some gambling-related cognitions (mainly excluding gambling biases) in the NPG group, with stronger cognitions in individuals with higher BNT scores. There were not any cases in which evidence supported an inverse relationship between reasoning abilities and gambling-related cognitions.

Discussion

The goal of the present study was to explore the relationships between domain-general reasoning abilities and gambling-related cognitions in non-problematic gamblers (NPG) and patients with gambling disorder (PGD). Results from

NHST (MANCOVAs on the association between BNT/Matrices and gambling-related cognitions, and subsequent dimension-by-dimension ANCOVAs) did not yield any significant associations. This result holds regardless of whether group (PGD, NPG) was included in the model or not. Subsequent Bayesian analyses yielded consistent support for the null hypothesis, i.e., no association between BNT/Matrices and gambling-related cognitions, except for anecdotal-to-substantial support for positive associations in the NPG subsample between BNT, on the one side, and gambling expectancies, inability to stop, and interpretative bias, on the other.

These results converge with the ones of some previous works. For instance, Perales et al. (2017) found gamblers with stronger biases to perform better in a causal learning task than those with weaker biases. This result was interpreted as originating in the fact that gambling-related cognitive distortions are significantly more intense in gamblers preferring skill-based games (i.e., sports betting, casino and card games) than in those preferring chance games (i.e., slots, bingo, or lottery) [see also (Myrseth et al., 2010; Navas et al., 2017b; Mallorquí-Bagué et al., 2019)]. Individuals preferring skill-based games are, on average, younger, better educated, and more sensitive to reward (Navas et al., 2017b), so that their distorted beliefs about gambling are unlikely to be originated in any general-domain reasoning disadvantage. Relatedly, Xue et al. (2012a) found students with higher cognitive abilities (intelligence and executive function) to be more prone to show the gambler's fallacy. And in Lambos and Delfabbro (2007) disordered gamblers were found to be more susceptible to cognitive biases than non-gamblers and non-disordered gamblers, but no significant differences were observed between the three groups for their knowledge of gambling odds [see also (Benhsain et al., 2004)].

This lack of substantial inverse relationships between domain-general reasoning abilities and gambling-related cognitions renders two theoretical puzzles unresolved. First, to describe the mechanisms responsible for bias generation and their activation during and between gambling sessions; and, second, accounting for the seemingly robust link between domain-general cognitive abilities and the risk developing gambling problems, without the mediation of gambling-related distorted cognitions.

With regard to the first question, a possible solution arises from the cognitive switching (Sévigny and Ladouceur, 2003) hypothesis. According to this hypothesis, individuals with disordered gambling “switch off” their rational beliefs during gambling, so that their behavior becomes governed by features of the game or the gambling device, and “switch them on” again when they finish. In other words, in-game behavior and cognitions remain impermeable to general-domain reasoning.

The cognitive switching hypothesis is inspired by dual-process models of cognition, according to which two competing systems, the intuitive and the analytic, filter the information necessary to control action. The intuitive system is regarded as fast, efficient, and heuristic-based, whereas the analytic system is slower and more effortful, but also more rational (Armstrong et al., 2020). The term cognitive reflection has been coined to denote the degree to which an individual is more or less willing to invest the necessary cognitive resources to engage in analytic thinking [see (Stange et al., 2018), for a discussion of its potential link with gambling]. Importantly, being less prone to cognitive reflection, especially under certain environmental and affective circumstances, does not imply having poorer reasoning abilities, but somehow eschewing the effort to use them, especially when motivated to do so. In words of Armstrong et al. (2019), "gamblers are often unlikely or unwilling to reflect on the veracity of beliefs as they are often used to justify gambling behaviors" (p. 183) [see also (Emond and Marmurek, 2010; Armstrong et al., 2019; Cosenza et al., 2019)]. This mechanism reminds of the "tilt" phenomenon in poker (Barrault et al., 2014), and some recent studies using functional magnetic resonance imaging (fMRI) (Xue et al., 2011), and transcranial direct current stimulation (tDCS) (Xue et al., 2012b) also indirectly support it.

A second, non-exclusive possibility is that some gamblers do remain reflective during gambling episodes, but they invest their cognitive resources in trying to "outsmart" the gambling device, and to find causal patterns where there are not any. Indirect evidence supporting this mechanism comes from the abovementioned reports that, especially in some sociodemographic sectors, individuals with preserved –or even superior– cognitive skills are more vulnerable to certain gambling-related fallacies. To our knowledge, there is no direct evidence of this mechanism, although the deleterious effects of trying to outsmart random devices on judgment and decision-making are well known (see Gaissmaier and Schooler, 2008).

That connects with a third possibility, emerging from the putative interaction of domain-general reasoning skills with age and/or education. Actually, when matrices scores were allowed to interact with age and education years (see Supplementary Materials, second section), some non-significant trends suggested that, in younger and more educated individuals, matrices scores were positively associated with GRCS scores, whereas in older and less educated individuals the association was non-existing or in the opposite direction. It is definitely premature to make any inferences from these trends, but they open the possibility that in younger, more educated people, distorted gambling cognitions were fueled by domain-general reasoning skills, whereas in older, less educated gamblers, poorer reasoning skills were a risk factor for developing gambling-related biases. Additionally, this interaction would explain why some studies have found no associations whatsoever between reasoning skills and gambling-related biases, whereas others have found a direct link (Xue et al., 2012a; Perales et al., 2017).

In summary, low domain-general reasoning skills are not necessary to develop gambling-related distorted beliefs, which reinforces the idea that, at least in some gamblers, in- or about-game emotion-laden states (e.g., urges triggered by conditioned cues, or negative affect caused by losses) can take control over gambling-related cognition, and probably motivate the individual to stick to irrational cognitions. Such possibility is one of the main tenets of the GSM, according to which the main source of gambling-related cognitive distortions is motivated reasoning, that is, the individual’s tendency to regulate affect by overestimating their degree of control or reinterpreting gambling outcomes in a more favorable, ego-protecting light (Navas et al., 2017b, 2019; Ruiz de Lara et al., 2019). Whether this motivated reasoning mechanism is specific to some gamblers (more educated, younger ones) or generalizes to a wider range of individuals remains an open question for future research.

The second puzzle, namely the moderate but seemingly robust relationship of intelligence and abstract reasoning with gambling problems without the mediation of gambling related cognitions, seems more difficult to address. In our sample, this link held for GD diagnosis across groups, but not for severity of gambling problems within groups, and its interpretation is limited by features of the design. This result resonates with the one from Rai et al. (2014), in which a link between IQ and gambling problems was also corroborated at the populational level, but no association was found between IQ and non-problematic gambling. Unfortunately, none of the possible explanations for this link has been explored in detail. Tentatively, the association between poorer reasoning abilities and a higher risk of developing gambling problems can be partially accounted for by the overlap between these abilities and aspects of executive function as self-control and top-down regulation of impulses (Meldrum et al., 2017). A detailed review of the role of executive functions related to cognitive control in gambling problems, and its neurobiological correlates, can be found at Moccia et al. (2017).

Clinical implications of our results, and the abovementioned related ones, are far-reaching. Gambling-related cognitions are hard to restructure, and the efficacy of cognitive therapy, although well-established, remains modest (Petry et al., 2017). Furthermore, individuals with problematic gambling are normally reluctant to change their beliefs when faced with disconfirming evidence, and often counterargument it (Delfabbro et al., 2006). In a variety of domains, this sort of reluctance has been related to the fact that, when motivated to maintain a given belief, individuals perceive information disconfirming it as confronting or uncomfortable (Gilbert et al., 1990; Mezirow, 1990; Stange et al., 2018). In consequence, altering beliefs will not only require more (or more accurate) information, but an increased degree of metacognition about how motives to gamble and to regulate emotions derived from gambling (and its consequences) relate to one's beliefs (Wells, 2009; Lindberg et al., 2014b; Caselli and Spada, 2016).

Limitations and final remarks

Results of our study should also be understood considering at least five main limitations. First, we cannot establish causal associations between the variables examined, since this is a cross-sectional study. Second, since the majority of the participants are male, generalizability to the entire population of gamblers should not be taken for granted. Third, assessing psychological constructs using self-report questionnaires may not fully represent the cognitive processes involved, and social desirability effects are possible. Fourth, no power analysis was performed a priori to determine sample size. As noted earlier, participants in this study were the ones in a larger project who had been assessed with all the measurements of current interest. This problem is, however, partially palliated by the use of Bayes factors, that provide evidence in support of the null or the alternative hypothesis in a continuous fashion, so that no dichotomous decisions leading to type I or type II errors are made. And fifth, we did not use stratified sampling (or any other method to ensure populational representativity), which means that the sampling strategy and the inclusion/exclusion criteria were very similar for the two groups, and we did not force matching on psychological/cognitive variables. That implies that the proportion of PGD in our sample is much larger than in the general population, but there are no reasons to expect substantial alterations of the correlations between psychological variables. Given that there is an association between gambling problems, on the one hand, and both stronger gambling-related biases and lower reasoning skills, on the other, the overrepresentation of PGD could have artificially inflated correlations between the latter when group was not controlled for (supplementary analyses). Despite this risk of inflation, gambling-related cognitions and domain-general reasoning remained mostly disconnected.

On the side of strengths, although some previous studies had explored the relationship between reasoning abilities and gambling-related beliefs, to our knowledge, this is the first one simultaneously assessing two core constructs of domain-general reasoning directly relevant to gambling (abstract and probabilistic reasoning), and their relationship with different dimensions of gambling-related cognitions in individuals without problem gambling and patients with gambling disorder. Additionally, the inclusion of Bayesian analyses allows to symmetrically assess the evidential support in favor of the null or the alternative hypothesis. Our results evidence that probabilistic and abstract reasoning abilities are mostly unrelated to the intensity of distorted gambling-related beliefs, and are thus unlikely to protect gamblers from them. This pattern or results reinforces the idea that distorted cognitions do not originate in a general lack of understanding of probability or low fluid intelligence, but probably result from motivated reasoning.

Data Availability Statement

The datasets presented in this study can be found in the OSF repository: https://osf.io/8ksxa/

CHAPTER IV:

Studies II

& III

How to pin a compulsive behavior down: A systematic review and conceptual synthesis of compulsivity-sensitive items in measures of behavioral addiction

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Abstract

Experimental models identify the transition from choice to compulsivity as the main mechanism underlying addiction. In behavioral addictions research, however, the adjective compulsive is used to describe virtually any kind of excessive or dysregulated behavior, which hinders the connection between experimental and clinical models. In this systematic review, we adopted a preliminary definition of compulsive behavior based on previous theoretical work. Subsequently, a systematic review following PRISMA guidelines was conducted (a) to identify the validated instruments, currently used in behavioral addictions research, that include items that are sensitive (intendedly or not) to compulsivity, and (b) to categorize those items into differentiable operationalizations of compulsivity. Six operationalizations of compulsivity emerged from item content analysis: 1. Automatic or habitual behavior occurring in absence of conscious instrumental goals; 2. Behavior insensitive to negative consequences despite conscious awareness of them; 3. Overwhelming urge or desire that impels the individual to initiate the activity and jeopardizes control attempts; 4. Bingeing, or inability to stop or interrupt the activity once initiated, resulting in an episode substantially longer or more intense than intended; 5. Attentional capture and cognitive hijacking; and 6. Inflexible rules, stereotyped behaviors, and rituals related to task completion or execution. Subsequently, a list of 15 representative items per operationalization was elaborated for independent assessment and identification of delimitation problems. A high degree of agreement was reached in assessing them as instantiating compulsivity, as well as in their assignment to the corresponding categories. However, many of them were also considered overinclusive, i.e.,

uncapable of distinguishing compulsivity from value-based momentary choice.To increase their discriminative value, items in future compulsivity scales should be refined to explicitly mention disconnection between behavior and declarative goals. Further research on factorial structure of a pool of items derived from these operational definitions is warranted. Such a factorial structure could be used as an intermediate link between specific behavioral items and explanatory psychobiological, learning, and cognitive mechanisms.

Introduction

The idea that the transition of goal-driven behaviors towards compulsivity is what turns them into *genuinely* addictive behaviors is present in prominent models of substance addiction. However, the exact meaning of compulsivity and its etiology in the field of behavioral addictions remain ill-defined (see Perales et al., 2020, for a recent review). Here, we intend to advance in the operationalization of compulsivity in non-substance addictions, to pave the way to develop instruments to measure it, and, eventually, to set conceptual and behavioral boundaries that allow to explore its underlying neurocognitive mechanisms.

Compulsive behaviors are repetitive acts characterized by one feeling ‘forced’ to perform them, despite awareness that these acts are not in line with one’s goal (Luigjes et al., 2019). As vividly expressed by William James, referring to alcoholism, “if a bottle of brandy stood at one hand, and the pit of hell yawned at the other, and I were convinced that I would be pushed in as sure as I took one glass, I could not refrain.” (James, 1890, p. 537).

This definition is similar to the one proposed by a recent Delphi review of transdiagnostic processes in addiction, namely “repetitive, or automatic behavior, associated with negative outcome expectancy that contributes to the experience of being forced or compelled to act despite negative consequences” (Yücel et al., 2019; pp. 1102-1103). In the same vein, in animal models of substance addiction, drug seeking and self-administration are considered as compulsive when they persist in face of severe punishment (see Lüscher, Robbins, & Everitt, 2020).

According to an influential hypothesis, compulsivity in addictions arises from the formation of habits and a progressive impairment of top-down control over them (Everitt & Robbins, 2022). In Yücel et al.'s (2019) review, however, habits and compulsivity are described as separate constructs, and the former is defined as "sequential, repetitive, motor or cognitive behavior elicited by triggers that, once initiated, can go to completion without constant conscious oversight". This distinction implicitly acknowledges that habit and compulsivity do not exactly overlap. Actually, the account of addictive behaviors as uncontrolled habits has been recently contested, based on evidence that drug demand is sensitive to costs (Hogarth et al., 2019; Hogarth, 2020), addictive drug-seeking can develop in the absence of habit learning (Singer et al., 2018), and drug use in people suffering from addiction remains sensitive to contingency management (Dutra et al., 2008).

Nonetheless, that evidence does not necessarily imply that compulsivity is useless to define addiction. For instance, according to Hogarth (2020), addictive behavior can be regarded as excessive goal-directed choice under extremely negative affect. According to this account, when the negative affect passes, it might look like the individual was not sensitive to the negative consequences. Still, even if this approach is correct, the question of why addiction-related outcomes become so dramatically overvalued remains. Possible answers rely on the motivational and emotional states that precede addictive behaviors. Among these, craving is frequently mentioned as the core one, so that craving relief would be the main motivation behind addictive behaviors. In that sense, addictive behaviors would be instrumental and maintained by negative reinforcement, but craving itself is triggered by conditioned cues, and is characterized, not only by overwhelming desire, but also by attentional capture and an automatic tendency to approach such cues (Franken, 2003).

Thus, although reinforcement accounts of compulsivity do not require the formation of habits, they do require hypothesizing some learning mechanism(s) by means of which environmental cues acquire the capacity to elicit the core state that motivates the addictive behavior (e.g., incentive sensitization, Berridge & Robinson, 2016).

Before considering how compulsivity can be operationalized, it is important to distinguish compulsivity as understood here (i.e., as an acquired feature of specific behaviors) from compulsivity as a transdiagnostic trait. The latter can be broadly defined as "a *tendency* towards repetitive, habitual actions, which an individual feels compelled to perform, and are repeated despite adverse consequences" (Hook et al., 2021, p. 455; italics added), is measured by psychometric instruments as, for instance, the Cambridge-Chicago Compulsivity Trait Scale (Chamberlain & Grant, 2018; for a review see Hook et al., 2021), and can be detected by means of neuropsychological and lab-based tasks (Chamberlain & Grant, 2018; van Timmeren et al., 2018; Albertella et al., 2019, 2020). Trait compulsivity can predate the development of specific compulsive behaviors, and thus play a role in vulnerability to addiction. And the other way round, people showing compulsive behaviors in one or more domains will tend to present high trait scores. Still, trait compulsivity scales only indirectly serve our aim of identifying specific behaviors that can be conceptualized as compulsive.

The present study

If transition towards compulsivity is crucial for understanding the etiology of substance addiction, it must also be so to understand behavioral addictions (Robbins & Clark, 2015; Figee et al., 2016). Unfortunately, in the field of non-substance addictive processes, 'compulsive' is frequently considered a synonym of excessive, problematic, or maladaptive, when applied to activities as buying (Mestre-Bach et al., 2017; Kirios et al., 2018), sexual behavior and pornography use (Starck et al., 2018; Antons & Brand, 2021), or exercising (Goodwin et al., 2011, 2014), without making any commitments regarding its specific meaning.

Not even the minimum agreement regarding the operationalization of compulsivity we have previously seen in substance addictions exists in non-substance ones. In view of this state of affairs, the main goals of the present study were (a) to identify specific items in current instruments that can be regarded as instances of compulsive behavior, (b) to classify them in conceptually separable operationalizations, and (c) to identify the potential delimitation problems of such operationalizations. More specifically, we first identified the studies in the current literature describing or using self-report instruments that could be considered sensitive to compulsivity. Once extracted from the articles, the available instruments were inspected in a search for specific items that realize the concept of compulsivity.

We adopted a set of criteria to identify compulsivity-sensitive items. These criteria were based on the elements that distill from the brief review outlined above. The first criterion, (a) *perseverative behaviors for which the individual is consciously aware of negative consequences*, directly arises from the definition of compulsivity proposed by Yücel et al. (2019). The second criterion, (b) *items referring to initiation or continuation of behaviors perceived as unintended or disconnected from their consequences*, is based on the concept of habit. We are aware that, according to animal models, habit is behavior that persists despite outcome devaluation (Balleine & Dickinson, 1998; Dolan & Dayan, 2013), whereas our criterion implies assuming that such insensitivity results from a transition of behavior from requiring the pre-representation of outcomes to being goal-detached. Despite this inferential step, we believe this is a reasonable translation of habit into human behavior (De Houwer et al., 2018; Heyes & Dickinson, 1990; Robbins & Costa, 2017). The third criterion relates to the pivotal role of craving in compulsivity: c) *urges, or behaviors motivated by an experience of craving intense enough to compromise control*. Finally, the fourth and fifth criteria arise from the idea that compulsivity can result from the capacity of conditioned cues to automatically trigger specific components of addictive behaviors, namely d) *automatic orientation of attention towards activity-related cues that interferes with other tasks requiring attentional/cognitive resources*; and e) *behaviors automatically triggered by exteroceptive or interoceptive stimuli*.

These criteria are partially overlapping, and intentionally over-inclusive. The contents of the selected items were subsequently examined to classify the identified items into differentiable categories or operationalizations. So, over-inclusiveness was intended to leave room for the definitive operationalizations to emerge from content analysis, and, subsequently, to allow us to zoom in on each of them, in order to identify potential delimitation problems.

This degree of over-inclusivity implies that some of the items identified here as operationalizing compulsivity could also tap onto related constructs. For instance, impulsive behaviors are customarily considered to be rash and inappropriate, but still reward-driven, whereas compulsive ones are normally considered outcome-detached (Fernández-Serrano et al., 2012). However, as noted earlier, transitory states can contribute to the overvaluation of action outcomes that are seen as less valuable when such states vanish. That is, outcomes that are overvalued in a 'hot' state, can be regarded as less valuable when the individual is in a 'cold' state (intrapersonal hot-cold empathy gap; Ruttan & Nordgren, 2015), leaving the individual with the feeling that behavior is not aligned with one's goal. This is an important problem we will need to consider in detail once the list of items is available.

In summary, we regard this review and synthesis as an intermediate step for the future development of a scale to measure compulsivity within any given behavioral domain. It could well be that such a scale is multidimensional, and it is also possible that the factorial composition of compulsivity does not mirror our set of operationalizations. Still, once the factorial composition of a set of putative compulsive behaviors is known, the scale could be applied across behavioral domains in order to analyze similarities and differences across candidate behavioral addictions, and the relative contribution of such components to clinically relevant outcomes.

Method

A systematic review was conducted following the PRISMA guidelines (Page et al., 2021). The flow diagram depicted in **Figure 1** illustrates the process of study identification and selection. The flowchart for selecting scales from those documents, and items from those scales is depicted in **Figure 2**. These diagrams, as well as search algorithms, and files for intermediate results of the whole process, can be downloaded from the OSF link https://osf.io/waev7/.

Eligibility criteria

In this section, selection criteria for articles, self-report instruments extracted from these articles, and items extracted from these instruments are described separately.

The inclusion criteria for articles, as firstly implemented in the automatic search algorithms, were: (IC1) to describe a self-report measure referring to a potential behavioral addiction or some of its components, and (IC2) to mention any of the following compulsivity-related terms: compulsion, compulsive, compulsivity, habit(s), habitual behavior, and craving. The inclusion of craving obeys to the reasons detailed in the introduction, that is, to the fact that craving is commonly associated with feeling forced or compelled to act against one's utilitarian preferences.

Exclusion criteria at this stage referred to the characteristics of the contributions, the language of publication, the possibility of accessing the full-text article, and the use or development of self-report measures of interest in the articles found. Retrieved records were excluded if: (EC1) we were unable to retrieve the full-text manuscript; (EC2) the article was not written in English, French or Spanish; (EC3) the article was not a peer-reviewed research report (dissertations, posters, commentaries, books and book chapters, essays, and *corrigenda* or *errata*); (EC4) the scales or questionnaires of potential interest mentioned in the text (i.e., the self-report instruments potentially measuring compulsive behavior) were not fully described in the main text or supplements of the article.

The inclusion criteria for self-report measures mentioned in those articles were: (IC3) to refer to a potential behavioral addiction, and (IC4) to contain at least one item that can be interpreted to be sensitive to compulsivity with the criteria defined earlier.

Exclusion criteria for self-report measures were: (EC5) to refer to substance addictions, but not to a putative behavioral addiction (EC6), not to be written in English, French or Spanish, and (EC7) to be an adaptation of a scale already recorded with no new items.

The only selection criterion for individual items from the previously identified self-report instruments was to instantiate compulsive behavior. This condition was interpreted to hold even when the coincidence was partial, that is, when the item referred to at least one of the six criteria specified in Section 2.

Search strategy and information sources

We examined the databases PsycINFO, PubMed, Scopus and Web of Science in search of eligible studies, entering the following syntax: "(habit OR 'habitual behavior' OR 'habitual behaviour' OR compulsi* OR craving) AND (scale OR measure* OR questionnaire OR validation OR self-report*) AND ('behavioral addiction' OR 'behavioural addiction' OR 'internet addiction' OR gambling OR videogames OR 'video games' OR 'compulsive shopping' OR 'compulsive sexual behavior' OR 'compulsive sexual behaviour')". In order to ensure the detection of records about the more thoroughly studied putative behavioral addictions, “video games”, “Internet addiction” and “gambling” were explicitly included in the search terms, apart from the more general “behavioral addiction” term, that should allow the detection of less frequently studied candidate behavioral addictions. As suggested by an anonymous reviewer, we also included “compulsive shopping”, and “compulsive sexual behavio(u)r”, because these explicitly mention compulsivity as part of the problematic behavioral pattern. (Please note that the inclusion of all putative addictive behaviors proposed to date would have made the results virtually unmanageable).

The search was performed on March 29th, 2022 (see the “search specifications per database” file available at the OSF link https://osf.io/yqcsd/, for the exact search algorithms used). Complementarily, we also cross-checked the references of the papers screened to search for scales of interest to identify other records eligible for the goals of the study.

Study selection

The first and third authors jointly conducted the automatic term-based search, and identified 4194 articles, 1496 of which remained after removing duplicate records. The title and abstract of each of these were explored to double-check for inclusion criteria. In case of doubt, the full text was retrieved if available and examined, so that 1112 records were retained. 98 reports were not retrievable (EC1), which yielded 1014 records. Thereafter, application of exclusion criteria EC2 to EC4 yielded 225 articles.

A citation search was conducted from these references to find articles containing further instruments of interest. Based on this citation search, 135 further articles were identified, 9 of which were not retrievable. After applying exclusion criteria, 105 of them were retained.

The list of references for the 330 articles later used for instrument extraction is available at the OSF link https://osf.io/5jxnu/ ("Articles scrutinized in search for self-report instruments of interest").

Scale selection

The two same authors independently explored all the documents in search for instruments that met the inclusion/exclusion criteria for self-report instruments (IC3, IC4, EC5-EC6; see "flowchart for scale and item selection"). Please note that IC3, EC5, and EC6 criteria are objective, whereas IC4 ("to contain at least one item that can be interpreted to be sensitive to compulsivity") leaves some room for subjectivity. After applying all but this criterion, there were 156 scales left. For these, inter-judges agreement regarding whether they contained at least one compulsivity-sensitive item was very good according to Cohen's kappa value (κ = 0.89). Total agreement was reached by discussion, and 138 self-report measures were finally retained. The self-report instruments included in this final list is available at the OSF link https://osf.io/dw6ur/ ("Instruments with compulsivity-sensitive items").

Identification of items

All items from those scales (*n* = 2,693) were individually assessed by the same two judges. This resulted in a very good agreement between the two experts (κ = 0.90). The identification of compulsivity-sensitive items finally resulted in the list of 586 items available at the OSF link https://osf.io/w3vp6/ ("Identified compulsivity-sensitive items"). Note, however, that the actual number of compulsivity-sensitive items is smaller, as many items appear (in almost identical forms) in more than one scale. For the sake of transparency, instances of the same item in different scales are retained in the file. The exclusion criterion EC7 was applied retrospectively here to exclude reduced or adapted versions or previous scales with no new items. Exceptions were made for the Compulsive Online Shopping Scale (COSS; Manchiraju, Sadachar, & Ridgway, 2017), the Food Cravings Questionnaire-Trait-Reduced (FCQ-T-R; Meule, Hermann, & Kübler, 2014), the Internet Gaming Disorder Scale - Short Form (IGD9-SF; Pontes & Griffiths, 2015), and the Modified Yale Food Addiction Scale (mYFAS; Flint et al., 2014) and the Yale Food Addiction Scale for Children 2.0 (dYFAS-C 2.0; Schiestl & Gearhardt, 2018) scales. These were versions of previous instruments, but contain items not included in the original ones. The references for all scales are included in the file for the full list of self-report instruments meeting the eligibility criteria mentioned in the previous section.

Formulation of operationalizations

The formulation of operationalizations proceeded in two steps. The first one started with the five compulsivity criteria mentioned earlier as preliminary categories. In this first step, the correspondence between items and themes was assessed, so that items that were classifiable in more than one category were identified, and content discrepancies between items classifiable as belonging to the same category were made explicit. In a second step, the first and fourth authors identified discrepancies and overlaps between the categories, based on the output of the first step, and redefined them accordingly.

Figure 1. PRISMA flowchart for article selection.

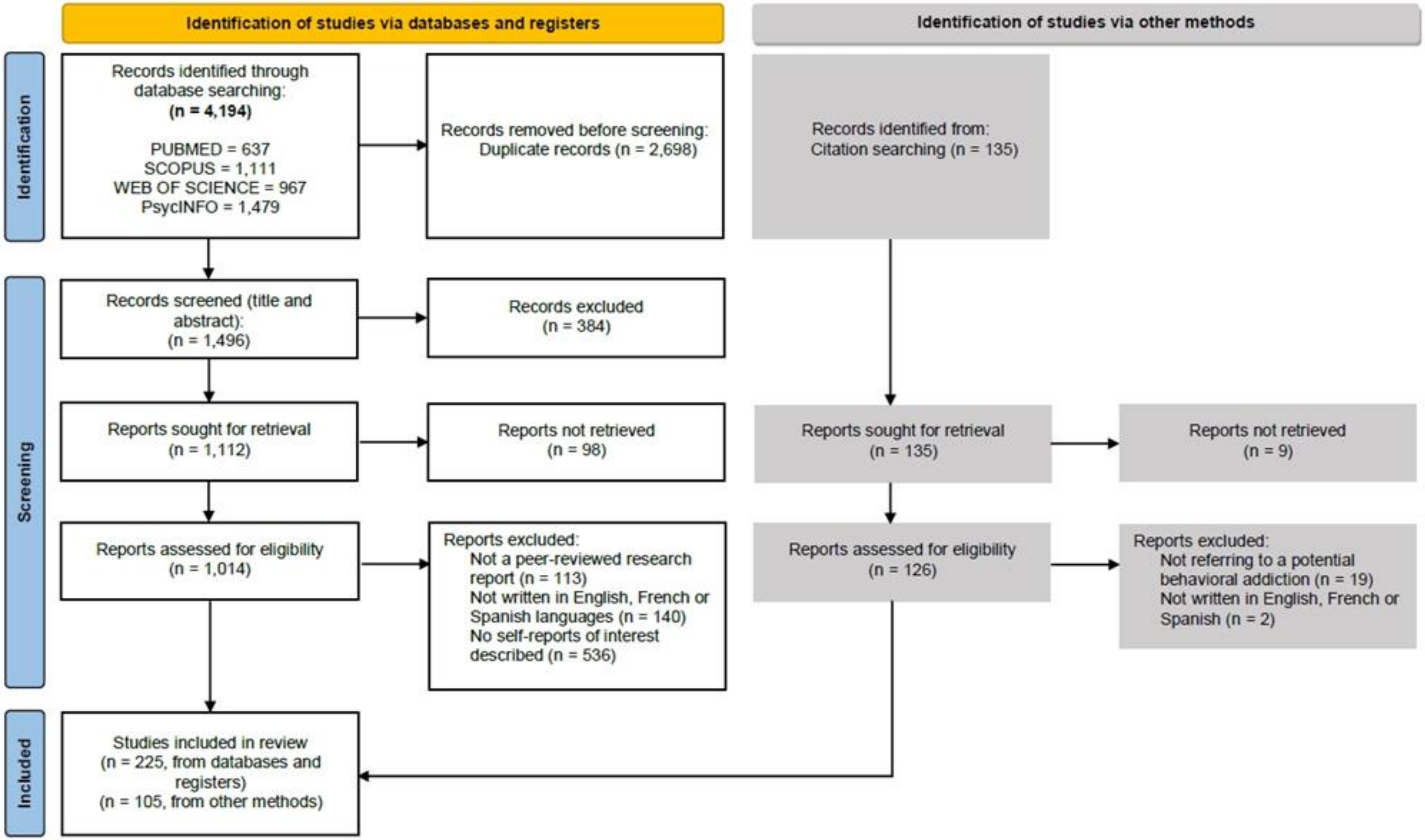

Figure 2. PRISMA flowchart for scale and item selection.

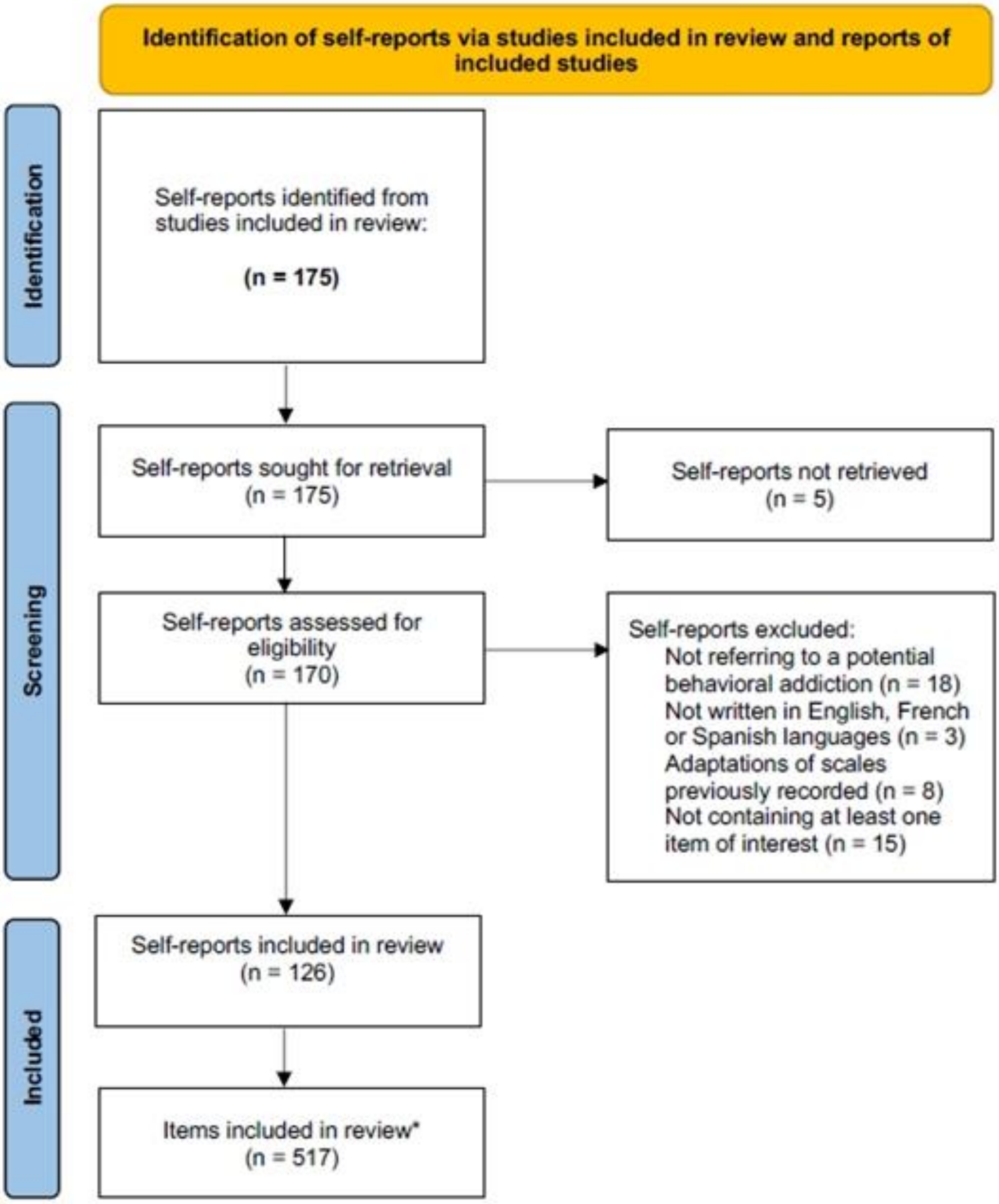

Table 1. Operationalizations of compulsivity, example items, and delimitation problems.

Operationalization	Exemplar item	Delimitation problems
1. Automatic or habitual behavior occurring in absence of conscious instrumental goals	*It happens that I am virtually doing something completely different and then, without thinking, start [doing X]. (KFN-CSAS-II; Rehebein et al., 2010)*	Reference to automaticity or disconnection between behavior and goals not explicit enough in some items.
2. Overwhelming urge or desire that impels the individual to initiate the activity and jeopardizes control attempts	*Every so often, I experience a compulsion to [do X] which I can't seem to control" (BEQ; Gormally et al., 1982).*	In many behavioral items, craving or intense desire is mentioned, but control compromise failure is not. Craving/intense desire can reflect goal overvaluation instead of compulsivity.
3. Inability to stop or interrupt the activity once initiated, resulting in an episode substantially longer or more intense than intended (bingeing).	*When I crave [something], I know I won't be able to stop [doing X] once I start (FCQ-Trait; Meule, 2020).*	Items referring to sessions or activity episodes that last longer than intended but making no reference to lack of control.
4. Behavior insensitive to negative consequences despite conscious awareness of them	*[Doing X] has created significant problems in my personal relationships with other people, in social situations, at work or in other important aspects of my life (PPUS; Kor et al., 2014).*	Items referring to negative consequences are not worded in such a way that negative consequences are pitched against potential rewarding outcomes of the activity. Items mostly insensitive to negative utility at the time of choice (local disutility).
5. Attentional capture and cognitive hijacking	*I can't stop thinking about [doing X] (OCS; Davis, Flett, & Blesser, 2002).*	Automatic orientation of attention towards addiction-related cues, and intrusive/persistent thoughts can be considered as separable. Potential overlap between this category and overwhelming urge or desire.
6. Inflexible rules, stereotyped behaviors, and rituals related to task completion or execution	*I feel unsatisfied until I have done everything I want to in a video-game (VGCS; Bodi, Maintenant, & Pennequin, 2021)*	Inflexible rules regarding the attainment of goals, task completion, or the way the activity is performed can reflect overvaluation of activity goals instead of compulsivity. Inflexible rules regarding goal attainment and those regarding stereotyped behaviors and rituals could be considered as separable.

Note: *[Do(ing) X]* refers to the potentially problematic activity, which varies across instrument

Selection and formulation of representative items

In order to externally assess the conceptual soundness of the proposed categories, the first and fourth authors listed 90 items representative of the six categories in a balanced manner. In order to elaborate this list, available at the OSF link https://osf.io/j8umc/ ("Item selection for external inter-judges assessment"), some original items that mentioned specific behaviors were reworded to be applicable to a wide range of different activities (e.g., gaming, gambling, exercising, etc.). In some cases, items that were present in several scales with very similar forms were unified into a common wording. Additionally, as we did not identify as many as 15 clearly differentiable items for some categories, we elaborated the ones necessary to complete the list. These new items were elaborated to represent the corresponding operationalizations, and then discussed and refined by all the authors.

The 90 items in this list were randomly shuffled and submitted for assessment by 4 experts. Although one of the experts has been finally included as the second author of this work (JN), neither they nor any of the other three experts had been involved in phases 1 and 2 (their names and professional/academic credentials are disclosed in the acknowledgements section). For expert assessment, the items were worded using "playing" as the target activity, but the judges were instructed to mentally picture this as gaming, gambling, or any other activity that can be done in excess or in a dysregulated manner. The experts were asked to (a) read the six operationalizations resulting from the previous round, (b) to judge whether each item reflected compulsivity, and (c) to assign each item to one of the operational definitions (1-6). Finally, (d) the experts were given the chance to justify their negative answers to the first question, and (e) to report any difficulties they might have had when categorizing the items.

Results

Steps 1 to 6 from the previous section eventually resulted in the definitive set of operationalizations (**Table 1**, left column).

For the first category, disconnection between behavior and intentions or goals was redefined as *automatic or habitual behavior occurring in absence of conscious instrumental goals*. This operationalization largely mirrors the definition of habit in habit-learning research. Notably, this operationalization left out several items that made an explicit reference to continuity of the activity for longer than intended, but not to automaticity or habit-like behavior.

The second and third operationalizations resulted from identifying two possible meanings of the initial ‘urge’ criterion: one closer to the original one (*overwhelming urge or desire that impels the individual to initiate the activity and jeopardizes control attempts*), and a different one that comprised items referring to the *inability to stop or interrupt the activity once initiated, resulting in an episode substantially longer or more intense than intended (bingeing)*. The latter mostly consists of the items referring to the continuity of the activity for longer than intended that were left out of the first operationalization.

Fourth, awareness of negative consequences was slightly reformulated as *behavior insensitive to negative consequences despite conscious awareness of them*. This formulation makes explicit that the individual sticks to the problematic activity, even in face of substantial punishment. This definition parallels the one used in Lüscher et al. (op. cit.) to characterize compulsivity in animal models of drug self-administration.

Fifth, relatively few items specifically referred to attentional capture. However, while exploring the instruments item-by-item, a large number of items were detected that described activity-related involuntary or unintended thoughts substantially interfering with normal functioning. So, the category was reformulated as *attentional capture and cognitive hijacking*. That is, it was expanded to include any type of excessive attention to internal or external activity-related stimuli, but also preoccupation, rumination or intrusive and persistent thoughts that cause substantial interference with any willful tasks requiring cognitive resources. All selected scales were reassessed to systematically search for items compatible with this new operationalization.

Finally, we spotted a number of conceptually connected items that were not adequately captured by any of the six initial criteria, but could still be considered instances of compulsive behavior. This led again to revisiting the scales and creating a last operationalization by recovering all items referring to *inflexible rules, stereotyped behaviors, and rituals related to task execution or completion*. As shown in the table, this sixth operationalization includes feeling forced or compelled to perform tasks in a certain way, but also some others relative to the necessity to complete the task or reach certain goals within the session in course. Non-completion or non-adherence causes substantial uneasiness, discomfort, or frustration.

At this point, one of the initial criteria (contextual dependency, or importance of exteroceptive or interoceptive stimuli at triggering the potentially problematic behavior) was discarded as a separate operationalization, as no items were found to distinctly fit into it. Contextual dependency, however, seems to be transversally present in the operationalizations of compulsivity identified here.

Finally, as previously described in the Methods section (subsection 3.7) a total of 90 items, selected or elaborated to fit the final operationalizations in a balanced manner, were assessed by 4 experts. The percentages of positive answers to the question regarding whether items reflected compulsivity or not were 83% (JN), 96% (SRA), 59% (PM), and 83% (DB). Regarding category assignment, interrater agreement was Fleiss' κ = 0.83 when our initial categorization was included, and κ = 0.80 when our categorization was not included (Landis & Koch, 1977).

Discussion

The final stage of this review involved identifying potential delimitation problems for the six operationalizations. These problems mainly arose from the experts' objections regarding each item as either reflecting compulsivity, or belonging to the corresponding proposed category, and will be used to make specific recommendations for item wording in future attempts to develop compulsivity measures. Additionally, the six operationalizations will be examined from a theoretical point of view, to take the first step towards ascertaining the cognitive and learning mechanisms underlying different manifestations of compulsivity.

Automatic or habitual behavior occurring in absence of conscious instrumental goals

This category comprises items like “It is common for me to unconsciously take out my mobile phone to check *Whatsapp*” (translated from Gutierrez & Morales, 2019) or “I involuntarily touch my smartphone” (Ezoe et al., 2016). This behavior is characteristic of some cases of problematic video gaming, excessive Internet or smartphone use (e.g., “doomscrolling”; Sharma, Lee & Johnson, 2022), and some forms of gambling (e.g., continuous, immersive gambling; Dixon et al., 2018). It is, however, notably absent in problematic patterns of more purposive behavior like working, exercising, or strategic types of video gaming (Delfabbro & King, 2015). When feelings of automaticity are present in these activities, they often adopt the form of positive mindlessness, absorption, or flow, which has been reported to be an ingredient of harmonious passion and engagement (Barberis et al., 2021).

Some of these items were judged by the experts as not well suited to implement the operationalization (e.g., “Often, when I am playing, I find that my mind has drifted”, “I often play spontaneously”; Flayelle et al., 2019; Rook & Fisher, 1995), as the mention to lack of monitoring or disconnection between behavior and goals was not explicit enough. The operationalization itself, however, remained unchallenged.

As noted earlier, this category conceptually overlaps with the definition of habit in animal learning research. However, recent evidence has challenged the idea that addictive behaviors are mere habits. On the one hand, recent attempts to induce habits in humans and macaques with extensive training have notably failed (De Wit et al., 2018; LaFlamme et al., 2022). On the other hand, habits seem unnecessary for the development of addictive behaviors. In words of Singer et al. (2018), drug seeking often requires considerable ingenuity and flexibility, thus it cannot be governed by motor habit alone.

If habit formation (understood in this restricted sense; see also Robbins & Costa, 2017) is neither necessary nor sufficient for drug use to become addictive, the same can be probably said about behavioral addictions. Compulsivity in the form of habit can contribute to certain activities becoming problematic, insofar as their monitoring and control is diminished. However, it is virtually absent or secondary even in *bona fide* behavioral addictions, as, for example, strategic or skill-based forms of disordered gambling.

Overwhelming urge or desire that impels the individual to initiate the activity and jeopardizes control attempts

The realm of compulsivity, however, is not restricted to habit learning. Craving can be a driving force behind compulsive behavior, at least in two senses. First, craving is automatically triggered by exteroceptive and interoceptive cues, and is thus experienced as occurring itself beyond voluntary control. And second, the overvaluation of the addictive activity resulting from the expectancy of craving relief can make such activity unmistakably disadvantageous in the long term. Accordingly, craving has been systematically shown to be a core component of substance use disorder (SUD), a close indicator of addiction severity, and a predictor of relapse and treatment outcomes (Stohs et al., 2019; Franken et al., 2003).

This centrality seems to apply beyond SUDs. Although craving is not included among the DSM-5 diagnostic criteria for gambling disorder, the available evidence strongly suggests that its role and its psychobiological underpinnings are very similar to the ones described for SUDs (Hormes, 2017; Limbrick-Oldfield et al., 2017), and the term is also frequently used for other putative behavioral addictions (Cornil et al., 2019; Savci & Griffiths, 2019; Meule, 2020). Accordingly, craving items are frequently included in non-substance addiction scales (e.g., “Sometimes I think there are internal forces that prompt me to shop online”, “The urge is so strong, I cannot help myself from playing this gambling game”; Huang, Chen, & Sun, 2022; Rousseau et al., 2002).

Recent theoretical models also attribute a central role to craving in the etiology of behavioral addictions, other than gambling disorder. For instance, in the I-PACE model (Brand et al., 2016, 2019) addictive behaviors are considered to be caused by progressively hyperactive impulsive/reactive neural systems (including the conditioned associations responsible for craving and cue reactivity), accompanied by an also gradual weakening of executive inhibitory control. Although compulsivity is not explicitly mentioned in the model, this transition is hypothesized to underlie feelings of automaticity, and the loss of importance of gratification in motivating the addictive behavior.

Despite its importance, the first substantial delimitation problem was identified in relation to this operationalization. Craving items in most scales merely refer to intense desire. However, the idea that intense desire by itself is indicative of compulsivity can be called into question, as it may reflect just the anticipation of reward. Overvaluation of the problematic activity could be boosted by reward immediacy, relative to delayed positive outcomes of abstinence, so that the individual shows some degree of ambivalence, and thus a certain feeling of acting against one’s goal. This behavior, however, would be better conceptualized as impulsive rather than compulsive. Mostly in accordance with this distinction, the authors of the I-PACE model highlight the importance of carrying out studies to “disentangle potential shifts from craving to compulsion and from expecting gratification to expecting relief from negative states” (Brand et al., 2019, p. 6), implicitly acknowledging that craving is not necessarily indicative of compulsivity.

This delimitation problem is probably behind the difficulties to incorporate craving into clinical conceptualizations of behavioral addiction. A recent Delphi review (Castro-Calvo et al., 2021) failed to reach an acceptable level of agreement regarding its diagnostic validity, clinical utility, and prognostic value in gaming disorder. This lack of agreement calls for the need to conduct etiologically informative studies, but these are still scarce. In one of the few available ones, King et al. (2016) asked a sample of individuals with gaming disorder to abstain from gaming for 84 hours, and interviewed them using open-ended questions, two of which were explicitly about craving: ‘*Did you experience any desire/craving to play? Can you say briefly what was happening when you felt that desire/craving?*’. Although many respondents answered the first question positively, the second one revealed that craving feelings were primarily associated with boredom and lack of mental stimulation, and also with the individual’s perception of ‘missing out’ or experiencing ‘losses’ if unable to play. In other words, cravings seemed to be tightly linked to overvaluation of the activity, and instrumental motives seemed to significantly contribute to such cravings. Unfortunately, the confirmatory approach customarily used in behavioral addictions research relies on closed questions about desire or urge, so they enforce similarity between potentially separable behavioral processes (see Billieux et al., 2015; Kardefelt-Winther, 2015).

Inability to stop or interrupt the activity once initiated, resulting in an episode substantially longer or more intense than intended (bingeing)

The third operationalization of compulsivity is closely related to craving, at least in conceptual terms. Our decision to consider it separately is based on the observation that perceived inability to interrupt the activity is prominent in certain putative behavioral addictions, but totally uncharacteristic of others. Items in this category include, for instance, "Once I have started [doing X], I can´t stop playing unless something external prevents me to", or "If I get carried away by the temptation to start playing, I lose control" (Ruiz-Juan, 2013; Meule, 2020). Among the putative behavioral addictions in which bingeing is more evident are, for example, compulsive shopping (Manchiraju, Sadachar, & Ridgway, 2017; Müller et al., 2015), binge eating (Schiestl & Gearhardt, 2018; Meule, 2020), binge watching (Flayelle et al., 2019), and video gaming disorder (Yilmaz, Griffiths, & Kan, 2017).

This operationalization presents delimitation problems that mirror the ones mentioned for the previous category. Most items refer to sessions or activity episodes that last longer than intended, but excessive duration or intensity of a behavioral episode can be due to purely utilitarian reasons, such as fear of missing the chance to reach a certain goal, or perceived social pressure (King & Delfabbro, 2014, 2016).

Behavior insensitive to negative consequences despite conscious awareness of them

Virtually all the questionnaires analyzed here included items worded to assess awareness of the negative consequences of the potentially problematic activity. Some prominent examples are: “I kept consuming the same types or amounts of food despite significant emotional and/or physical problems related to my eating” (Flint et al., 2014), “I exercise despite persistent physical problems” (Hausenblas & Downs, 2002), or “Although using smartphone has brought negative effects on my interpersonal relationships, the amount of time spent on the Internet remains unreduced” (Pavia et al., 2016). These sometimes include ‘internal’ aversive consequences, such as feelings of guilt or regret, resulting from the perceived inability to keep on engaging in an activity that goes against personal moral principles or undermines one’s sense of control. Items of this type are frequent, for example, in scales for compulsive sexual behavior (e.g., “You continue to use pornography even though you feel guilty about it”; Kraus et al., 2020).

Variety of wordings reflects the range of contexts and life domains in which negative consequences occur, but awareness of these negative consequences does not necessarily imply that the net utility value of such consequences is negative. An individual can be aware of the negative consequences of a certain activity, and still attribute more value to the positive ones.

Moreover, even if the activity is plainly disadvantageous in the long term, it can be subjectively perceived as advantageous in the short term (Rachlin, 2000). At the local level, the choice is between an immediate (and overvalued) reward and a delayed (and thus discounted) one. The individual can thus be aware of the long-term negative consequences of the activity, and, at the same time, fail to resist temptation because the discounted utility of distant consequences is smaller than the immediate rewarding value of falling into it. For a behavior to be considered compulsive in the strictest sense, it would need to be goal-detached. However, overvaluation of the expected utility of an immediate reward when one is in a ‘hot’ state can lead the individual to feel forced to do something they will later regret (when in ‘cold’ state), i.e., to a seemingly compulsive behavior (in weaker sense; see Heather, 2020).

Despite the many items assessing insensitivity to negative consequences in the questionnaires analyzed in this review, virtually none of them is worded to be sensitive to any of these distinctions. First, none of the items referring to negative consequences is worded in such a way that such consequences are pitched against rewarding outcomes of the activity. And second, no items are sensitive to negative utility specifically at the time of choice.

Attentional capture and cognitive hijacking

On the one hand, this operationalization comprises items regarding automatic orientation towards cues that have become associated with the problematic activity and the availability of the rewards resulting from it. On the other, it comprises items reflecting preoccupation, and intrusive thoughts. These meanings are exemplified in items like “When I know a delicious food is available, I can’t help myself from thinking about having some” (Cappelleri et al., 2009) and “When I haven't been able to connect for some time, I become preoccupied with the thought of connecting” (Armstrong, Phillips, & Saling, 2000).

As mentioned by one of the experts, in terms of delimitation, it can be argued that automatic orientation of attention towards addiction-related cues, as also measured using cue-reactivity and eye-tracking techniques (e.g., Maurage et al., 2021), and intrusive/persistent thoughts depend on separable processes. For instance, in Berridge and Robinson's model, attentional capture arises (along with craving) from incentive sensitization, whereas the intrusiveness of certain thoughts has been linked to elaboration of desire (May et al., 2015), or to the fact that thoughts that involuntarily intrude one's mind are interpreted as threatening, and suppression or avoidance attempts make them progressively more salient and difficult to ignore (Moss et al., 2015; Enkema et al., 2021). In this second sense (when intrusiveness is fueled by perceptions of threat), there seems to be a mechanism in common between uncontrollable thoughts in addictive disorders and in obsessive-compulsive disorder (OCD). This mechanism, however, seems to play a more fundamental role in the case of OCD, where compulsions are primarily performed to seek relief from obsession-related anxiety (Marcks & Woods, 2007).

Relatedly, there is a potential overlap between this category and *overwhelming urge or desire*. For instance, an item such as "I cannot control my thoughts about gambling" seems useless to discriminate between overwhelming craving and cognitive hijacking. More importantly, these two concepts could be even difficult to separate at the conceptual level. In the incentive sensitization model, motivational and cognitive salience result from the same underlying learning process. Alternatively, the previously mentioned elaborated intrusion theory of desire conceptualizes episodes of craving as high-level cognitive processes – or elaborations – recruiting mental imagery and executive (controlled) mechanisms (Cornil et al., 2018), i.e., uncontrollable thoughts and desires are not neatly dissociable.

Also closely related to cognitive hijacking are the items included in some scales to measure salience (as one of the proposed addiction criteria proposed by the components model; Griffiths, 2005). Salience-related items usually refer to preoccupation, rumination, and interference. Indeed, some of these items have been identified here as sensitive to compulsivity [for example, “Has thinking about food, eating or calories made it very difficult to concentrate on things you are interested in (for example, working, following a conversation, or reading)?”; Mond et al., 2004]. However, in some recent scales for putative behavioral addictions, items of this sort have been replaced by items referring to the subjective importance of such an activity in the individual’s life. For example, in the validation study of the Exercise Addiction Inventory (EAI, Terry et al., 2004), excessive salience is said to occur when exercise dominates the individual’s thinking (preoccupations and cognitive distortions), feelings (cravings), and behavior (deterioration of socialized behavior), but the scale itself measures it with a single item, namely “exercise is the most important thing in my life”. Quite ostensibly, the reformulation of this item has altered its content, and loosened the criterion for the detection of so-called salience (Brevers et al., 2022).

That said, here we remain agnostic regarding the commonality or separability of the etiological mechanisms underlying attentional capture and intrusive thoughts. Still, we advocate that both sorts of behaviors can be considered compulsive, as far as (a) the two occur independently of one’s will and in spite of attempts to control them, and (b) they detract resources from other goal-directed mental activities. Hence, attentional capture and cognitive hijacking items should remain in future compulsivity scales, yet only if carefully worded to incorporate undesired interference and uncontrollability, and not willful planning and fantasizing, or activity-related mind wandering.

Inflexible rules, stereotyped behaviors, and rituals related to task completion or execution

The last category partially mirrors – particularly when it refers to rituals or superstitions – the definition of compulsion in OCD (i.e., repetitive behaviors that the person feels driven to perform in response to an obsession, *or according to rules that must be applied rigidly, and are aimed at preventing or reducing distress, or preventing some dreaded event or situation*; APA, 2013, italics added). Items of this type are, for example, “I feel unsatisfied until I have done everything I want to do in a video game.” or “There are certain things I do when I am betting (for example, tapping a certain number of times, holding a lucky coin in my hand, crossing my fingers, etc.) which increase the chances that I will win” (King & Delfabbro, 2014; Steenbergh et al., 2002).

The potentially compulsive nature of these behaviors could account for the overlap between OCD and addictive disorders. Actually, compulsivity could be a common transdiagnostic ingredient in addictive disorders and OCD, and differences between the two would emerge from specific non-overlapping acquisition and maintenance factors (e.g., obsession-related anxiety is hypothesized to play a more crucial role in OCD; Figee et al., 2016; Fontenelle, 2012).

In this case, delimitation problems arise again from the fact that the stereotyped behaviors that some items in this category describe are not necessarily compulsive. For instance, inflexible rules regarding the attainment of goals or task completion, despite being severely problematic in some cases (e.g., Billieux et al., 2020), seem to have more to do with the valuation of activity goals. For instance, "exercise addiction" scales normally include items referring to inflexibility (e.g., "I follow a set routine for my exercise sessions"), that is, to training routines that are firmly believed by some sportspeople to contribute to performance, but actually increase overtraining and health risks (Goodwin et al., 2011). Similarly, in scales for video gaming problems, some items refer to inflexibility as persevering, whatever it costs, to attain certain in-game goals (for example, "When I make mistakes, lose progress, or fail in a game, I must reload and try again"; King & Delfabbro, 2014). Perseveration is in some cases also linked to irrational cognitions (e.g., the sunk-cost and gambling fallacies). These fallacies are frequently present in gambling disorder scales, along with superstitions and rituals aimed to attract luck (for example, "I have specific rituals and behaviors that increase my chances of winning"; Raylu & Oei, 2004).

These instances of inflexible, stereotyped or ritualistic behavior, anchored in less-than-rational beliefs, can be certainly dysfunctional, and can be involved in the process by which certain activities become problematic. However, we doubt they can be regarded as compulsive. These behaviors are clearly goal-oriented and based on beliefs that can be considered irrational from an external observer's point of view, but reflect the individual's knowledge about the world.

Conclusions and recommendations

The present review was aimed at detecting compulsivity in behavioral items from available psychometric instruments used in the field of (putative) behavioral addictions. After funneling the scales through a theory-informed definition of compulsivity, we identified and listed the items that fitted it. Subsequently, the contents of those items were carefully analyzed to identify item categories that could be used as operationalizations. And finally, such categories were scrutinized to assess the degree to which they can be used as better delineated operationalizations of compulsivity in future attempts to measure it.

As a result, this attempt has revealed that behaviors can be categorized as compulsive in non-trivially different ways. Yet, disutility seems to be a common element to all of them. Behaving on autopilot, being unable to resist craving, to stop when intended, to ignore certain stimuli, or to suppress certain thoughts, behaving in a stereotyped way, persevering in following inflexible rules, and neglecting negative consequences, can be considered compulsive when behaviors are disconnected form goals, or their net utility is negative.

Moreover, in a strict sense, for a certain behavior to be intrinsically compulsive, disutility should occur at the moment of choice. Unfortunately, even if compulsivity exists in this strict sense (which is debatable; see Hogarth & Field, 2020), retrospective self-report methods are probably incapable of capturing it. Still, in our view, psychometric tools remain valuable to detect compulsivity as global (instead of local) disregard of utility. Even in this weaker sense, however, many of the items considered in this review are too imprecise and over-inclusive. The lack of any explicit reference to inability to help engaging in the activity, to stop it, or to do it in a certain way, despite awareness of net disutility or disregard of goals make them almost useless to detect compulsivity, so our recommendation is to include these elements when wording items for compulsivity scales. This suggestion should have the effect of raising the bar to conceptualize a given behavior as compulsive. In doing so, our prediction is that the presence of compulsivity in behavioral problems, and its role in their aggravation, and even its composition, will largely vary across conditions. In other words, many of the activities currently regarded as compulsive (as, for instance, compulsive exercising or compulsive working) are likely to reveal little real influence or presence of compulsivity.

If corroborated, this prediction should converge with results obtained with scales inspired by transdiagnostic models, i.e., people showing specific compulsive behaviors in one or more domains are expected to also show higher scores in trait compulsivity. Conversely, people experiencing dysregulated or problematic behaviors that, despite being maladaptive, cannot be characterized as compulsive, would not necessarily present high trait compulsivity scores.

For instance, the Brief Assessment Tool for Compulsivity Associated Problems (BATCAP; Albertella et al., 2019) was developed to cover several activities and behaviors (including alcohol use, gambling, eating, Internet use, and contamination, checking, and ordering compulsions), so that "individuals who reported having engaged in any of these behaviors in the past month were asked to complete the corresponding BATCAP" (Albertella et al, 2019; p. 498). In that sense, the aim of the BATCAP aligns with our aim to develop a compulsivity scale that can be applied to different behavioral domains. However, instead of on bottom-up content analysis, the development of this scale was based on a theory-driven selection of items from previous scales, so that, for each potentially problematic behavior, individuals are asked to answer questions about time lost, distress, loss of control, functional impact, anxiety if prevented from doing the behavior, and strongest urge.

On the one hand, and despite the different methodologies used, it is reassuring that these items fit the operationalizations described here. Actually, these items are closer to our final operationalizations than to the original criteria we used to categorize items as compulsivity-sensitive, which implies that some degree of conceptual convergence can be reached. On the other hand, the items in this scale are affected by the delimitation problems we have discussed in the previous sections. For instance, items like “On average, how much time was occupied by these behaviors?” or “What was the strength of your strongest urge/craving to perform these behaviors?” are surely sensitive to compulsivity, but they would probably fail to isolate compulsivity defined in a stringent manner. In other words, measures like this could also benefit from the present effort to operationalize compulsive behaviors as precisely as possible.

Relatedly, further research is warranted on the link between compulsivity as a trait and vulnerability to develop compulsive behaviors in specific domains. The availability of a well-defined operationalization to determine if a specific activity (as exercising, working, gaming, or gambling) has become compulsive could help establish associations between the transdiagnostic dimensions tackled by trait compulsivity and the learning processes that underpin vulnerability to behavioral addictions.

A second recommendation for compulsivity operationalization also cuts through all the categories identified. The present review is specific compulsive behaviors. However, many of the reviewed items do not explicitly refer to overt or covert behaviors, but about the mental states (beliefs and desires) that account for such behaviors. So, to count as instances of an operationalization of compulsivity, items should be worded to refer to observable behaviors, or to non-observable ones (thinking, imaging, planning, paying attention, etc.) that can nevertheless be reported by the individual. Regardless of their observable or unobservable nature, their suitability to be conceptualized as compulsive, and to be included in one of the proposed operational categories, is the same. This requires items about beliefs and desires to be reworded as items about the behaviors such beliefs refer to, or such desires mobilize (e.g., “I *gamble* despite *knowing* it makes more harm than good” instead of “I *know* gambling makes me more harm than good”, or “I *cannot avoid gambling* when I *feel the urg*e to do so”, instead of “I often *feel an irrepressible urge* to gamble”).

To determine whether compulsivity is a single construct is beyond the aims of the present study. We have briefly reviewed here (and more extensively in Perales et al., 2020) how different models account for compulsivity by alluding to different learning and psychobiological mechanisms. It could well be that compulsivity is multicomponential, as also suggested by research with trait compulsivity scales, so the logical next step would be to analyze the factorial structure of a pool of items generated from the operational definitions identified here, following the recommendations we have formulated for such items to be maximally sensitive and discriminative. We do not have any strict commitment with the ontological value of these operational definitions. These have mostly arisen, in a bottom-up fashion, from the common themes already present in currently available instruments, but different items corresponding to different operationalizations could be found to load to a common factor. The observed factorial structure could thus be used as an intermediate link between specific behavioral items and explanatory psychobiological, learning, and cognitive mechanisms.

Operationalization and measurement of compulsivity across video gaming and gambling behavioral domains

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Abstract

Background: Compulsivity is the hallmark of addiction progression and, as a construct, has played an important role in unveiling the etiological pathways from learning mechanisms underlying addictive behavior to harms resulting from it. However, a sound use of the compulsivity construct in the field of behavioral addictions has been hindered to date by the lack of consensus regarding its definition and measurement. Here we capitalize on a previous systematic review and expert appraisal to develop a compulsivity scale for candidate behavioral addictions (the Granada Assessment for Cross-domain Compulsivity, GRACC). *Methods*: The initial scale (GRACC90) consisted of 90 items comprising previously proposed operationalizations of compulsivity, and was validated in two panel samples of individuals regularly engaging in gambling and video gaming, using exploratory structural equation modeling (ESEM) and convergence analyses. *Results*: The GRACC90 scale is unidimensional and structurally invariant across samples, and predicted severity of symptoms, lower quality of life, and negative affect, to similar degrees in the two samples. Additionally, poorer quality of life and negative affect were comparably predicted by compulsivity and by severity of symptoms. A shorter version of the scale (GRACC18) is proposed, based on selecting the 18 items with highest factor loadings. *Conclusions*: Results support the proposal that core symptoms of behavioral addictions strongly overlap with compulsivity, and peripheral symptoms are not essential for their conceptualization. Further research should clarify the etiology of compulsive behavior, and whether pathways to compulsivity in behavioral addictions could be common or different across domains.

Background

Compulsivity refers to the experience of feeling forced or compelled to act despite awareness of serious negative consequences, and to the behavior accompanying that experience (for reviews, see Yücel et al., 2019; Luigjes et al., 2019). At a mechanistic level, compulsivity has been proposed to imply that: (a) the behavior has become goal-detached, and thus mostly automatic and inflexible (i.e., outcome expectancy valuation no longer plays a role in motivating it, as shown by insensitivity to contingency manipulation and outcome devaluation procedures (Graybiel, 2008; Everitt & Robbins, 2022), or (b) the individual perseveres in behaviors driven by strong short-term motives (e.g., relief of craving/withdrawal symptoms or other intense affective states (Koob, 2020) despite knowing such behaviors are pernicious in the long run. Therefore, compulsivity may encompass both stimulus-driven and goal-directed control. In the words of Heather (2017), "the truth about addiction lies somewhere between the extremes of free choice and no choice" (p. 31), with different etiological models differing in their relative position between these extremes (for discussions, see Groman et al., 2019; Lüscher et al., 2020; Perales et al., 2020).

In spite of their differences, most models converge on conceptualizing compulsivity as the hallmark of addiction progression and maintenance (Yücel et al., 2019; Brooks et al., 2017). This view is supported by translational research showing that compulsive drug use corresponds to an extreme stage of otherwise functional learning and neuroadaptation processes (Berridge, 2022; Lewis, 2018). The endpoint of this process could be either the formation of inflexible habits, or the abnormal valuation of addictive (relative to alternative) rewards. In any case, a precise and data-driven behavioral operationalization of compulsivity should provide, first, a gateway to understanding the etiological mechanisms underlying loss of control in addictive processes. And second, it should allow researchers to identify differences and similarities between addictive disorders and other patterns of behavioral over-engagement.

A variety of non-substance-related activities, such as video gaming or Internet use, are frequently described as potentially addictive (not without controversy (Griffiths et al., 2016; Petry et al., 2014; Van Rooij & Prause, 2014).

Beyond semantic arguments, operationalization and measurement of compulsivity is regarded here as a necessary step to determine its role in these candidate addictions, in comparison to well-established ones, as gambling disorder or substance use disorders (SUDs). This ‘intensional’ (i.e., etiology-, or process-based) approach (Sussman, 2017) differs from the ‘extensional’ one adopted by the dominant components model of behavioral addiction (Griffiths, 2005), according to which an addictive behavioral pattern is defined by the co-occurrence of a set of criteria (salience, withdrawal, tolerance, relapse, mood modification, and conflict). On the one hand, the components model does not distinguish between behaviors and ensuing harms (Tseng et al., 2023), and conflates core and peripheral features of addiction (Billieux et al., 2019). On the other, flexibility and overinclusiveness in the delimitation of components allow a rather liberal application across behavioral domains (see, for example, Castro-Calvo et al., 2021; Castro-Calvo et al., 2022). This has caused a proliferation of new candidate addictions and tools to measure them, and an elevated risk of overdiagnosis and unnecessary psychiatrization of everyday life (Billieux et al., 2015; Brevers et al., 2022). Along these lines, some authors have criticized the application of the addiction framework to understand conditions such as problematic Internet use (PIU) or (Internet) gaming disorder (IGD), and propose instead that these conditions are better conceptualized as resulting from their use to cope with life problems or compensate for lack of life skills (Kardefelt-Winther, 2017).

In that context, the overarching aim in the present study is to advance in defining and measuring compulsivity clearly enough to gauge its presence in different domains of potentially addictive behavior. To this date, attempts in this direction have been hindered by the current state of conceptual vagueness regarding compulsivity. With that goal in mind, here we capitalize on a recent systematic review by Muela et al. (2022), who carefully analyzed available measures of behavioral addiction in search for items that could be considered sensitive to compulsivity. Bottom-up item content analysis and synthesis yielded six different possible operationalizations of compulsivity (see **Table 1**, left column). Importantly, these operationalizations largely overlapped with the ones identified using more theoretically driven, top-down, approaches (Brooks et al., 2017; Albertella et al., 2020).

Muela et al. (2022) also used an expert appraisal procedure to detect delimitation problems in items included in these operationalizations of compulsivity, with the most important problems being that (a) many items mentioned negative consequences but not disutility (i.e., net imbalance between harm and reward); and (b) many items that mentioned feeling compelled towards the problematic activity made no mention of loss of control, or inability to stop the habit or to resist the urge to engage in activity-related behavior. In other words, the most repeated comments by the experts were that being aware of negative consequences but not of the global irrationality of one’s actions (i.e., harms overcome rewards), or just experiencing a strong desire but not feeling such a desire seriously jeopardizes control, are insufficient for an item to reflect true compulsivity. As Muela et al.’s initial search just included the items as worded in the scales reviewed, many of the items lacked the specificity required.

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Muela et al.'s review (2022) resulted in the selection of 90 items representing the six proposed manifestations of compulsivity in the field of behavioral addictions. So, following the recommendations formulated in that review, in the present work part of those 90 items were reworded to explicitly mention disutility or lack of control. The definitive set was administered to a convenience sample of individuals with high degrees of engagement in gambling or video gaming activities (including participants below and above clinical significance thresholds). The aims were: (a) To unveil the factor structure of the 90-items pool of compulsivity-sensitive items; (b) to examine whether compulsivity can be measured across different behavioral domains using a single instrument, i.e., to assess cross-domain structural invariance of the scale; (c) to explore differential relationships of compulsivity (or its components) with correlates of gaming/gambling problems, i.e., negative affect, quality of life, and gaming/gambling motives; and, (d) to order the 90 items based on of their ability to capture any factor/s previously identified. That ordering should result in a shortened and more usable version of the questionnaire, to be employed in further research.

Although the six operationalizations of compulsivity are conceptually separable, our hypotheses remained open regarding the factorial composition of the scale. That is, we do not necessarily expect such operationalizations to correspond to separable dimensions of compulsivity. Hence, exploratory factor analyses were used to assess the structure of the compulsivity scale.

Our predictions were more specific with regard to differential correlations across gambling and gaming domains. Previous theoretical reviews (Groman et al., 2019; Navas et al., 2019) have proposed that gambling problems are crucially driven by structural features of gambling devices that interfere with the normal functioning of the reinforcement learning system, similar to how addictive drugs do. Video gaming-related problems were conceptualized in those reviews as resulting from overvaluation of gaming and game-related outcomes, rather than mostly automatic conditioning processes. We thus hypothesize gambling problems to be more driven by compulsivity than video gaming-related problems. Hence, we expect to find stronger negative correlations of compulsivity with quality-of-life, negative affect, and severity scores in the gambling sample than in the video gaming one, under the assumption that wellbeing reduction in problem video gamers would more substantially be accounted by factors other than compulsivity.

Table 1. Operationalizations of compulsivity (adapted from Muela et al., 2022).

Operationalization
1. Cognitive/attentional hijacking or interference caused by activity-related thoughts or images.
2. Insuperable urge compelling the individual towards the activity that jeopardizes the ability to control it.
3. Behavior continuance despite awareness of imbalance between harm and reward.
4. Inability to interrupt the problematic behavior once initiated, resulting in sessions lasting longer than planned or binging.
5. Automatic behavior triggered by cues in absence of declarative instrumental goals (habit)
6. Inflexible or stereotyped behaviors or rituals regarding completion or execution of parts of the activity

Methods

Participants and procedure

Participants were members of a Spanish online panel (following the UNE ISO 20252 and ESOMAR standards). The online survey was offered to active panel members being at least 18 years old. Potential candidates received an invitation via email to participate in the study. Before their potential inclusion, candidates were told this was a study for academic purposes, were warranted confidentiality and anonymity, and were informed about the estimated duration of the survey, and incentive conditions. The panel provider uses a financial compensation system based on points that can be redeemed through different online payment partners or be paid directly into panelist´s bank accounts.

Two pools of potential participants playing video games or gambling games were contacted. The main inclusion criterion for each of them was self-categorizing as being a regular gambler or a regular video gamer. Lottery-only gamblers were not eligible for the study, and the same participant was not eligible for the two samples. After acceptance, participants were provided detailed information about the specific procedure and general aims of the study, and were informed they could abandon the study at any time. After explicit informed consent, access to the full behavioral survey was granted, starting with the initial ad-hoc questionnaire to collect sociodemographic and gambling or gaming participation information.

The following measures were taken to ensure data quality. The response to the question on the preferred gambling or gaming modality in the initial survey was contrasted with responses to the last part of the full behavioral survey, including yes/no questions for having used each game type. If there was no correspondence between these answers (e.g., reporting First Person Shooter as their favorite game genre and then answering not having played that type of game) the participant was discarded. Additionally, two control items were included in the full survey. In the first one, the participant was simply asked to select a specific response option. In the second one, the participant was asked to select the lowest number in a series. If the response in any of these items was not the one instructed, the participant was discarded.

Recruitment continued until reaching a minimum of 300 fully valid and complete surveys in each subsample, which finally yielded 312 participants in the gambling sample and 319 in the gaming sample with no missing data. 39.74% of the participants who gamble presented a score equal to or above the cut-off for gambling disorder (4 or more symptoms present, according to the GD9 instrument described below), whereas the percentage of participants who played video games with scores equal to or above the 5-symptom cut-off for clinical significance was 29.68% (according to the IGD instrument described below).

Measures

The instruments used in the entire protocol for both the video gaming and the gambling samples are available (in Spanish) in the accompanying Open Science Framework (OSF) link (see Availability of data and materials section).

Initial ad-hoc survey

The initial questionnaire collected quantitative information on age, and categorical information on education level, monthly income, and the modality of video game or gambling games they preferred. In the case of video gaming the options were (i) Multiplayer Online Battle Arena (MOBA); (ii) Massively Multiplayer Online Role-playing Game (MMORPG); (iii) Battle Royale; (iv) First Person Shooters (FPS); (v) strategy games, (vi) fighting or sport games; (vii) action games; (viii) mobile games; and (ix) other games not listed above. In the case of gambling the list included (i) scratchcards, (ii) card games, (iii) bingo, (iv) slot machines, (v) roulette, (vi) sport bets, and (vii) other games not listed above. In both lists, there was a last option for 'none'.

90-item Granada Assessment for Cross-Domain Compulsivity (GRACC90)

As noted earlier, this questionnaire is the target measure in the present study, and was developed after Muela et al.'s (2022) selection of compulsivity-sensitive items. In their systematic review, these items were assessed by a pool of experts, who identified potential delimitation problems in the items from some categories. In order to solve such delimitation problems “negative consequences” items were reworded to explicitly mention the irrationality of behaviour, or perceiving negative consequences as costlier than potential benefits (e.g., “I cannot quit playing, despite it is causing me more harm than good”); and “urge/craving” items were reworded when necessary to explicitly mention lack of control (e.g., “I can’t control the urge to start playing”). All items were worded and administered in Spanish. Gambling and gaming versions of all items were identical except for the target activity (video gaming, gambling). Responses were collected using a 5-point scale (from 1 = *totally disagree* to 5 = *totally agree*). The complete pool of items and their English translation can be found in **Table S1** in the accompanying Open Science Framework (OSF) link for Supplementary Materials, Data, and Code (see Availability of data and materials section). Note, however, that the English version has not been validated and is reported here for information purposes only.

Despite this attempt to better delineate the items, and to make them as discriminative as possible, we are aware that items cannot be completely free of delimitation problems. Indeed, some degree of over-inclusiveness, in combination with the large number of items, is recommendable at this stage (Clark & Watson, 1995), in order to further assess item quality based on participants’ responses.

Quality of Life in Individuals Addicted to Psychoactive Substances Test (TECVASP)

This instrument (Lozano-Rojas et al., 2007) consists of 22 5-point Likert-type items, ranging from 1 = *a lot* to 5 = *not at all*, assessing perception of physical and psychological wellbeing and health, both in general and in relation to substance use. For the purposes of this study, this questionnaire was slightly adapted by rewording items mentioning drug use as referring to video gaming or gambling. A higher score represents better quality of life. Internal consistency, as measured by Cronbach's alpha, was .86. (All reported Cronbach's alphas –for this scale and all the following ones– correspond to the samples of the present study).

Diagnostic questionnaire for gambling disorder (GD9)

This measure (Stinchfield, 2003) (Spanish validation, Jiménez-Murcia et al., 2009) was originally used to measure severity of gambling-related problems, and consists of 19 items that evaluate the ten diagnostic criteria for pathological gambling in the DSM-IV-TR (American Psychiatric Association, 2000). Since the illegal acts *criterion* was eliminated in the DSM-5 diagnosis for gambling disorder, the answers to the 17 items that explore the 9 DSM-5 symptoms of gambling disorder have been used for the present study ($\alpha = .89$). The present DSM-5-adapted version has also been satisfactorily validated in previous studies (Jiménez-Murcia et al., 2019).

Diagnostic questionnaire for Internet gaming disorder (IGD9)

This scale was used to measure severity of video gaming-related problems. The nine IGD criteria proposed in Section III (emerging conditions) of the DSM-5 (American Psychiatric Association, 2013) were assessed with 9 items (one per criteria) as *proposed* by Mallorquí-Bagué et al. (2017). The cut-off point for the diagnosis of IGD is set at 5 or more criteria. This particular form of the questionnaire was used instead of the more common IGDS9-SF (assessing the same criteria with Likert scales (Beranuy et al., 2020)) to allow the highest possible degree of comparability between this and the GD9 measure, without any loss of reliability (α = .85 in the current sample).

Negative Affect scale of the Positive and Negative Affect Scales (PANAS)

Only the negative affect subscale of the PANAS (Watson et al., 1988) (Spanish version, Sandín et al., 1999) was used here, i.e., a general dimension of psychological distress composed of 10 adjectives (e.g., "Nervous"). Responses were collected using a 4-point Likert scale representing how well the adjective describes how the participant has felt in the last week (0 = nothing, 3 = a lot; α = .92).

Brief Gambling Motives Inventory (bGMI)

The bGMI (Barrada et al., 2019) assesses four gambling motives with 18 items with response options ranging from 0 = never/almost never to 3 = always/almost always. The four dimensions are Affect Regulation (7 items; e.g., "To forget my worries"; α = .94), Financial (4 items; e.g., "To win money"; α = .85), Fun/Thrill (4 items; e.g., "Because it's fun"; α = .83), and Social motives (3 items; e.g., "Because it makes a social gathering more enjoyable"; α = .72).

Video-gaming Motives Questionnaire (VMQ)

The VMQ (López-Fernández et al., 2020) assesses eight video gaming motives with 24 items (three for each dimension) with response options ranging from 1 = *strongly disagree* to 5 = *strongly agree*. The eight dimensions are Cognitive Development (e.g., "Games make me think"; α = .68), Competition (e.g., "I like to win"; α = .76), Coping (e.g., "It helps me get rid of stress"; α = .82), Customization (e.g., "I enjoy customizing things in games"; α = .81), Fantasy (e.g., "I enjoy putting myself into a new character's shoes in each game"; α = .87), Recreation (e.g., "I enjoy gaming"; α = .83), Social Interaction (e.g., "I make new friends"; α = .88), and Violent Reward (e.g., "I like violence in video games, the more violent the better"; α = .89).

Final ad-hoc survey

A final survey was used to evaluate the self-assessed degree of involvement in gaming or gambling activities, classifying them into the same modalities referred to in the initial ad-hoc survey. For each gaming/gambling modality, participants were asked first to report whether they had played a specific modality in the past 12 months. If the answer was affirmative, they were asked to answer two additional questions on frequency and money spent in a typical day, in the case of gambling, and time (instead of money), in the case of gaming. The survey finished with two general questions on weekly time spent and monthly monetary expenditure for the totality of gaming/gambling activities. Only these two final questions were used for analysis in the present study. For video games, participants were told that monetary expenditure referred to any kind of game-related transaction or purchase, including the game itself, supplementary software, upgrades, in-game microtransactions, and gaming gear. For gambling, monetary expenditure referred to net loss.

Statistical analyses

We analyzed the internal structure of GRACC90 scores with an exploratory structural equation model (ESEM; Asparouhov & Muthén, 2009). Although item generation was completed according to a multicomponential theoretical model, the number of factors to be retained could not be anticipated before data analysis. Thus, the number of factors was determined by parallel analysis (Garrido et al., 2013), visual inspection of the scree-plot, theoretical interpretability of the solutions, factor simplicity, and loading sizes. This analysis was done first for the full (combined) sample and, after deciding the number of factors, we tested the resulting model with the gambling and video gaming samples separately.

Subsequently, a factor invariance analysis according to type of activity (gambling or video gaming) was also carried out. In order to test invariance, the equality (or minimal difference) of the fit between consecutive models was evaluated. First, we tested the equality of form. In ESEM, this involves fixing the number of factors and pairs of correlated uniqueness (if any). Subsequently, we tested the equality of thresholds and factor loadings across groups. We considered these restrictions to be satisfactorily met if the decrease in CFI was lower than .01 and RMSEA increased by less than .015 (Chen, 2007; Cheung & Rensvold, 2002). Models were analyzed using robust weighted least squares (WLSMV estimator in MPlus). According to conventional cut-offs (Hu & Bentler, 1999), values greater than .95 for the comparative fit index (CFI) and Tucker-Lewis index (TLI) are considered to be indicative of an adequate and excellent fit to the data, respectively, whereas values smaller than .06 for the root mean square error of approximation (RMSEA) and smaller than .08 for standardized root mean square residual (SMSR) are indicative of acceptable model fit. It should be noted that these cut-offs were developed for confirmatory factor analysis with continuous responses, so these values should be interpreted with caution (Xia & Yang, 2019). Additionally, these cut-off values should be considered as rough guidelines and not interpreted as “golden rules” (Marsh et al., 2004).

We developed a short version of the instrument by selecting the items with highest loadings and inspection of their content. With this brief version (GRACC18), we repeated the same analysis to test its internal structure.

Internal consistencies of the different scales scores were then computed with Cronbach's alpha. We computed Pearson correlations between the different dimensions of the GRACC90 scores and the other measures splitting by type of activity.

The analyses were performed with Mplus 8.4 (Muthén & Muthén, 2019) and R 4.2.2 (R Core Team, 2022). The open database and code files for these analyses are available at the analysis folder of the OSF site for supplementary materials (see Availability of data and materials section).

Results

Descriptive analyses

Sociodemographic data for the two samples, as well as measure of involvement in the main activity of interest are shown in **Table 2**.

The two samples were well matched on all demographic characteristics, but differed – as expected – in expenditure of time and money, with gamers spending longer hours in their main activity of interest, and gamblers larger sums of money.

Table 2. Descriptive statistics for the participants in the two samples.

	Gamblers	Gamers
	n = 312	n = 319
Educational Level	Number (percentage)	
No formal studies/Compulsory education not finished	7 (2.3%)	5 (1.5%)
Compulsory education finished	26 (8.3%)	22 (6.9%)
High school/Professional training not finished	58 (18.6%)	43 (13.5%)
High school/Professional training finished	92 (29.5%)	93 (29.2%)
University studies not finished	35 (11.2%)	27 (8.5%)
University studies finished	94 (30.1%)	129 (40.4%)
Household monthly income		
Less than 1000 euros	31 (10.0%)	29 (9.1%)
Between 1001 and 1500 euros	45 (14.4%)	56 (17.6%)
Between 1501 and 2000 euros	72 (23.1%)	63 (19.7%)
Between 2001 and 2500 euros	74 (23.7%)	88 (27.6%)
More than 2500 euros	90 (28.8%)	83 (26.0%)
Gender	Number (percentage)	
Male	137 (43.9%)	147 (46.1%)
Female	172 (55.1%)	171 (53.6%)
Other	3 (1%)	1 (.3%)
	Mean (Standard deviation)	
Age (years)	37.9 (11.8)	40.4 (10.9)
	Median [25-75th percentile]	
Weekly time spent (hours)	3.0 [1.0-9.25]	9.0 [4.0-17.5]
Monthly expenditure (euros)	31.0 [10.0-135.0]	7.0 [.0- 20.0]

Notes: Gambling severity was assessed with GD9 and gaming severity, with IGD9. For weekly time and monthly money invested, the median and lower and upper bounds of the interquartile range were calculated instead of mean and standard deviation to avoid the influence of extreme scores.

Internal structure and consistency of the GRACC90

The scree-plot and the results of the parallel analysis are displayed in **Figure 1**. In the scree-plot, a single eigenvalue clearly outstood relative to the others. In the parallel analysis, three eigenvalues from the sample (62.85, 2.76, and 2.04) were greater than the eigenvalues from the randomly generated datasets (2.07, 1.98, and 1.92). In view of this, we tested uni-, bi-, and three-dimensional solutions. Fits of the different models are shown in **Table 3**. The unidimensional solution was satisfactory (CFI = .971, TLI = .970, RMSEA = .054, SRMR = .039). Although model fit was slightly improved in a bidimensional model (CFI = .980, TLI = .979, RMSEA = .045, SRMR = .029), that second factor could not be theoretically interpreted. Only three itemspresented higher loadings in that second factor than in the first one (loadings in the range [.50, .59]), but, even in those cases, relevant cross-loadings to the first factor were present (loadings in the range [.26, .47]). Again, fit was improved in the three-factor model (CFI = .987, TLI = .986, RMSEA = .037, SRMR = .023), but no items showed a higher loading in the third dimension than in the first one.

Considering this, we decided to retain a single factor, as the second and third dimensions, if extracted, were residual and not interpretable. Item loadings are shown in Table S2 (see OSF link for supplementary materials in Availability of data and materials section; item order is the same as in Table S1 and the scales as presented to participants). Although the item categories, as identified by Muela et al., were not retained in this analyses, the mean loads for the eight categories differed to some extent. In the same order used for Table 1, mean loads [range] for items in each category were: .89 [.83; .92], .87 [.79; .92], .86 [.76; .93], .83 [.68; .91], .78 [.48; .91]. and .77 [.48; .85].

Table 3. Goodness-of-fit indices for the different models.

	χ^2	*df*	CFI	TLI	RMSEA	SRMR	ΔCFI	ΔRMSEA
Full version (GRACC90)								
Full sample								
M1. 1 factor	11,112.9	3915	.971	.970	.054	.039		
M2. 2 factors	8,752.9	3826	.980	.979	.045	.029		
M3. 3 factors	7,019.7	3738	.987	.986	.037	.023		
Subsamples								
M4. Gambling sample	6,309.6	3915	.984	.984	.044	.033		
M5. video games sample	7,504.3	3915	.968	.967	.054	.052		
Invariance by type of activity								
M6. Equal form	13,904.2	7830	.977	.976	.050	.044		
M7. Equal loadings and thresholds	14,325.2	8188	.977	.977	.049	.044	.000	–.001
Short version (GRACC18)								
Full sample								
M8. 1 factor	501.0	135	.996	.996	.066	.013		
Subsamples								
M9. Gambling sample	298.0	135	.997	.996	.062	.014		
M10. video games sample	407.6	135	.994	.993	.080	.019		
Invariance by type of activity								
M11. Equal form	713.6	270	.995	.995	.072	.017		
M12. Equal loadings and thresholds	723.7	340	.996	.996	.060	.018	.001	–.012

Notes. *df* = degrees of freedom; CFI = comparative fit index; TLI = Tucker-Lewis index; RMSEA = root mean square error of approximation; SRMR = standardized root mean square residual; Δ = increment in fit index with respect to previous model. All *p*-values for the chi-square test were < .001.

Overall, loadings were very high in this factor (M = .83; max = .93 –"I continue to play even though I'm fully aware that I have increased the risks in certain aspects of my life so much that it's not worth it"–; min = .48 –"Often, when I'm playing, I find that my mind has drifted"–). When we tested this model in the gambling and video gaming samples separately, fit was satisfactory for both of them (CFI = .984/.968, TLI = .984/.967, RMSEA = .044/.054, SRMR = .033/.052), although slightly better for the gambling sample. Evidence that the model was invariant with respect to type of activity was obtained by comparing fits of a model with equal form and with equal loading and thresholds. The more restrictive model led to no meaningful change in fit (ΔCFI = .000, ΔRMSEA = –.001).

In order to meet the last aim of the study, i.e. providing a more usable scale in conditions of time constraints, we developed a shortened version of the questionnaire. Given the previously observed unidimensional structure and invariance with respect to activity, we included the 18 items with highest loadings across samples (cross-sample load ≥ .90, rounded to the second decimal; henceforth, GRACC18). **Table 4** shows the English translation of these items, whereas the original items as worded in Spanish are available in Table S1 in the OSF link (see Availability of data and materials section).

The GRACC18 consisted of items 78, 74, 80, 83, 56, 82, 57, 47, 45, 46, 60, 55, 48, 39, 79, 40, 20, and 90 from the GRACC90. For this version, the parallel analysis (**Figure 1**) clearly showed the convenience of retaining a single factor. Model fit indices in the GRACC18 for the full/gambling/video gaming samples were: CFI = .996/.997/.994, TLI = .996/.996/.993, RMSEA =

.066/.062/.080, RMSEA = .013/.014/.019. As expected, item loadings were very high (in the range [.88, .94]).

As with the full version, we found support for invariance with respect to activity, as the model with equality of loadings and thresholds implied no relevant change in fit (*Δ*CFI = .001, *Δ*RMSEA = –.012). As expected, in view of the item loadings and scale lengths, internal consistency indices were very high for both the GRACC90 (α = .99) and the GRACC18 (α = .98).

Associations with other variables

Descriptives and Pearson correlations for all measures are shown in **Table 5** for the gambling sample and **Table 6** for the video gaming sample. The mean scores in the GRACC90 showed no statistically significant difference by type of activity [$M_{gambling}$ = 2.41, SDgambling = 1.10, $M_{video\ gaming}$ = 2.34, $SD_{video\ gaming}$ = .96, t(629) = .860, p = .390, d = .07].

With respect to the constructs that were assessed in both samples, GRACC90 scores presented the highest correlation with severity scores ($r_{gambling}$ = .81, $r_{video\ gaming}$ = .75), followed by Quality-of-Life scores (rgambling = –.60, $r_{video\ gaming}$ = –.57), and, to a smaller degree, with Negative Affect ($r_{gambling}$ = .45, $r_{video\ gaming}$ = .35). All correlations were statistically significant, at p < .001. Of interest, although all the associations were slightly higher for the gambling sample, when comparing these correlations pair-by-pair only the difference of correlation size for severity was statistically significant. For severity, rdifference = .06, z = 2.003, p = .045; for Quality of Life, $r_{difference}$ = .03, z = .556, p = .578; for Negative Affect, $r_{difference}$ = .10, z = 1.419, p = .156.

Table 4. English translation of the items included in GRACC18

I continue to play even though I'm fully aware that I have increased the risks in certain aspects of my life so much that it's not worth it.
I feel I can't get thoughts about playing out of my head.
Anything related to playing immediately catches my attention and interferes with what I'm doing at that moment.
I feel an uncontrollable desire to play even right after I'm done.
The game is on my mind even when I'm not playing, and I should be thinking about something else.
I often find myself thinking when I will play again, instead of focusing on what I should be doing.
I keep playing even though I am aware that the harm it does me is greater than the benefits.
I can't stop playing, even though playing has had a negative impact on my life that clearly outweighs its positive impact.
Every time I play, I feel like I'm on a slippery slope that I can't get back up.
Spending a lot of time playing has become an almost involuntary habit.
Sometimes, the desire to play dominates me.
I keep playing even though I feel guilty for my irrational behavior.
Once I have started, I can't stop playing unless something external forces me to.
I often play because I feel an irrepressible desire to play when a surge of strong emotions take over me.
Often playing is something that I want to do so badly that I feel my heart beating faster.
My thoughts continuously revolve around playing, even when I'm not playing.
I can't stop the desire to play when I'm overpowered by certain bodily or internal sensations.
I haven't stopped playing, even though doing so is causing me more disadvantages than advantages.

Note: The items were originally worded in Spanish. Any use of the scale with an English speaking sample would require an independent validation.

Table 5. Measure descriptives (lower panel) and correlations (upper panel) between measures for the sample of gambling participants.

	GRACC90	***GD9***	***TECVASP***	***PANAS - NA***	***bGMI Affect***	***bGMI Financial***	***bGMI Fun***	***bGMI Social***
GRACC90								
Severity (GD9)	.81							
QoL (TECVASP)	-.60	-.60						
Neg. affect (PANAS)	.45	.50	-.73					
bGMI - Affect	.77	.74	-.56	.40				
bGMI - Financial	.35	.39	-.30	.30	.35			
bGMI - Fun	.55	.51	-.32	.23	.71	.32		
bGMI - Social	.61	.55	-.42	.26	.72	.31	.62	
	GRACC90	***GD9***	***TECVASP***	***PANAS - NA***	***bGMI Affect***	***bGMI Financial***	***bGMI Fun***	***bGMI Social***
Mean	2.41	3.08	81.18	18.62	7.03	6.56	5.74	3.04
Standard deviation	1.10	3.05	13.56	7.29	5.90	3.56	3.14	2.38
Skewness	.34	.59	-.42	.74	.47	-.20	-.04	.44
Kurtosis	-1.17	-1.06	-.59	-.32	-.89	-1.03	-.79	-.63

Note. All the correlations are statistically significant at $p < .05$. GRACC90 scores were computed as means of item scores. For all other measures, scores are computed as sums of item scores. See Measures section for further details of the variables.

Table 6. Measure descriptives (lower panel) and correlations (upper panel) between measures for the sample of video gaming participants.

	GRACC90	***IGD9***	***TECVASP***	***PANAS NA***	***VMQ Dev.***	***VMQ Comp.***	***VMQ Coping***	***VMQ Custom***	***VMQ Fantasy***	***VMQ Recr.***	***VMQ Social***	***VMQ Violence***
GRACC90												
Severity (IGD9)	.75											
QoL (TECVASP)	-.57	-.62										
Neg. affect - PANAS	.35	.49	-.68									
VMQ - Development	.49	.39	-.25	.21								
VMQ - Competition	.54	.48	-.23	.17	.57							
VMQ - Coping	.54	.46	-.42	.38	.65	.48						
VMQ - Customization	.41	.36	-.28	.24	.48	.44	.51					
VMQ - Fantasy	.51	.44	-.31	.22	.59	.52	.63	.70				
VMQ - Recreation	.14	.14	<u>.02</u>	<u>.07</u>	.37	.38	.37	.38	.46			
VMQ - Social Interaction	.63	.52	-.34	.19	.51	.61	.53	.46	.52	.20		
VMQ - Violence	.59	.43	-.30	.16	.35	.43	.41	.26	.36	<u>.05</u>	.54	
	GRACC90	***IGD9***	***TECVASP***	***PANAS NA***	***VMQ Dev.***	***VMQ Comp.***	***VMQ Coping***	***VMQ Custom***	***VMQ Fantasy***	***VMQ Recr.***	***VMQ Social***	***VMQ Violence***
Mean	2.34	2.17	83.57	17.21	8.18	8.27	8.37	8.33	8.36	10.52	6.45	5.37
Standard deviation	.96	2.52	11.64	6.36	2.25	2.45	2.45	2.59	2.72	1.76	2.93	2.77
Skewness	.42	.95	-.69	.80	-.27	-.30	-.40	-.41	-.50	-1.07	.29	.84
Kurtosis	-.90	-.21	.17	-.15	-.53	-.80	-.68	-.59	-.70	.64	-1.18	-.58

Note. All the correlations were statistically significant at $p < .05$, except underlined values. GRACC90 scores were computed as means of item scores. For all other measures, scores are computed as sums of item scores. See Measures section for further details of the variables.

For the gambling sample, GRACC90 scores were positively correlated with all gambling motives (M_r = .57), with a maximum association with Affect regulation motives (r = .77) and a minimum association with Financial motives (r = .35). For the video gaming sample, GRACC90 scores were positively correlated with all gaming motives (M_r = .48), with a maximum association with Social Interaction motives (r = .63) and a minimum association with Recreational motives (r = .14). All p-values were < .001, except for the correlation with Recreational motives, p = .01.

GRACC90 scores and severity scores showed similar associations with Quality of Life and Negative Affect for both samples. The only statistically significant difference in correlation size was that, for the videogaming sample, severity scores overlapped to a larger degree with Negative Affect than compulsivity, $r_{\text{difference}} = .14$, $z = 3.969$, $p < .001$.

GRACC90 and GRACC18 scores showed an extremely high overlap (r = .98). Accordingly, correlations between GRACC18 scores and the other assessed constructs mimicked those obtained with GRACC90, although slightly smaller (mean change of unsigned correlations was .03).

Discussion

This study was aimed at developing a scale to measure compulsivity across two domains of potentially addictive behavior. Gambling and video gaming were selected as the best available representatives of a broadly recognized addictive activity (gambling) and a strong candidate to be recognized as such (video gaming). A pool of items comprising six proposed compulsivity operationalizations was developed following the recommendations appraised by a pool of experts, as collected and assembled by Muela et al. (2022). An initial 90-item version of the survey was administered to two samples of frequent gamblers and gamers. Item wordings were identical for both samples, except for the target activity.

Responses to the compulsivity scale were best comprised by a unidimensional model. Although two- and three-factor solutions yielded slightly better model fit indices, substantial cross-loadings and lack of content coherence rendered the one-factor solution clearly superior. In line with previous studies using panel samples for similar purposes, mean severity scores and proportions of individuals above the clinical cut-off in both samples were high, relative to samples obtained with other recruitment methods (Belliveau et al., 2022). In other words, our factor analysis seems to be valid for the whole severity continuum and is not compromised by scores' range restriction. Moreover, invariance analyses showed that this structure held across samples. As shown in **Table S2** (OSF link for supplementary materials) item loadings were similar across domains, with loads for the most discriminative items being almost coincident in the gambling and video gaming scale versions. In other words, results do not support the view that compulsivity (at least when assessed with a self-report measure) is multifactorial, or that different dimensions could be more clearly present in one domain or the other. Regardless of its specific definition, compulsivity seems to be unidimensional and mostly not differentiable –at least when assessed with self-reports– between both domains.

We also observed that compulsivity scores were slightly more strongly correlated with severity scores in the gambling sample (r = .81) than in the video gaming sample (r = .75). Although the difference between these correlations was significant, it must be interpreted with caution. First, in both severity scales, the contents of some items strongly overlap with the ones of compulsivity items (actually, many of the scales included in Muela's review were behavioral addiction severity scales), so the correlations could be inflated. And second, in spite of their strong similarities, gambling and gaming disorder severity scales are different instruments, and their distributions are not parallel (e.g., the diagnostic threshold for gambling disorder is four symptoms, whereas the proposed DSM-5 Section III cut-off for gaming disorder is five). That was the main reason to include negative affect and quality-of-life measures for the two samples in convergent validity analyses.

As expected, compulsivity was strongly and negatively correlated with quality-of-life scores (-.60 and -.57 for the gambling and gaming samples, respectively), and moderately and positively correlated with negative affect (.45 and .35 for the gambling and gaming samples, respectively). Correlations of compulsivity with negative affect and quality of life scores did not significantly differ across samples. Importantly, in the gambling sample, compulsivity by itself was as good as severity at predicting quality of life and negative affect. This pattern of correlations converges with recent studies that critically appraise gambling severity indices for failing to discriminate between core features of addictive behavior (e.g., lack of control or craving) and harms derived from those behaviors (e.g., missing work opportunities or jeopardizing social relationships) (Tseng et al., 2023). The unifactorial structure of behavioral addiction severity scales is likely to be attributable to the strong correlation between causes and consequences (Boldero & Bell, 2012), but a core of psychological features seems to play a larger role in the etiology of the myriad of manifestations or ‘components’ measured by customary addiction scales.

In the video gaming sample, on the contrary, severity was a slightly but significantly better predictor of negative affect (r = .49) than compulsivity (r = .35). This could mean that the IGD severity score captures elements that contribute to reduced wellbeing in problematic video gaming that are not accounted for by compulsivity. In other words, the contribution of factors other than compulsivity to functional deterioration is probably larger in video gaming-related problems than in gambling problems. Again, however, the difference in correlations is small, and the GD9 and IGD9 measures are not exactly equivalent, so this potential difference must be interpreted with caution.

Although all items included in the GRACC90 substantially loaded to the common factor, we selected the items with highest loadings across samples in order to provide a shortened version of the questionnaire. Among the 18 best items (load ≥ .90, rounded to the second decimal, in both samples), five of them referred to persevering despite knowledge of the imbalance between harm and reward (items 47, 55, 57, 78, and 90), 5 to cognitive hijacking (40, 56, 74, 80, and 82), 5 to irresistible urge jeopardizing control attempts (20, 39, 60, 79, 83), and only 2 to automaticity (45, 46), and 1 to sessions lasting longer than planned/binging (48, although this item also explicitly mentions lack of control), and none to rituals/inflexible rules. At the other end, items referring to rituals/inflexible rules, sessions lasting longer than planned (binging), and automaticity are systematically among the least discriminative ones. This selection procedure obviously made the GRACC18 more neatly unidimensional than the GRACC90 (with only one eigenvalue above the eigenvalues of randomly generated samples; see **Figure 1**, right panel), but did not alter at all the capacity of the scale to predict quality of life and negative affect.

Importantly, these results converge with (a) a recent machine learning analysis showing that a subset of diagnostic criteria (withdrawal, relapse, and conflict) strongly and specifically predict dysfunctional and harmful video gaming (Shi et al., 2019); and (b) seminal works on core components of behavioral addiction, i.e. salience, withdrawal, relapse, and conflict (Griffiths, 2005). The effect of craving/urge on diminished control is not included as a diagnostic criterion for IGD, but the withdrawal and relapse criteria largely capture it (Kaptsis et al., 2016; King et al., 2018), whereas conflict and salience capture harm-reward imbalance and interference attributable to cognitive hijacking (see also Billieux et al., 2019). In other words, compulsivity seems to be at the very core of behavioral addiction.

In summary, although compulsivity seems to be a slightly better predictor of severity of gambling problems than of video gaming-related problems, and factors other than compulsivity might play a stronger role in video gaming-related than in gambling harms, compulsive behavior presents strikingly similar features in the two domains. Still, this similarity does not necessarily imply the existence of a common etiological pathway to gambling and gaming-related problems. Specifically, Heather (2017) distinguishes between strong and weak conceptualizations of compulsivity. In the first sense, “compulsion is seen as an example of automatic, involuntary behaviour following repeated learning experiences” (p. 32). In the second sense, compulsion is seen as “resulting from a failure to resist abnormally strong desires to engage in addictive behaviour” (p. 32). These two versions mostly parallel the two general mechanisms of habit formation and reward overvaluation mentioned earlier, but these mechanisms are not mutually exclusive and their relative effects on behavior can be indistinguishable when assessing using the customary psychometric tools. Indeed, both are present in the GRACC scale and, according to our analyses, they are psychometrically inseparable.

So far, and applying a basic principle of parsimony, if compulsivity in gambling and video gaming domains is almost indistinguishable, the simplest answer to the etiology question is assuming the commonality of mechanisms. Any proposal of differentiable mechanisms across behavioral domains must be accompanied by testable predictions. Our tentative hypothesis for future investigation is that compulsive video gaming results from excessive valuation of gaming activities, and this, in turn, from lack of competition from alternative activities with sufficient potential to satisfy personal needs and goals, whereas compulsive gambling is more directly motivated by conditioned, cue-driven states (e.g., craving). If this hypothesis is correct, compulsive video gaming could be attributed to basic principles of operant learning and behavioral economics (see, for example, Field et al., 2020), whereas compulsive gambling would require specific conditioning mechanisms to account for progressive acquisition of urges and disproportionate short-term expectancies (Ross, 2020). To date, both the role of need frustration and activity overvaluation in video gaming disorder (Allen & Anderson, 2018; King & Delfabbro, 2014; Mills et al., 2018), and the centrality of acute, cue-triggered states in gambling (Limbrick-Oldfield et al., 2017; Ciccarelli et al., 2022; Brevers et al., 2019) have been extensively reported, but a direct comparison of trait and state predictors of compulsivity in both samples is pending. Unfortunately, in the present study, the only predictors collected were declarative motives, with largely different scales for each activity. Still, the ordering of correlations between motives and compulsivity seem to diverge to some degree, with coping/affect regulation motives playing a stronger role in compulsive gambling than in compulsive gaming (see Marino et al., 2020; Haagsma et al., 2013; for converging evidence).

Our main proposals for future research are, first, to explore the mechanisms of compulsivity –once it has been precisely operationalized– by directly searching, not only the similarities, but also the potential differences, using comparable instruments; and, second, to incorporate qualitative analysis to the exploration of subjective and phenomenological experiences of compulsivity that also likely to differ across domains (Shi et al., 2019; Albertella et al., 2020).

Limitations, strengths, and conclusions

This study has succeeded in delineating an operationalization of compulsivity, and developing a scale consisting only of highly discriminative items. However, this self-reported measure probably lacks the potential to provide evidence –by itself– on the etiology of compulsivity. Further translational, experimental, and process-based research is necessary to disentangle explanatory mechanisms.

Although some differential correlations open paths for future research (e.g., compulsivity seemingly playing a more central role in functional deterioration and harm in the gambling domain than in the video gaming domain), significant differences in correlation sizes between the two samples are small, and may result from the use of slightly different instruments across domains. Further research pursuing these differences should extend the use of the same instruments for the same constructs in different samples. Actually, the GRACC scale developed here could be an important step ahead in overcoming the fragmentation problem in behavioral addiction measurement. If there are common mechanisms for different putative behavioral addictions, research will certainly benefit from the existence of measures of those mechanisms that are applicable to different activities (instead of slightly different, non-comparable measures for each of them).

Actually, our scale is not the only available measure of compulsivity that can be applied across behavioral domains. On the one hand, the BATCAP (Hook et al., 2021) questions individuals about the following domains: alcohol use, gambling, compulsive eating, contamination compulsions, checking compulsions, just right and ordering compulsions, and compulsive Internet use. If the individual reports any of these behaviors in the last 30 days, they are asked to answer six further questions about time lost, distress, loss of control, functional impact, anxiety if prevented from doing the behavior, and strongest urge. This scale was developed following a theory-driven method, and was intended to detect transdiagnostic commonalities between addictive disorders and obsessive-compulsive disorder. There is some evidence, however, that compulsivity in the obsessive-compulsive spectrum and addictive disorders present important differential features, and does not necessarily constitute a single construct (Albertella et al., 2020). This evidence is consistent with our finding that items about inflexible rules and rituals –normally considered highly representative of obsessive-compulsive behavior– are the ones with lowest correlations with the common compulsivity factor in our analyses.

The GRACC has been, however, developed in a mostly data-driven manner, and is applicable to any putatively addictive activity (minimally rewording it to refer to the activity of interest). This data-driven method allowed us to start with a very large pool of items and then select the ones that best reflect the underlying construct. It is indeed reassuring that BATCAP items and Muela et al.'s operationalization largely overlap, but the GRACC goes a step further in showing that not all of those operationalizations are equally central for the conceptualization of compulsivity. Other compulsivity scales available in the literature, as the Cambridge-Chicago Compulsivity Trait Scale (Chamberlain & Grant, 2018) (for a review see Hook et al., 2021), are not directly comparable to ours, as they measure compulsivity as a trait, that is, as a general proneness or vulnerability to develop compulsive behaviors. So, they cannot be used to determine whether or not specific activities have become compulsive. Our aim here is not to assess individuals' traits, but a feature of a specific activity as currently presented by an individual.

Our data-driven approach was intentional. Indeed, this approach has shown that, although the six operationalizations identified by Muela et al. (**Table 1**) were conceptually different, in the end, all of them are too tightly correlated to be considered psychometrically separable dimensions. Although this is still highly speculative, urges and salience are probably two sides of the same coin, one reflecting motivational and affective aspects of craving (either appetitive or aversive), and the other reflecting the cognitive elaboration of desire. When these are strong enough, they end up causing the subjective feeling that the problematic behavior has escaped voluntary control, despite its harms having overridden its benefits. In other words, urgency and over-salience are possibly the core of compulsivity, and disutility is a sign that they are strong enough to override one's goals. These behaviors are also likely to be perceived as habitual, stereotyped, or excessive, but these features are probably close correlates rather than key ingredients of compulsivity.

The multistep procedure followed in the development of the GRACC is probably the most detailed and systematic one in the fields of compulsivity and behavioral addictions to date. The result is a measure with outstanding psychometric properties, in terms of both reliability and convergent validity. Importantly, and despite its high correlations with severity measures, it goes beyond them in terms of intensionality (it does not depend on an extensional set of features). Specificity, however, does not come at the cost of predictive power, as compulsivity by itself accounts for as much variability in quality of life and negative affect measures as severity. This counts as strong evidence, by itself, that some symptoms are accessory to define a behavior as compulsive and eventually problematic.

Availability of data and materials

Supplementary materials and datasets generated and/or analysed during the current study are available in the Open Science Framework (OSF) repository as: https://osf.io/xdfmw/?view_only=9831ce7702c34347ac67b45719ddf643.

CHAPTER V:

Study IV

The associative learning roots of affect driven impulsivity and its role in problem gambling: A replication attempt and extension of Quintero et al. (2020)

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Abtract

Background and aims: Negative/positive urgency (NU/PU) refers to the proneness to act rashly under negative/positive emotions. These traits are proxies to generalized emotion dysregulation, and are well-established predictors of gambling-related problems. We aimed to replicate a previous work (Quintero et al., 2020) showing NU to be related to faulty extinction of conditioned stimuli in an emotional conditioning task, to extend these findings to PU, and to clarify the role of urgency in the development of gambling-related craving and problems. *Methods*: 81 gamblers performed an acquisition-extinction task in which neutral, disgusting, erotic and gambling-related images were used as unconditioned stimuli (US), and color patches as conditioned stimuli (CS). Trial-by-trial predictive responses were analyzed using generalized linear mixed-effects models (GLME). *Results*: PU was more strongly related than NU to craving and severity of gambling problems. PU did not influence acquisition in the associative task, whereas NU slightly slowed it. Extinction was hampered in individuals with high PU and a follow-up analysis showed this effect to depend on relative preference for skill-based and casino games. *Discussion and conclusions*: Results suggest that resistance to extinction of emotionally conditioned cues is a sign of malfunctioning emotion regulation in problematic gambling. In our work, the key effect was driven by PU (instead of NU), and gambling craving and symptoms were also more closely predicted by it. Future research should compare the involvement of PU and NU in emotion regulation and gambling problems, for gamblers with preference for different gambling modalities (e.g. pure chance vs skill games).

Introduction

Urgency Facets and Gambling

Impulsivity is defined as the tendency to act rashly or with lack of forethought, and comprises both cognitive, conscientiousness-related facets, and incentive or emotion-related facets (Verdejo-García et al., 2010). According to the UPPS-P model of impulsive behavior, the affect-driven facet of impulsivity is neuropsychologically separable from cognitive impulsivity (lack or perseverance and lack of premeditation) and from sensation seeking, and can be further factorized into positive and negative urgency, namely, the tendency to lose control over behavior when experiencing strong positive and negative affect, respectively (Cyders et al., 2007; Smith et al., 2007).

Nevertheless, the necessity of dissociating positive from negative urgency remains a topic of discussion. On the one hand, a recent large network analysis suggests that urgency could be better conceptualized as a single construct (Billieux et al., 2021). On the other, a number of studies have shown differential correlations of positive and negative urgency with other constructs or aspects behavior (e.g. Grimaldi et al., 2014; Zapolski et al., 2009). Still, and beyond its composition, there is some agreement that (1) urgency reflects the synergistic effects of heightened emotional reactivity and compromised emotion regulation (Billieux et al., 2021), and (2) it accounts for a large part of the shared variability between several psychological disorders, especially (although not exclusively) those characterized by externalizing behavior (Settles et al., 2012). According to a recent and well-supported theoretical proposal (Carver & Johnson, 2018), altered regulation of emotion-driven behaviors and thoughts (i.e., urgency) is a common transdiagnostic psychopathology risk factor, whereas reward sensitivity would determine whether that vulnerability is expressed in the form of internalizing or externalizing behavior.

In consonance with this proposal, urgency has been identified as a key factor in the etiology of addictive processes, including gambling disorder (Cyders et al., 2016; MacLaren et al., 2011). It has been suggested that positive urgency may lead to increases in gambling involvement in early stages of the disordered gambling cycle, when the addictive activity is still predominantly driven by appetitive motives (Cyders & Smith, 2008). Negative urgency, in turn, would be more prominent in clinical samples (e.g., Torres et al., 2013), and would be associated with a larger risk of comorbidity (e.g., Grall-Bronnec et al., 2012).

Unfortunately, this depiction is not congruent with the totality of available evidence. On the one hand, some studies have indeed found negative urgency to be a stronger predictor of gambling severity than positive urgency in the high end of the gambling severity continuum (e.g. Torrado et al., 2020; Jara-Rizzo et al., 2019; Savvidou et al., 2017). On the other hand, some studies have reported the opposite pattern –positive urgency showing a greater capacity to account for gambling-related problems, relative to negative urgency–, even in clinical samples. For example, in a study by Velotti and Rogier (2021) positive urgency (but not negative urgency) was a significant predictor of severity in individuals with gambling disorder. Similar results have been reported by Willie and colleagues (2022), who found positive urgency, but not negative urgency, to predict problem gambling and online gambling disorder, using hierarchical regression. Canale et al. (2016) found that only positive urgency was associated with higher scores of problem gambling and gambling frequency in an adolescent sample. And in a study by Mestre-Bach et al. (2020) positive urgency predicted gambling severity in a sample of male patients with gambling disorder. Although this study suggested that negative urgency could be more strongly related to gambling symptom severity in women, a study by Farstad and Von Ranson (2019), with a sample of women showing at-risk gambling, at-risk binge eating, or both, reported positive urgency (but not negative urgency) to be linked with problem gambling severity. Rogier, Colombi and Velotti (2020) also found that positive urgency was the only significant predictor of severity scores, and attributed the seemingly inconsistent results to the different sample compositions across studies, in terms of gambling preferences and motivations. In accordance with this argument, Howe et al. (2019) found that positive urgency was more strongly associated with certain game types, such as Internet gambling, games of skill, cards, and board games.

Finally, some studies report both positive and negative urgency to be significant and independent predictors of problem or disordered gambling. For instance, Brunault and colleagues (2020) explored the link between impulsivity facets and gambling severity in male gamblers with and without self-reported ADHD. In both groups, positive and negative urgency were associated with problem gambling. Mestre-Bach et al. (2019) also showed both positive and negative urgency to vary across groups with increasing gambling severity. Steward et al. (2017) conducted a path analysis to explore the associations between impulsivity measures and gambling severity. Their results revealed significant and independent relations of positive and negative urgency with severity in younger patients, but only the one of negative urgency remained significant in older patients. Using mediation analysis, Kim et al. (2019) reported both negative and positive urgency to be associated with problem gambling severity, with coping motives mediating these associations (although see Canale et al., 2015). In Haw's (2017) study both positive and negative urgency were predictors of gambling severity in a sample composed by regular electronic gaming machines (EGM) players, with negative urgency being a much stronger predictor than positive urgency. Similar results are reported by Blain et al. (2015), although, interestingly, negative urgency highly correlated with the preference for EGMs gambling modality, whereas positive urgency correlated with EGMs, card/dice games and off-line games. Other studies reporting similar associations between the two impulsivity facets and gambling problems are Marmurek et al. (2015), Albein-Urios et al., (2012), Clark et al. (2012), and Michalzuk et al. (2011).

In summary, evidence supports the role of urgency as a vulnerability and chronification factor for gambling-related problems, yet the potentially distinct roles of positive and negative urgency in different stages, problem severity levels or subpopulations remain unclear. The present study aims to contribute to better define the neurocognitive mechanisms of positive and negative urgency, and their roles in clinically relevant aspects of gambling, such as gambling problems severity and gambling craving.

The role of emotion regulation in the association between urgency and disordered gambling

As noted above, urgency is tightly linked to emotion regulation. In their dual model, Etkin et al. (2015; see also King, Feil, & Halvorson, 2018) proposed a distinction between intentional (or strategic) and incidental modes of emotion regulation. The former is hypothesized to be goal-driven and to require engagement and model-based control, that is, to involve the conscious identification of the emotion to be regulated, followed by the identification and implementation of the best available strategy to modulate it (e.g. reappraisal). The latter would be model-free, and would depend on relatively simple associative processes, with extinction of conditioned emotional responses as the paradigmatic example. In line with associative learning research (Dunsmoor et al., 2015), extinction is driven by error-prediction signals, and involves a change of the affective meaning of a stimulus that has lost its predictive value. As a result, the conditioned response this stimulus previously triggered is progressively attenuated. Importantly, extinction is not simply unlearning, as it requires the formation of a context-dependent inhibitory association that competes for expression with the original excitatory one when the conditioned stimulus is presented again (Bouton et al., 2006). According to Etkin et al.'s model, this arbitration process, although relatively simple and incidental, is in essence regulatory.

Based on this model, Navas et al. (2019) proposed negative urgency as a psychometric proxy to the malfunctioning of incidental mechanisms of emotion regulation. This idea was directly tested and mostly confirmed by Quintero et al. (2020), who found an association between negative urgency and slowed extinction of emotion-laden conditioned associations in a simple acquisition-extinction associative learning task. This study thus supported incidental emotion regulation processes as a plausible explanatory mechanism for negative urgency. Complementarily, it also explored the relationship between negative urgency and two clinically relevant aspects of disordered gambling: craving and severity of problem gambling symptoms.

As noted earlier, negative urgency is defined as the proneness to rash action under the effect of negative affect, and it seems to underlie a range of related disorders and to partially account for their comorbidity. So, negative urgency could impact on gambling severity via this overarching, domain-general mechanism. Or, alternatively, it could hamper craving control, and dysregulated craving could, in turn, prompt compulsive gambling (craving is probably the single best momentary predictor of addictive behavior and relapse; Tiffany & Wray, 2012). Quintero et al.'s results supported only the second possibility: negative urgency predicted gambling severity, but only via heightened craving (negative urgency was strongly associated with craving, and this with severity, but the link between negative urgency and severity remained non-significant when craving was controlled for).

The present study

Quintero et al.'s study, however, presents two major limitations. First, the study focused exclusively on negative urgency, under the initial assumption that positive urgency plays a secondary role in disordered gambling symptomatology. However, that assumption seems now unwarranted, in view of the evidence briefly reviewed above that positive urgency could play a substantial and independent role in the risk of disordered gambling.

And second, a substantial part of the sample in Quintero et al.'s study were lottery players, and their average severity of problem gambling symptoms was low. This composition is potentially problematic in inferential and representativity terms. Lottery is a very widespread, pure chance, relatively nonhazardous gambling modality. Hence, the association of negative urgency with gambling craving and severity was probably driven by only a small fraction of participants who presented higher severity scores.

Here, we intend to replicate and extend these findings. In addition to severity of disordered gambling symptoms (SOGS), craving, and negative urgency (brief UPPS-P), positive urgency was measured and included in the analyses. The decision to keep the two urgency dimensions separated is based on the previously mentioned evidence showing differential correlation patterns for positive and negative urgency, but also on methodologically practical reasons. Even if a common emotion dysregulation factor underlies the two urgency dimensions, urgency also comprises an emotion reactivity component (Billieux et al., 2021). People differ in their reactivity to appetitive and aversive states, and these states can be differentially involved in motivating gambling (and especially in gambling craving) for different individuals (e.g. van Holst et al., 2010), so urgency could manifest itself differently depending on which emotions are more relevant in motivating gambling. In other words, differential correlations patterns of positive and negative urgency can provide indirect evidence on the role of appetitive and aversive states on craving and gambling behavior.

Importantly, recruiting explicitly excluded non-gamblers and lottery-only gamblers. This recruiting procedure was aimed at obtaining a sample much more representative of the population of gamblers incurring some risk of gambling-related problems, while still allowing a large severity range.

Extinction was assessed with the same task described in Quintero et al. (2020). In brief, different color patches were used as conditioned stimuli (CS), and erotic, disgust, gambling-related, and neutral pictures were used as unconditioned stimuli (US). During acquisition, each CS was probabilistically paired to one US type. During extinction, the CS-US contingency was degraded to zero (with no explicit warning or separation), except for the neutral picture, for which the association with its corresponding CS remained the same as during acquisition. In each trial, right after the onset of the CS, the participant was asked to predict which type of picture would follow. This predictive response was dichotomized (correct/incorrect prediction) and used as the dependent variable in analyses of task performance. The main aspect of this response to be analyzed and interpreted was the rate with which CS-related predictions progressively reflected the degradation of CS-US contingencies during extinction.

Regarding negative urgency, we expect to replicate the two previously described findings. Negative urgency is hypothesized to be specifically associated with slowed extinction of predictive responses for CSs associated with emotion-laden pictures. And the relationship between negative urgency and severity is hypothesized to be mediated by craving.

Regarding positive urgency, our hypotheses remain open. If negative urgency is, as initially assumed, a stronger index of emotion dysregulation than positive urgency, its relationship with slowed extinction, craving and severity should be weaker or non-existent. On the contrary, if positive and negative urgency are manifestations of the same construct, their pattern of association should be similar to the ones of positive urgency. In case mixed patterns are found, these will be subject to supplementary analyses using gambling participation measures as covariates.

Methods

Openness and transparency

All data and analysis code are available at the following Open Science Framework link: https://osf.io/tyjmq/?view_only=1062e72b26814d1f90a5994a899c02c7

Following the 21-word solution proposed by Simmons et al. (2012), we report here how sample size was determined, all data exclusions, all manipulations, and all study measures.

The present study attempts to closely replicate and to extend Quintero et al.'s (2020). In their data analysis plan and preregistration, Quintero et al. estimated in n = 70 their minimum sample size. This sample size was sufficient to yield differential sensitivity in their study, so the same criterion was taken as reference here, and no specific power analyses were carried out. In view of the potential loss of participants not reaching the learning criterion in the acquisition-extinction task, data collection continued until n = 81. The learning criterion and the final sample for analyses including the acquisition-extinction task (n = 65) are detailed in the Statistical Analysis section. For the reasons mentioned the previous section, the two studies also differed in sample composition, with the present study not recruiting any lottery-only gamblers.

Direct manipulations were only those regarding the experimental component of the study, that is, the design of the acquisition-extinction learning task, and are reported in the Measures (Acquisition-Extinction Predictive Learning Task) and Statistical Analysis sections.

The key input and output measures for analyses were the same in the two studies and were collected using virtually identical methods, although some supplementary measures, not relevant for the present purposes, were different in the two protocols (with the most relevant difference being the collection of psychophysiological measures here, but not in the original study; see Other Variables in the Measures section). Importantly, positive urgency was collected in the two studies but analyzed only in the current one, for the reasons detailed in The Present Study section.

In view of the adherence to Quintero et al.'s methods, we did not consider preregistration for the present study as strictly necessary. Nevertheless, when judging the relative strength and reliability of the evidence provided by the two studies, there are two important considerations for the reader to make. On the one hand, Quintero et al.'s study slightly departed from the preregistration (as explicitly acknowledged in their article). On the other, the present study closely followed the original study's methods and procedure, but a key aspect of the study (namely, the inclusion of positive urgency in the analysis) was not explicitly preregistered.

Participants and Procedure

We initially recruited 81 participants (18 self-identified as female, 63 as male, 0 non-binary), 65 of whom reached the learning criterion in the acquisition-extinction task, so that n = 65 was the final sample for the analyses involving that task (whereas analyses with self-report instruments were carried out in the full sample). **Table 1** displays descriptive statistics of males and females in the full sample, and **Figure 1** depicts the distribution of variables of theoretical interest, also for the whole sample. (Please note that the psychometrics file in the OSF link contains all psychometric input and output variables from the analyses reported here, and can be easily tabulated in any alternative way). Severity of disordered gambling symptoms will be considered as a continuous variable, so no categorical thresholds will be established or discussed. Still, the average SOGS score (M = 3.68), especially for the majority of males in the sample, and its distribution clearly indicate that a nontrivial proportion of participants presented a high-risk of disordered gambling.

A multi-method recruitment procedure was used. Notices were posted or handed in gambling venues, social networks, and University facilities. Researchers also visited University classes during breaks to inform students about the possibility of participating in the study. A snowball method was subsequently used to recruit the rest of participants. After first contact, potential participants were interviewed by phone to ensure inclusion criteria were met, namely, being 18 years old or older, fluent in Spanish, and having engaged in any gambling activity at least with an average frequency of once a month in the last year. Potential participants who reported having ever been diagnosed or treated for any psychopathology, or informed of any history of neurological disease or brain trauma causing unconsciousness for 10 minutes or longer, did not take part in the study.

Once recruited, participants were invited to visit the laboratory where the experiment took place. After providing informed consent, participants were randomly assigned an identifying code, which in no case could be linked to their personal information. The procedure consisted of three blocks of tasks: emotion-related questionnaires (block A), gambling-related questionnaires (block B), and the learning task (block C). These blocks were counterbalanced in order to control for order and carryover effects, and the order in which each participant carried out the protocol was recorded. The experimental session lasted approximately 150 minutes. Participants received €10/hour as compensation.

Data was collected between October 2019 and May 2021. Individuals who participated in the experiment during the covid-19 pandemic signed a Statement of Responsibility developed by the research center, declaring that they had complied with safety and health regulations before attending the experiment. They also were informed that appropriate measures were taken to limit the risk of covid-19 transmission in the laboratory. Unlike the participants who participated in the study before March 2020, during the pandemic participants had to wear a facemask during the whole of their stay in the research center facilities.

Measures

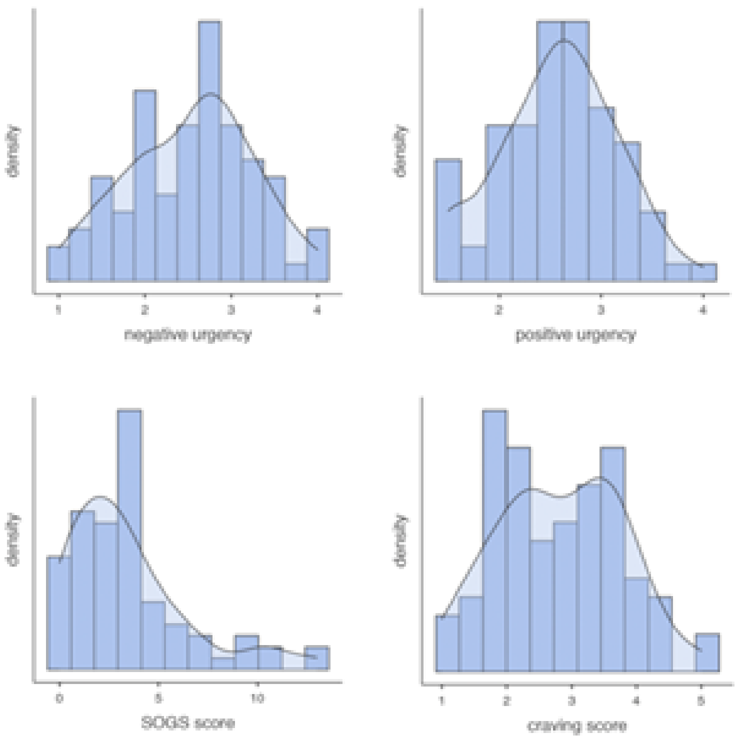
South Oaks Gambling Screen

This instrument is one of the most widely used screening questionnaires to assess disordered gambling symptoms' severity. The Spanish version has shown good psychometric properties (Echeburúa et al., 1994), and a recent meta-analysis has concluded that SOGS is a reliable instrument for evaluating gambling addiction (Esparza-Reig et al., 2021). For the sample in the current study Cronbach's α= 0.826.

Table 1. Descriptive statistics for sociodemographic variables and scores in target measures of the sample.

	gender	age	neg. urg.	pos. urg.	SOGS	craving
Mean	male	22.80	2.53	2.56	3.68	2.76
	female	24.90	2.54	2.64	2.56	3.07
Median	male	20.00	2.75	2.50	3.00	3.00
	female	23.50	2.63	2.63	1.50	3.00
SD	male	6.23	0.74	0.61	3.17	0.91
	female	8.67	0.68	0.45	2.66	1.11
Minimum	male	18.00	1.00	1.50	0.00	1.00
	female	18.00	1.00	1.50	0.00	1.00
Maximum	male	46.00	4.00	4.00	13.00	5.00
	female	55.00	3.50	3.25	11.00	5.00

Figure 1. Distributions of the variables of interest for the whole sample of participants in the study.



Positive and negative urgency

To measure positive and negative urgency, we used the two corresponding subscales from the Spanish version of the 20-item UPPS-P impulsive behavior scale (Cándido et al., 2012). Each subscale includes four items with response options in the 1-4 range. For the present analysis, the score for each subscale was computed by averaging responses to the items in that subscale, coded in such a way that 1 corresponded to the lowest, and 4 to the highest degree of impulsivity. This scale is one of the most commonly used self-report measures of impulsivity, and has shown good psychometric properties (Pilatti, Lozano, & Cyders, 2015). In the present study, Cronbach's α values were 0.782 and 0.637 for negative and positive urgency, respectively.

Craving

We used the same craving scale as in Quintero's et al. (2020) work in order to be consistent across studies. The scale consists of three items which were developed with the intention of assessing three different manifestations of gambling craving: (a) intense urge, "*At times, I cannot help feeling an intense desire to gamble*", (b) stimulus-driven compulsivity, "*Some situations, events or stimuli incite me to gamble, even if I had not planned it*", and (c) attentional bias, "*Gambling-related situations, events or stimuli immediately grab my attention*". Each item is rated on a five-point Likert-type scale, from 1 (totally disagree) to 5 (totally agree), where higher scores indicate a higher craving experience. For this study, the craving scale showed a good level of internal consistency (Cronbach's α = .812).

Gambling habits

Participants were classified in accordance with their gambling preferences. According to Navas et al. (2017), Type I gamblers are those showing a preference for skill-based, high-arousal games, such as cards and sports betting, as well as casino games, while Type II gamblers are those who prefer chance, lower arousal games such as slots, lotteries, and bingo. During the interview with the researcher, participants were asked to identify their favorite gambling activity, and were assigned to one type or the other based on their declared preference.

Gambling habits were also explored using an adapted version of the Canadian Problem Gambling Index (CPGI; Ferrys & Wynne, 2001). This extensive instrument includes (a) an assessment of severity of gambling-related problems (the Problem Gambling Severity Scale, PGSI), and two more sections (b) to assess the presence of common gambling correlates, and (c) to assess gambling involvement. Although three sections were administered, only the involvement section (adapted for gambling games with detectable presence in Spain) was analyzed in the present study. In that part, participants were presented with a list of 18 gambling activities (scratch cards, pools and lotteries, card games in licensed venues, card games in family and social gatherings, card games in other unlicensed venues, online card games, land-based bingo, online bingo, land-based slots, online slots, land-based casino games [excluding cards and slots], online casino games [excluding cards and slots], land-based sport bets [excluding pools], online sport bets [excluding pools], betting on one's skills, stock market or currency trading [excluding funds], land-based other, online other). For each one, participants were asked if they had engaged in that type of game/activity in the last year. If the answer was no, they were asked to skip it and to consider the next activity. In case of a positive answer, they were asked to report how often they had played that type of game in the last 12 months, using an ordinal 7-point scale (1-5 times a year, 6-11 times a year, monthly, 2-3 times a month, weekly, 2-6 times a week, daily), and how much they spent on an average day in which they had participated in that activity.

There was a high degree of correspondence between preference as classified using the declared preferred game, and measures of involvement in different game types. For each participant, frequency of participation scores for Type-I and Type-II games were summed separately, which yielded total Type-I and Type-II games participation scores. For self-identified Type-I gamblers (N = 66), mean (SD) frequency score was 9.70 (4.84) for Type-I games, and 3.65 (3.74) for Type-II games. Accordingly, for self-identified Type-II gamblers (N = 14), mean (SD) frequency score was 3.21 (3.21) for Type-I games, and 10.29 (5.48) for Type-II games. Data on the preferred game was missing for one participant.

Acquisition-extinction predictive task

The experimental task was identical to the one in Quintero, Navas and Perales (2020), programmed and administered using E-prime software (Psychology Software Tools, 2012). In this task, participants were asked to learn to predict, as accurately as they could, the occurrence of each picture type (Unconditioned Stimulus, US: neutral, disgusting, erotic, and gambling related pictures) on the basis of the previously presented color patch (Conditioned Stimulus, CS: red, blue, yellow, green).

Disgusting and neutral pictures were chosen based on their arousal and valence values from the IAPS database (Lang, Bradley, & Cuthbert, 2005). Erotic and gambling-related images were obtained from an Internet search, were matched in size with IAPS pictures (1024 x 768), and were assessed individually by participants in the arousal, dominance, and valence dimensions at the end of the task. Before starting the learning task, participants were asked which set of erotic images (female nudes, male nudes), and which type of gambling-related pictures (sport betting, slot machines, casino bingo, online bingo, casino poker, online poker) they preferred to see throughout the task, based on their sexual orientation and their gambling habits. In each trial, a picture from the relevant category was randomly selected from a predefined set. Disgusting and neutral IAPS pictures in the two corresponding sets are the ones referenced in the supplementary_materials.doc file available at the OSF link (Section 1). Gambling-related and erotic sets consisted of 20 items each. In Section 2 of the same supplementary materials file, we report the results of analyzing participants' SAM assessments of these two picture types. In brief, pictures were effective at generating the expected emotions, and valence and arousal assessments for gambling-related pictures were a function of individual differences in SOGS severity and gambling craving.

The task started with a practice phase (with stimuli different to the ones used for the main task), for participants to familiarize with the response mode (pressing a key for each type of image), and to get accustomed to the task pace. The main task was divided into two parts, an acquisition and an extinction phase, with no warning or perceptual discontinuity between them. Each phase consisted of two blocks of 96 trials each (which yields two acquisition and two extinction blocks, and 384 trials in total). Blocks were considered as such only for pseudorandomization purposes (trial types were randomly distributed within each block, in order to ensure that they were sufficiently dispersed throughout the whole task), again with no warning or perceptual discontinuity between them. The distribution of trials in each acquisition and extinction block was as described in **Table 2**.

Each trial started with a brief presentation (300 ms) of a fixation point in the center of the screen, followed by a patch of one color (out of four possible). This patch (CS) remained on screen for 1500 ms, after which the participant was asked to predict the type of picture they thought it would be presented next (disgusting, gambling-related, erotic, neutral). To collect the predictive response, a response menu with four options ("disgusting", "neutral", "erotic", "gambling"), corresponding to four keys in the computer keyboard, was presented onscreen. After the participant made their prediction, the color patch was replaced with the picture (US) corresponding to the current trial (see **Table 2**).

Other variables

Finally, some questionnaires were administered but not related to the objectives of this study, and brain activity (EEG) was also recorded during the performance of the predictive task using BrainVision Recorder (Brain Products GmbH, version 1.20.0801). In other to avoid analytical flexibility and potential HARKing, none of these variables was analyzed before completing and interpreting the analyses carried out for the present purposes. To the date of the present submission, they remain unanalyzed.

The questionnaires included in the protocol but not directly relevant for the aims of the present study were the following: the *Emotional Regulation Questionnaire* (ERQ; Spanish version, Cabello et al., 2013), the *Beck's Depression Inventory* (BDI-II; Spanish version, Sanz, Perdigón, & Vázquez, 2003), the *Symptom Checklist-90 Revised* (SCL-90-R; Derogatis & Unger, 2010), the *Internet Gaming Disorder Severity Scale* (IGD9; Spanish version, Beranuy et al., 2020), the *Gambling Related Cognitions Scale* (GRCS; Spanish version, Del Prete et al., 2017), the *brief Gambling Motives Inventory* (bGMI; Barrada et al., 2019), the *MultiCAGE CAD-4* (Pedrero-Pérez et al., 2007), the *Positive Affect and Negative Affect Scale* (PANAS; Spanish version, Sandin et al., 1999), a screening consisting of nine items for DSM criteria for Gambling Disorder, and an adaptation of Quintero's craving scale for gaming behavior. As noted earlier, the *Canadian Problem Gambling Index* was also part of the protocol. The PGSI and correlates parts were however not considered for analysis.

Statistical analyses

The relationships between positive and negative urgency, SOGS, and craving scores are initially assessed using partial correlations, with gender and age as control variables. Subsequently, a mediation model, with positive and negative urgency as input variables, craving as mediator, SOGS score as output variable, and gender and age as background confounders, is tested using the mediation analysis function from the SEM module in JASP 0.16.2 (JASP Team, 2022).

The relationship between (1) negative urgency and acquisition, (2) positive urgency and acquisition, (3) negative urgency and extinction, and (4) positive urgency and extinction, are analyzed using generalized linear mixed-effects (GLME) models with a logit link. The response in each trial of the corresponding phase (acquisition or extinction) is coded as 1 (CS-congruent) if the participant predicted the US that was paired with the CS presented in that trial, and 0 (CS-incongruent) if they predicted any other US or did not make any prediction in the designated time. These analyses were performed including only the participants who performed the task well enough to consider they had understood the instructions. The criterion to select those participants (n = 65) was to make at least a 50% of CS-congruent responses (96 out of 192) during the acquisition phase.

Table 2. Frequency of conditioned-unconditioned stimuli (US-CS) combinations (trial type) in each acquisition and extinction block of the task.

Acquisition					
		US			
		Erotic	Gambling	Disgust	Neutral
CS	A	18	0	0	6
	B	0	18	0	6
	C	0	0	18	6
	D	2	2	2	18
Extinction					
		US			
		Erotic	Gambling	Disgust	Neutral
CS	A	2	2	2	18
	B	2	2	2	18
	C	2	2	2	18
	D	2	2	2	18

Note: A, B, C and D stand the four different types of colors that could be used as CS during the task.

Fixed-effects predictors in the model are CS type (corresponding to the four colors of the patches used as CSs), trial number (ranging from 1 to 48 for each CS type), and urgency, along with first and second-order interactions between them. The participant identity code is the only random-effects factor in the model. The predictor of theoretical interest (positive or negative urgency, depending on the specific analysis) is zero-centered and scaled to facilitate model convergence. Importantly, trial number is log-transformed before entering the model. This is done to reflect the characteristic negative acceleration of learning curves. For a detailed justification of this transformation see Quintero et al. (2020), and Robinson et al. (2021).

The effect of CS type is decomposed into three contrasts: C1 [-3, 1, 1, 1], corresponding to the comparison between the CS paired with the neutral US and the rest; C2 [0, -2, 1, 1], comparing the CS paired with disgust and the two CS paired with erotic and gambling related pictures; and C3 [0, 0, -1, 1], comparing the two CS paired with erotic and gambling-related pictures against each other. *P*-values are computed using z-approximation significance tests. P-values are considered significant at $p = 0.05$, except for contrasts involving C1, C2 and C3 (corrected threshold $p = 0.05/3 = 0.017$).

Additionally, all significant effects in the four models are double-checked using hierarchical tests. Each hierarchical test involves pitching the model containing the effect of interest (and all the effects at the same or a lower complexity level, e.g., for a second-order interaction, all the other possible second-order interactions along with first-order interactions and non-interactive effects), against the same model without the effect of interest. The Akaike Information Criterion (AIC) and a χ^2 test are used to select the best-fitting model in each comparison. The result of this comparison is interpreted as an assessment of whether or not the effect of interest substantially contributes to accounting for observed variance in the response.

The significance of effects identified as substantial using this triple criterion (z-approximation tests in the global model, plus hierarchical comparisons using AIC and χ^2 tests) are corroborated in a further model including age, gender, and their first and second-order interactions with trial number and CS type as fixed-effect control covariates.

Analyses regarding GLME models are run using the lme4 statistical package (Bates et al., 2015) in R programming software (version 4.0.3; The R Core team, 2020).

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 the 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

Positive and negative urgency, craving, and SOGS severity

Table 3 displays partial correlations between positive and negative urgency, craving, and SOGS scores for the 81 participants in the total sample, conditional on age and gender. As expected, positive and negative urgency were strongly correlated. Both positive and negative urgency also correlated with disordered gambling symptoms' severity (SOGS) and with gambling craving. Importantly, positive urgency correlated with craving more strongly than negative urgency. This is indicative that, in this sample, cravings were more strongly driven by appetitive cues than by aversive ones.

The details and results of the mediation analysis are fully disclosed (and graphed) at the OSF link (mediation_analysis.jasp file). Negative urgency had a significant direct effect on SOGS scores ($\beta = 0.252$, $z = 2.470$, $p = 0.014$). The direct effect of positive urgency was non-significant ($\beta = 0.077$, $z = 0.660$, $p = 0.509$), but its indirect effect via craving was significant ($\beta = 0.230$, $z = 3.168$, $p = 0.002$). Contrarily, the indirect effect of negative urgency via craving was non-significant ($\beta = -0.019$, $z = -0.393$, $p = 0.694$). This combination of direct and indirect effects yielded significant total effects for both positive and negative urgency, although the former was stronger ($\beta = 0.307$, $z = 2.709$, $p = 0.007$; and $\beta = 0.233$, $z = 2.069$, $p = 0.039$).

Table 3. Partial correlations between positive and negative urgency, craving, and SOGS

		Neg. urg.	Pos. urg.	SOGS
Positive urgency	*r*	0.490		
	p	<0.001		
SOGS score	*r*	0.383	0.420	
	p	<0.001	<0.001	
Craving score	*r*	0.214	0.504	0.529
	p	0.058	<0.001	<0.001

Note: Partial correlations controlling for 'age' and 'gender'.

This mediation analysis was complemented with a regression analysis of craving over positive and negative urgency (with gender and age as covariates). In accordance with the mediation analysis, positive urgency was positively associated with craving ($\beta = 0.530$, $t = 4.626$, $p < 0.001$), whereas negative urgency was not ($\beta = -0.043$, $t = -0.382$, $p < 0.703$).

Effect of negative urgency and positive urgency on acquisition

The relationship between negative urgency and acquisition in the acquisition-extinction task was analyzed using a generalized linear mixed-effects (GLME) with a logit link, as described above. Fixed-effects predictors in the model were CS type (corresponding to the four colors of the patches used as CSs), trial number (ranging from 1 to 48 for each CS type), and negative urgency, along with first and second-order interactions between them. The participant identity code was the only random-effects factor in the model.

The left panel of **Table 4** displays the odd ratios (OR), confidence intervals (CI), and *p*-values for all effects in the model. The only theoretically relevant significant effect was the interaction between negative urgency and trial number. The OR for that effect indicates that acquisition was slightly slower for participants with high negative urgency scores. A hierarchical test (pitching the model containing all first order interactions against the equivalent without the negative urgency x trial number interaction), confirmed this result [AIC = 10880, and AIC = 10883, respectively, $\chi^2 = 4.758$, $p = 0.029$]. As shown in the right panel of **Table 4**, that effect survived the inclusion of age and gender (and their interactions with the other predictors) in the model.

The same type of analysis was carried out for the relationship between positive urgency and acquisition. The left panel of **Table 5** displays the odd ratios (OR), confidence intervals (CI), and *p*-values for all effects in the model. Positive urgency interacted with the C3 component of CS-type in the no-covariates model. The hierarchical test confirmed the contribution of the positive urgency x CS-type interaction to model fit [AIC = 10873, and AIC = 10884, respectively, $\chi^2 = 17.066$, $p < 0.001$]. As shown in the right panel of **Table 5**, the C3 x positive urgency effect remained significant after including the gender and age covariates in the model.

Figure 2 displays the observed proportion of CS-congruent responses throughout the acquisition phase and across the four CS types, for high and low negative urgency participants (top row), and for high and low positive urgency participants (bottom row). Please note that the median split was performed for visualization purposes only, but positive and negative urgency were treated as continuous variables in all models. Proportions are shown as directly observed and not adjusted for covariates. The effects of positive and negative urgency on acquisition are rather small and mostly restricted to acquisition of the CS-erotic US association. In addition, the effect of positive urgency was preasymptotic.

Effects of Positive and Negative Urgency on Extinction

The same logic was followed for extinction analysis. **Table 6** displays the odd ratios (OR), confidence intervals (CI), and *p*-values for all effects in the model for the relationship between negative urgency and extinction. Negative urgency had no significant direct or interactive effects in any of the two models (with and without the inclusion of age and gender covariates). Extinction proceeded as expected, with the predictive response gradually decreasing for emotion-laden

CSs, and remaining high for the neutral US-paired CS (contingency was not degraded for neutral stimuli during this phase of the task).

The CS x trial type interaction thus obeys to this difference in the contingencies of the emotion-laden CS and the neutral one.

Effects of positive and negative urgency on extinction

The same logic was followed for extinction analysis. **Table 6** displays the odd ratios (OR), confidence intervals (CI), and *p*-values for all effects in the model for the relationship between negative urgency and extinction. Negative urgency had no significant direct or interactive effects in any of the two models (with and without the inclusion of age and gender covariates). Extinction proceeded as expected, with the predictive response gradually decreasing for emotion-laden CSs, and remaining high for the neutral US-paired CS (contingency was not degraded for neutral stimuli during this phase of the task).

The CS x trial type interaction thus obeys to this difference in the contingencies of the emotion-laden CS and the neutral one.

Results were very different for positive urgency. As shown in the left panel of **Table 7**, positive urgency interacted with CS type and trial number. Namely, the rate of extinction of emotion-laden CSs (relative to the constant baseline defined by the neutral CS) was a function of positive urgency (see C1 x positive urgency and C1 x trial number x positive urgency significant effects in both models). The second-order interaction was corroborated by a hierarchical test [AIC = 13139, and AIC = 13147, for the models with and without the effect, respectively, $\chi^2 = 14.001$, $p = 0.003$], and survived after covariate control.

Table 4. Effect estimates in the generalized linear mixed-effects model for CS-congruent responses during acquisition (with negative urgency as impulsivity predictor).

	No covariates model			Gender/age controlled		
Fixed part	OR	CI	p	OR	CI	p
Intercept	0.39	0.31 – 0.49	<0.001	0.34	0.27 – 0.45	<0.001
Trial number (log)	2.39	2.27 – 2.52	<0.001	2.52	2.38 – 2.67	<0.001
CS type						
C1	1.14	1.05 – 1.24	0.002	1.19	1.08 – 1.31	<0.001
C2	1.17	1.05 – 1.32	0.007	1.21	1.06 – 1.38	0.005
C3	1.06	0.86 – 1.30	0.581	0.98	0.78 – 1.23	0.865
Negative urgency (NU)	1.11	0.86 – 1.42	0.425	1.14	0.88 – 1.47	0.312
CS type x trial number						
C1 x trial number	1.00	0.98 – 1.03	0.779	0.99	0.96 – 1.03	0.713
C2 x trial number	1.02	0.98 – 1.06	0.400	1.01	0.97 – 1.06	0.657
C3 x trial number	0.95	0.88 – 1.03	0.203	0.97	0.89 – 1.06	0.485
NU x trial number	0.93	0.88 – 0.99	0.016	0.93	0.88 – 0.98	0.013
CS type x negative urgency						
C1 x NU	1.07	0.98 – 1.16	0.138	1.07	0.98 – 1.17	0.142
C2 x NU	1.09	0.96 – 1.23	0.176	1.11	0.98 – 1.26	0.099
C3 x NU	0.97	0.78 – 1.20	0.758	0.96	0.77 – 1.20	0.724
Trial number x CS type x negative urgency						
C1 x trial number x NU	0.97	0.94 – 1.00	0.077	0.97	0.95 – 1.01	0.109
C2 x trial number x NU	0.96	0.92 – 1.00	0.064	0.96	0.91 – 1.00	0.044
C3 x trial number x NU	1.06	0.97 – 1.14	0.182	1.05	0.97 – 1.14	0.204
Random part						
σ2	3.29			3.29		
τ00	0.59 id			0.58 id		
ICC	0.15			0.15		
Marginal R2 / Conditional R2	0.163 / 0.291			0.182 / 0.305		

Table 5. Effect estimates in the generalized linear mixed-effects model for CS-congruent responses during acquisition (with positive urgency as impulsivity predictor).

	No covariates model			Gender/age controlled		
Fixed part	*OR*	*CI*	*p*	*OR*	*CI*	*p*
Intercept	0.39	0.31 – 0.50	**<0.001**	0.35	0.27 – 0.45	**<0.001**
Trial number (log)	2.39	2.27 – 2.52	**<0.001**	2.51	2.37 – 2.67	**<0.001**
CS type						
C1	1.14	1.05 – 1.23	**0.002**	1.19	1.08 – 1.30	**<0.001**
C2	1.16	1.03 – 1.31	**0.012**	1.20	1.05 – 1.36	**0.007**
C3	1.07	0.87 – 1.32	0.498	1.00	0.79 – 1.25	0.970
Positive urgency (PU)	1.14	0.89 – 1.46	0.303	1.20	0.92 – 1.55	0.173
CS type x trial number						
C1 x trial number	1.00	0.98 – 1.03	0.769	0.99	0.96 – 1.03	0.741
C2 x trial number	1.02	0.98 – 1.06	0.355	1.01	0.97 – 1.06	0.642
C3 x trial number	0.95	0.88 – 1.02	0.176	0.97	0.89 – 1.05	0.438
PU x trial number	0.96	0.91 – 1.01	0.131	0.96	0.91 – 1.02	0.187
CS type x positive urgency						
C1 x PU	1.02	0.94 – 1.12	0.583	1.02	0.93 – 1.12	0.658
C2 x PU	0.88	0.78 – 1.00	**0.044**	0.90	0.79 – 1.02	0.105
C3 x PU	1.30	1.05 – 1.62	**0.016**	1.33	1.06 – 1.66	**0.013**
Trial number x CS type x negative urgency						
C1 x trial number x NU	0.99	0.96 – 1.02	0.355	0.99	0.96 – 1.03	0.732
C2 x trial number x NU	1.02	0.98 – 1.07	0.336	1.02	0.98 – 1.07	0.361
C3 x trial number x NU	0.93	0.87 – 1.01	0.080	0.92	0.84 – 0.99	**0.030**
Random part						
σ^2	3.29			3.29		
τ_{00}	0.59 $_{id}$			0.58 $_{id}$		
ICC	0.15			0.15		
Marginal R^2 / Conditional R^2	0.159 / 0.287			0.178 / 0.300		

Abbreviations: CS = Conditioned stimuli; CI = Confidence Interval; PU, positive urgency; ICC = Intraclass correlation coefficient. *Note*: Significant results are marked in bold.

Table 6. Effect estimates in the generalized linear mixed-effects model for CS-congruent responses during extinction (with negative urgency as impulsivity predictor).

	No covariates model			Gender/age controlled		
Fixed part	*OR*	*CI*	*p*	*OR*	*CI*	*p*
Intercept	5.32	3.66 – 7.73	**<0.001**	5.80	3.85 – 8.74	**<0.001**
Trial number (log)	0.61	0.58 – 0.64	**<0.001**	0.59	0.56 – 0.62	**<0.001**
CS type						
C1	1.14	1.04 – 1.24	**0.003**	1.23	1.11 – 1.35	**<0.001**
C2	0.96	0.85 – 1.08	0.518	0.99	0.87 – 1.13	0.887
C3	0.89	0.72 – 1.09	0.251	0.87	0.69 – 1.10	0.240
Negative urgency (NU)	0.88	0.60 – 1.31	0.540	0.87	0.59 – 1.29	0.497
CS type x trial number						
C1 x trial number	0.83	0.81 – 0.85	**<0.001**	0.81	0.78 – 0.83	**<0.001**
C2 x trial number	1.03	0.99 – 1.08	0.097	1.02	0.98 – 1.07	0.297
C3 x trial number	1.00	0.93 – 1.07	0.931	1.00	0.92 – 1.08	0.943
NU x trial number	1.00	0.95 – 1.05	0.932	1.00	0.94 – 1.05	0.872
CS type x negative urgency						
C1 x NU	0.95	0.87 – 1.04	0.254	0.97	0.89 – 1.06	0.477
C2 x NU	1.06	0.93 – 1.20	0.388	1.05	0.92 – 1.19	0.450
C3 x NU	1.08	0.87 – 1.34	0.467	1.06	0.85 – 1.33	0.581
Trial number x CS type x negative urgency						
C1 x trial number x NU	1.01	0.98 – 1.04	0.365	1.01	0.98 – 1.04	0.561
C2 x trial number x NU	0.98	0.94 – 1.02	0.396	0.99	0.95 – 1.03	0.582
C3 x trial number x NU	0.98	0.92 – 1.06	0.666	0.99	0.92 – 1.07	0.816
Random part						
σ^2	3.29			3.29		
τ_{00}	1.94 $_{id}$			1.91 $_{id}$		
ICC	0.37			0.37		
Marginal R^2 / Conditional R^2	0.138 / 0.458			0.150 / 0.462		

Abbreviations: CS = Conditioned stimuli; CI = Confidence Interval; NU, Negative urgency; ICC = Intraclass correlation coefficient. *Note*: Significant results are marked in bold.

Table 7. Effect estimates in the generalized linear mixed-effects model for CS-congruent responses during extinction (with positive urgency as impulsivity predictor).

	No covariates model			Gender/age controlled		
Fixed part	*OR*	*CI*	*p*	*OR*	*CI*	*p*
Intercept	5.55	3.84 – 8.01	**<0.001**	6.10	4.06 – 9.18	**<0.001**
Trial number (log)	0.61	0.58 – 0.64	**<0.001**	0.58	0.55 – 0.62	**<0.001**
CS type						
C1	1.11	1.02 – 1.21	**0.019**	1.20	1.09 – 1.33	**<0.001**
C2	0.94	0.84 – 1.07	0.359	0.97	0.84 – 1.11	0.653
C3	0.89	0.72 – 1.10	0.281	0.88	0.69 – 1.11	0.270
Positive urgency (PU)	1.32	0.90 – 1.93	0.149	1.35	0.90 – 2.01	0.142
CS type x trial number						
C1 x trial number	0.84	0.81 – 0.86	**<0.001**	0.81	0.79 – 0.84	**<0.001**
C2 x trial number	1.04	1.00 – 1.08	0.059	1.03	0.98 – 1.08	0.193
C3 x trial number	0.99	0.93 – 1.07	0.875	0.99	0.92 – 1.07	0.889
PU x trial number	1.01	0.96 – 1.06	0.763	0.99	0.94 – 1.05	0.711
CS type x Positive urgency						
C1 x NU	0.87	0.80 – 0.95	**0.003**	0.92	0.84 – 1.01	0.082
C2 x NU	0.92	0.81 – 1.04	0.178	0.90	0.78 – 1.02	0.104
C3 x NU	1.10	0.89 – 1.35	0.385	1.05	0.84 – 1.32	0.678
Trial number x CS type x Positive urgency						
C1 x trial number x PU	1.05	1.02 – 1.08	**<0.001**	1.04	1.01 – 1.07	**0.014**
C2 x trial number x PU	1.02	0.98 – 1.06	0.383	1.03	0.99 – 1.08	0.131
C3 x trial number x PU	0.97	0.91 – 1.04	0.429	0.99	0.92 – 1.07	0.766
Random part						
σ^2	3.29			3.29		
τ_{00}	1.86 $_{id}$			1.86 $_{id}$		
ICC	0.36			0.36		
Marginal R^2 / Conditional R^2	0.151 / 0.458			0.158 / 0.462		

Abbreviations: CS = Conditioned stimuli; CI = Confidence Interval; PU, Positive urgency; ICC = Intraclass correlation coefficient. *Note*: Significant results are marked in bold.

Figure 2. Observed proportions (and logarithmic trendlines) of CS-congruent responses across CS-type and NU/PU during acquisition. NU and PU were median-split for visualization purposes only.

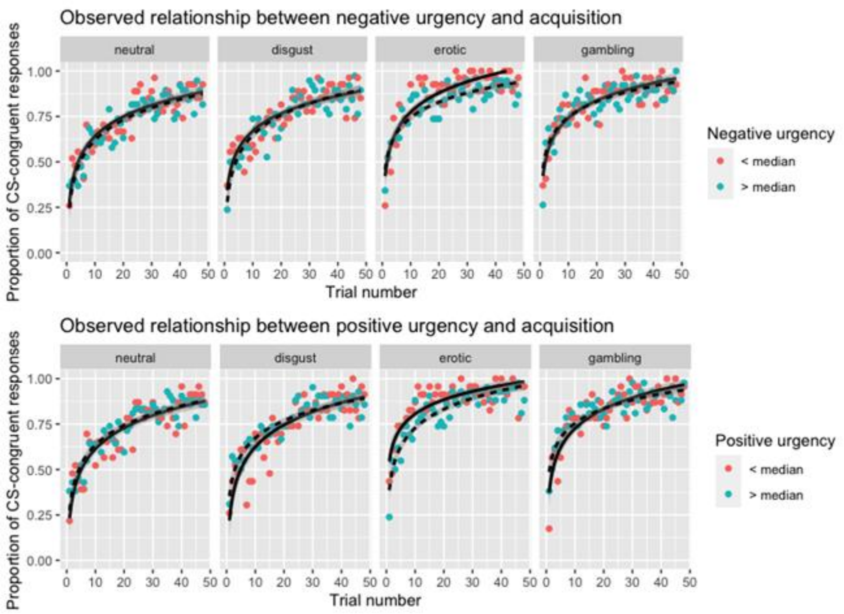


Figure 3. Observed proportion (and logarithmic trendlines) of CS-congruent responses across CS-type and NU/PU during extinction. NU and PU were median-split for visualization purposes only.

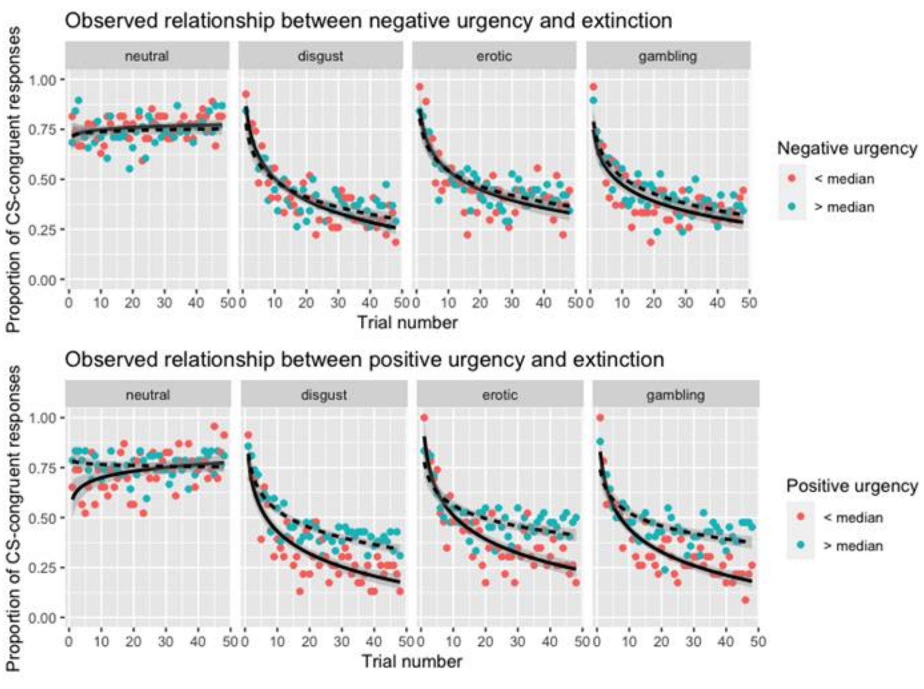


Figure 3 displays the observed proportion of CS-congruent responses throughout the extinction phase and across the four CS types, for high and low negative urgency participants (top row), and for high and low positive urgency participants (bottom row). Again, the median split was performed for visualization purposes only, and proportions are shown as directly observed and not adjusted for covariates. The figure shows quite an evident slower extinction for participants with high positive urgency scores.

These analyses show the effect of positive urgency was restricted to emotion-laden CS (disgusting, erotic, and gambling-related). In view of that, a simplified model was built excluding the neutral CS-type. As expected, this model yielded a significant trial x positive urgency interaction (z = 2.022, p = 0.043). Given that no components of the CS-type x trial x positive urgency interaction were significant (i.e., the effect of positive urgency on extinction was similar for the three remaining emotion-laden CS-types; al p > 0.35), a further simplified model was built without the second-order interaction. The trial x positive urgency interaction also remained significant in this model (z = 2.056, *p* = 0.040).

Post-hoc exploratory analyses: the moderating role of gambling preferences on the positive urgency-extinction association

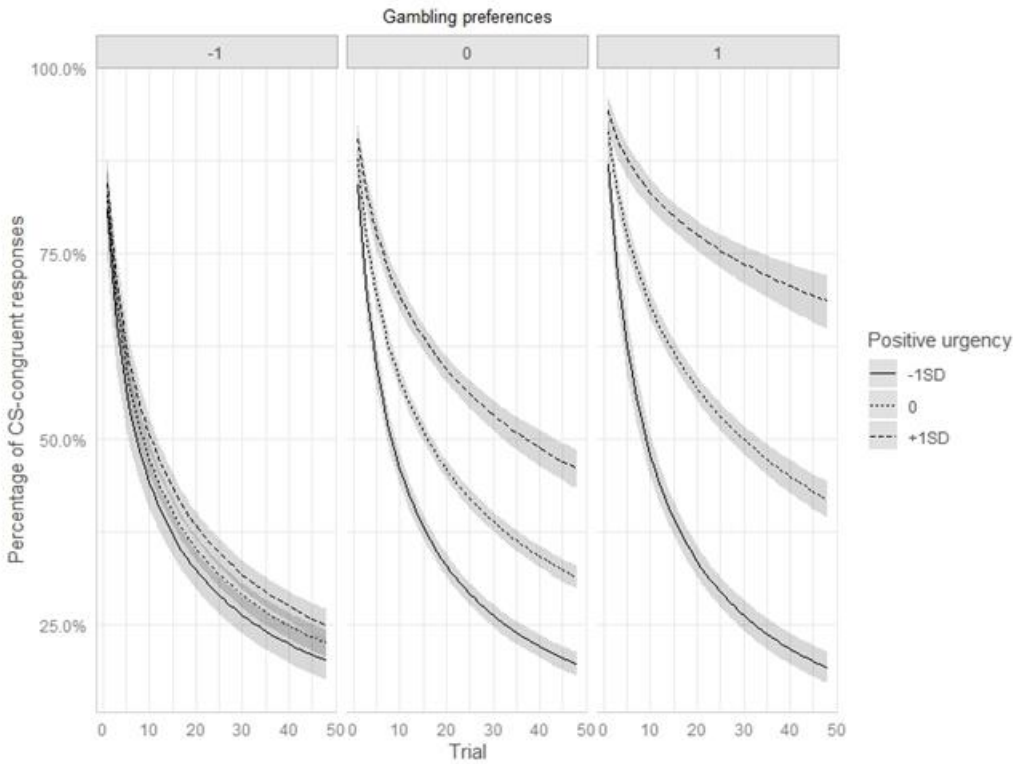
In order to test whether positive urgency effects on extinction were modulated by gambling preferences, a preference measure was computed from gambling frequency measures (as collected in the gambling habits questionnaire). Frequency scores for type-II games (lotteries, bingo, and slots, either online or land-based) and type-I games (card games, sport bets, and casino games) were first separately summed, and then zero-centered and scaled. The type-I/type-II classification of games was based on Navas et al. (2017). The preference score was computed as the difference between these two standardized frequency measures. This difference score will thus be more negative as the individual shows an exclusive preference for participating in type-II games, and more positive the more exclusively their participation is biased towards type-I games. Individuals with mixed patterns will be located somewhere in-between these extreme scores.

This preference measure, plus its interaction with trial, its interaction with positive urgency, and the preference x positive urgency x trial interaction were added as fixed-effects predictors to the last (simplified) model of the previous section. The trial x positive urgency interaction survived in this model ($z = 2.661$; $p = 0.008$). More interestingly, however, this effect was qualified by a significant preference x positive urgency x trial interaction ($z = 2.452$; $p = 0.015$); that is, the detrimental effect of positive urgency on extinction was strongly modulated by gambling preferences. As shown in **Figure 4**, participants with a more biased preference for participating in type-I games showed a neat positive urgency effect on extinction, whereas this effect tended to vanish in participants who participate in type-II games in a more exclusive manner.

Discussion

Our results reinforce previous findings that affect-driven impulsivity (urgency) is linked to gambling craving and symptoms of problematic gambling, and also support its association with difficulties to extinguish conditioned associations between initially neutral stimuli and unconditioned, emotion-laden pictures. This association between urgency and slowed extinction cannot be explained as resulting from previous deficits in acquisition. Although in the present study urgency significantly interfered with acquisition, this effect was small, partial, and, in the case of positive urgency, preasymptotic. In other words, performance differences between high and low-urgency individuals are not attributable to insufficient understanding of the task, or more general faulty reinforcement learning, as observed with associative learning tasks in other addictive disorders (Robinson et al., 2021).

Figure 4. Predicted values of conditioned responses (percentage of CS-congruent responses) for CSs associated with type-I and type-II gambling preferences as a function of positive urgency.



However, the specific pattern of relationships shown by positive and negative urgency depicts a complex picture that requires detailed discussion. Although both positive and negative urgency correlated with severity of disordered gambling symptoms, negative urgency remained a significant predictor after controlling for craving (i.e., its relationship with severity was independent of craving, as shown by its significant direct effect in the mediation model), whereas the effect of positive urgency was explained away by craving. This result is suggestive of a mediational role of craving in the positive urgency - severity association. In accordance with the argument presented in the introduction, if craving is an intrinsically emotional state, the finding that urgency exerts its effect on gambling symptoms severity via craving suggests that urgency reflects a difficulty with regulating emotions, including regulation of craving.

This pattern of conditional and unconditional associations is compatible with the view that craving (at least in some subpopulations of gamblers) is triggered and fueled by appetitive cues, namely those that signal the availability of a reinforcer or share motivational features with it (Barrus, Cherkasova, & Winstanley, 2015; Cornil et al., 2018; Ostlund & Marshal, 2021). Individuals with higher positive urgency scores will experience more intense cravings (hyperreactivity to appetitive cues), and will find it more difficult to control gambling when experiencing such craving states (compromised regulation).

There are at least two other pieces of evidence that strengthen the view that cravings are more incentive-related than aversive, at least in the current sample. As detailed in the analyses reported in the supplementary materials file, (a) individual differences in craving intensity predicted participants' assessments of affective valence and arousal for the gambling-related pictures used as USs (see Images_SAM_SOGS.jasp file in the OSF link mentioned earlier). That is, people reporting more intense cravings also valued gambling images more positively. And (b) negative urgency predicted severity independently of craving, but did not predict craving itself (after controlling for positive urgency). That means that the role of negative urgency here would be more general. As we have previously hypothesized, and partially evidenced (see Perales et al., 2020; Navas et al., 2019), the transdiagnostic nature of negative urgency would make people with disordered gambling more vulnerable to other conditions (especially in the high end of the externalizing continuum), increasing the risk of clinical complications not necessarily caused by gambling itself.

That said, the present study failed to replicate the key results reported by Quintero et al. (2020). First, in that study negative urgency did not predict severity in a direct manner, but a direct association between negative urgency and craving was found. Given the strong overlap between positive and negative urgency, the possibility exists that the negative urgency-craving link would have disappeared if positive urgency had been controlled for. Or, alternatively, as both clinical and laboratory studies suggest, not only appetitive, but also aversive cues and states (e.g. stress) could trigger and fuel cravings (Bresin et al., 2018; Koob & Volkow, 2016). If this were the case, it would remain to be explained why aversive states dominated craving in Quintero et al.'s study, whereas appetitive ones did so in the present one.

And second, and most importantly, our results also contrast with Quintero et al.'s with regard to the relationship between urgency and extinction. As noted earlier, extinction of affect-laden associations can be interpreted as an index of incidental emotion regulation. Slowed extinction of these associations can reflect a hampered modulation of emotional responses by contextual cues, leading to inappropriate emotional reactions. However, in the present study, it was positive urgency, instead of negative urgency, the facet of impulsivity that was associated with slowed extinction. Moreover, slowed extinction in high positive urgency individuals was evident for all CS paired with emotion-laden US, regardless of the hedonic sign of such US (negative in the case of disgusting pictures, and positive in the case of gambling-related and erotic pictures). That is, the urgency-related alteration of the associative mechanisms of extinction seems to extend to a broad range of conditioned emotions.

Our supplementary analyses provide, however, a viable (ex post facto) mechanism for our suspicion that replication failure could be due to sample differences between studies. As noted above, the possibility exists that urgency is expressed differently depending on the differential sensitivity of the individual to aversive or appetitive states. If that is the case, an individual with slowed extinction of affect-laden stimuli will show elevated positive or negative urgency scores depending on a pre-existing proneness to overreact to appetitive or aversive drives. This proposal is highly tentative, but it is supported by (a) the almost symmetrical association of positive/negative urgency with slowed extinction and gambling cravings in the present and our previous study, and (b) the finding, in the current study, that slowed extinction is associated with positive urgency only in gamblers with preference for Type-I games. Actually, Navas et al. (2017) found that Type-I gamblers are more sensitive to reward and have more positive expectancies about gambling than individuals preferring Type-II games (see also Balodis, Thomas, & Moore, 2014).

If this idea results to be correct, it could indirectly help resolve the apparent puzzle regarding why in some studies urgency seems to be unifactorial, whereas in some other positive and negative urgency seem to have differentiable etiological roles in addictive behaviors. According to our proposal, positive and negative urgency have a common etiological root in the malfunctioning of processes of contextual control of conditioned emotional states, but can manifest itself differently depending on the interaction of such processes with more fundamental traits of sensitivity to appetitive and aversive drivers (e.g. activity of Gray's BIS/BAS systems; Bijttebier et al., 2009).

Limitations and final remarks

This study is not free of limitations. The most important ones arise from its cross-sectional nature, which limits the possibility of making causal statements. Note, however, that the chain of nodes in mediation analysis responds to the logic that traits (positive and negative urgency) have a causal influence on states (craving), and these on behaviors (problem gambling symptoms).

A second limitation arises from the ambiguous status of the present study as a direct or conceptual replication. There are variations in this study relative to the original one that are substantial enough for this attempt not to be considered a direct replication, with several of such variations being included simultaneously. We are aware that further research is required in which all hypotheses are preregistered, including the ones regarding the relative roles of positive and negative urgency, and the ones regarding the roles of gambling preferences (ideally, in a sample in which preferences for type I and type II gambling modalities are well balanced).

Additionally, the craving measure used in this study is not broadly validated, but theoretically rooted in the incentive sensitization hypothesis. The idea that a common sensitization process makes reward-related cues acquire the capacity to elicit strong desire, attentional capture, and automatic approach responses is however supported by the strong convergence of the three items, both in the current and Quintero et al.`s (2020) studies.

The strengths of the study stem from its carefully pre-planned design and data analytic plan. In these conditions, the fact that the original results were not replicated does not take the research question to square one, but opens new pathways for investigation. The evidence that (a) emotion regulation, impulsivity, and craving control are intertwined, (b) they play a key role in the etiology of gambling problems, and (c) they can be at least partially traced back to basic learning processes is solid, and improves our understanding of the connection between basic processes of behavioral control and addiction. The picture is however more complex that initially considered, and implies that gambling research can no longer ignore the importance of heterogeneity. Further research on the link between gambling preferences and the affective content and valence of craving, and the role of regulation of positive and negative emotions in craving control for different subpopulations of individuals with gambling problems, is warranted.

Data availability

The open database and code files for these analyses, and the supplementary materials, are available at the Open Science Framework repository as https://osf.io/tyjmq/?view_only=1062e72b26814d1f90a5994a899c02c7

CHAPTER VI:

Study V

No evidence of associations between gambling-related problems and self-report, task-related, and heart rate variability indices of intentional emotion regulation in active community gamblers

Abstract

The maladaptive use of emotion regulation strategies is an important ingredient of recent theoretical models of gambling disorder. However, the available results regarding the association between gambling-related problems and these strategies are mixed and mostly arise from comparisons between patients with gambling disorder and matched controls in self-report measures of the dispositional use of these strategies. In the present study, we use the Emotion Regulation Questionnaire (ERQ), the experimental cognitive reappraisal task, and vagally-mediated heart rate variability (vmHRV) measures during the performance of the task, to investigate possible associations between emotion regulation strategies and gambling-related measures (SOGS gambling problems' severity and craving), in a sample of active gamblers from the community in a wide range of severity. Bayesian analyses did not show SOGS scores and craving to reliably relate to intentional emotion regulation indices. Neither the dispositional use of reappraisal predicted less severe gambling problems or less craving, nor the use of suppression predicted more severe problems or craving. SOGS and craving scores were not meaningfully associated with performance in the cognitive reappraisal task, nor with vmHRV measures taken before the task, in return-to-baseline intervals after task blocks, or during task blocks. In line with previous reports, however, gambling problems' severity and craving were associated with emotional facets of impulsivity (positive and negative urgency). Results also showed evidence of an association of suppression and positive urgency with a stronger impact of time-on-task on vmHRV. The association between gambling problems and emotional impulsivity confirms previous reports with similar samples and reinforces the

role of incidental emotion regulation in gambling craving and ensuing gambling-related problems. Complementarily, the association between the impact of time-on-task on vmHRV measures (taken during return-to-baseline intervals in the cognitive reappraisal task) suggests that these indices of emotion regulation could underlie the mental fatigue effects of emotion regulation. Beyond these, results were consistent in showing no evidence of differences in emotion regulation strategies (either dispositional or lab-based), or in their vmHRV correlates, that could be attributed to differences in gambling problems' severity or craving. Taken together, these results undermine the involvement of intentional emotion regulation in the variability of gambling-related problems in community gamblers. More generally, they reinforce previous proposals restricting domain-general neurocognitive alterations to specific groups of individuals with gambling problems or those from clinical populations.

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 et al., 2019; Navas 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 are partially distinct to other addictive disorders (Bonnaire et al., 2022; Navas et al., 2017).

Emotional regulation is a transdiagnostic construct that refers to an individual's capacity to influence their own emotions, either positive or negative (Gross, 1999; Velotti et al., 2022; Mansson et al., 2023). 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 (Manson et al., 2023), whereas others suggest that they need not necessarily be (see Bonnano et al., 2004; Rogier, Garofalo & Velotti, 2019). Similarly, the term emotional dysregulation refers to deficits in their functioning, or to any difficulties in implementing them (Sancho et al., 2019; Estévez et al., 2020; Buen & Flack, 2022; Jara-Rizzo et al., 2019). However, operationalizing both terms remains challenging, due to their multifaceted nature. Nowadays, emotion regulation is still considered an umbrella construct, and its precise conceptualization is still a topic of debate (Velotti et al., 2022; Marchica et al., 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 John & Gross, 2004; Williams et al., 2011; Gyurak, Gross, & Etkin, 2011; Aldao, Nolen-Hoeksema, & Schweizer, 2010; Gross, 1998), the model proposed by Etkin and colleagues (2015) remains preponderant. This neurocognitive model proposes a distinction between incidental and intentional emotion regulation. The former refers to automatic associative processes, such as extinction or Pavlovian-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). In a previous series of works, we 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 (Quintero et al., 2020; Muela et al., 2023).

In contrast, intentional mechanisms involve explicit or controlled regulation (Braunstein, Gross & Ochsner, 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 (Gyurak, Gross, & Etkin, 2011; Fitzgerald et al., 2020). 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 (Ruiz de Lara et al., 2019; Jara-Rizzo et al., 2019; Navas 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, Garofalo, & Velotti, 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 (Marchica et al., 2019; Velotti et al., 2022; Mansson et al., 2023; Gross, 1998). This strategy is considered adaptive and antecedent-focused, and several studies suggest that it is useful in reducing reactivity to negative emotional experiences in individuals with addictive disorders (Marchica et al., 2019; Velotti et al., 2022; Mansson et al., 2023; Goldstein & Volkow, 2011). 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 (Velotti et al., 2022; Marchica et al., 2019). Different works suggest that attempting to suppress or avoid emotional states can increase arousal which, in turn, may perpetuate unwanted emotions (Williams et al., 2011; Wenzlaff & Wegner, 2000; Campbell-Sills et al., 2006).

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 a negative association between the use of reappraisal and the development of problem or disordered gambling (Bonnaire et al., 2022; Rogier et al., 2019, 2021; Pace et al., 2015), and a positive link between the use of expressive suppression (and other avoidant coping strategies) and gambling-related problems (Bonnaire et al., 2022; Rogier et al., 2019, 2021; Navas et al., 2017). This finding is also supported by two recent systematic reviews (Marchica et al., 2019; Neophytou et al., 2023) and a meta-analysis (Velotti et al., 2021). On the other hand, some studies have found little evidence of these associations (Barrault et al., 2017; Barrault et al., 2018; Mestre-Bach et al., 2021; Williams et al., 2011; Pace et al., 2015; Navas et al., 2017). 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., 2015) has been the most commonly used. This task presents participants with sequences of negatively valenced pictures. Participants are instructed to modify or reinterpret the meaning of the pictures 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. Picó-Pérez et al., 2022, Bastiaansen et al. 2018). 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 or pathological gambling. One such study was conducted by Navas et al. (2017). The study 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 analyze 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 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 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 et al. In the present study, however, fMRI will be replaced by a heart rate variability (HRV) measure.

Empirical research and previous theoretical proposals support the use of HRV as a reliable non-invasive marker of individual differences in the ability to regulate emotions (Appelhans & Luecken, 2009; Christou-Champi, Farrow, & Webb, 2014). 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 (Thayer &

Lane, 2009; Hansen, Johnsen, & Thayer, 2003). This implies that phasic HRV can be used as a measure of mental load elicited by tasks involving emotional regulation (Sagerstrom & Nes, 2007). Among the several HRV parameters used, 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 (**ref**), 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 et al. (2017). Instead of patients 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 continuum and also avoids the overrepresentation of participants in the high-severity end, who are more likely to present complications and comorbidities that may act as confounders in the specific associations 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 Navas et al. and Picó-Pérez et al.'s studies, 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 do 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 HRV, and assuming that individuals with emotion regulation difficulties find the reappraisal task as a whole more fatiguing 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 HRV modulation throughout the task remain open. If any, known correlates of gambling problems’ severity (e.g. positive and negative urgency) as expected to exert an effect on HRV in the same direction as severity.

Finally, we expect to find evidence of more severe gambling problems being associated with (v) a more frequent dispositional use of expressive suppression, as well as (vi) a more detrimental effect on HRV 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.

Method

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. Individuals with a history of psychopathological treatment or diagnosis, neurological disease, or brain trauma resulting in a loss of consciousness for 10 minutes 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 euros 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. For the purposes of this study, only the second recording was analyzed (see Measurements section). The EEG measures will be reported elsewhere.

Measures

Gambling problems' severity

The severity of disordered gambling symptoms (henceforth, gambling problems' severity) was assessed using the SOGS questionnaire (Lesieur & Blume, 1987), a reliable and widely used screening instrument (Esparza-Reig et al., 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 et al., 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 (Cándido et al., 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 (see 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; Spanish validation, Cabello et al., 2013) was administered to assess the dispositional use of cognitive reappraisal and expressive suppression. The ERQ items are scored on a scale of 1 to 7, ranging from strongly disagree to strongly agree, respectively. 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 strategies. 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.

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	–
Negative Urgency	2,50	2,50	0,75	1,00	4,00	28/26
Positive Urgency	2,57	2,50	0,64	1,25	4,00	27/27
Cognitive Reappraisal	4,71	4,80	0,94	2,80	7,00	34/20
Expressive suppression	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 condition	5,29	3,60	4,53	0,65	20,48	–
Experience condition	47,27	50,24	23,21	4,50	89,67	–
Regulate condition	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	–

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.

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

		Negative urgency	Positive urgency	Expression suppression	Cognitive reappraisal	Severity	Craving	ER success
Positive urgency	τ	**0.318*** **	—					
	BF_{10}	215.747	—					
Expression suppression	τ	-0.009	-0.097	—				
	BF_{10}	0.159	0.309	—				
Cognitive reappraisal	τ	0.095	0.144	0.094	—			
	BF_{10}	0.302	0.689	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

*$BF_{10} > 10$, **$BF_{10} > 30$, ***$BF_{10} > 100$, † sample size n = 54, τ *Kendall's tau*, ER *Emotion Regulation*

Craving

For this study, we used the same craving scale as in previous works from our research team (Quintero et al., 2020; Muela et al., 2023). 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 et al., 2017). Participants were exposed to neutral and negatively valenced pictures, all extracted from the IAPS catalog (Lang et al., 2001). The task consists of three different trial types, in which participants were 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). The task consists of 120 trials. Each trial begins with the presentation of a fixation point (2000 ms), followed by an instruction indicating the strategy to be followed depending on the condition (*Observe*, *Experience*, or *Regulate*; 2000 ms). Then, two different pictures of the same category (neutral or negative valence; 5000 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).

The 120 trials are 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 instructed 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. Hear-rate variability measures during these periods reflect HRV dynamics (carryover effects) during the task, not acutely depending on mental activity during the task blocks.

HRV measures

For HRV data acquisition, we used a Polar H7 heart rate sensor and a Polar v800 receiver unit (Polar Electro Öy, Kempele, Finland) 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 1000 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 collecting the data, they 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 sub-section Participants and Procedure). 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 et al., 2014). With this method, artifacts and ectopic beats are automatically identified by comparing every RR 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 seconds 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 et al., 2022). In order to adhere to HRV reporting standards (Malik et al., 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 to 0.40 Hz) for the frequency-domain (via Fast Fourier Transform). All HRV parameters were obtained by using custom Matlab scripts and HRVTool toolbox (Vollmer, 2019).

All results concerning vmHRV in the main text of the manuscript refer to RMSSD, whereas data concerning pNN50 and HFms2 can be found in Supplementary material. 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 et al., 1996).

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, and for the sake of consistency and comparability, Kendall's □ correlation indices were used, 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).

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).

Given the multiplicity of correlations, BF10 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.

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. Participant attrition in HRV analyses was caused by recording problems in 14 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 (4x2) 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 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 (B0, 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 B0 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 high and low groups in negative urgency, positive urgency, cognitive reappraisal, expressive suppression, gambling problems' severity, and gambling craving, respectively. In addition to the between-participants group factor (high, low), the within-participant vmHRV measurement point (1-4), 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 x 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). BF_{inc} values larger than or equal to 3 will be interpreted as substantial evidence in favor of H1, BF_{inc} values smaller than or equal to 1/3 will be interpreted as substantial evidence in favor of H1, and BF10 values between 1/3 and 3 will be interpreted as anecdotal evidence. Any BF_{inc} factors below 1/10 or above 10 will be considered indicative of strong evidence in favor of H0 and H1, respectively.

Regression analyses

Two Bayesian linear regressions were conducted to investigate whether gambling problems' severity 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. any 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* x *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.

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.

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) evidence of a correlation of negative urgency with craving and severity was merely anecdotal (BF < 10). In other words, positive urgency was a better predictor of gambling problems' severity and craving than negative urgency.

All other Bayes factors anecdotally supported the lack of correlations (1/10<BF<0), except for the association between SOGS severity score and the dispositional use of reappraisal (BF = 3.196). Regarding this correlation, it is important to note that, although the evidence in favor of a positive association is anecdotal, the BF provides strong evidence against a negative association. That is, 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.

Complementary correlation analyses using a frequentist approach yielded similar results (see Supplementary Material).

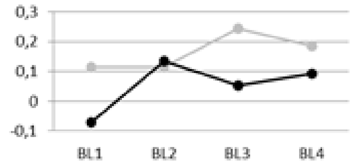
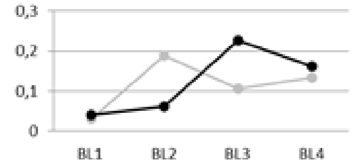
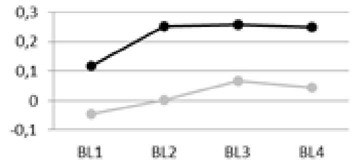
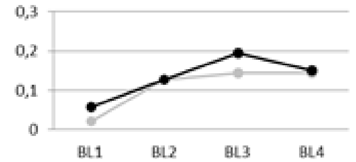
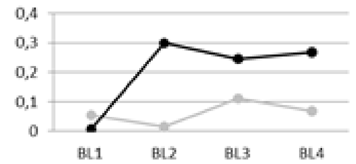
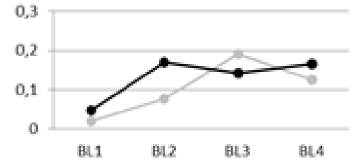
Changes in HRV over time-on-task

Table 3 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 OSF platform (https://osf.io/zh2n9/).

BF_{inc} values for the main effect of time-on-task provided no substantial support for or against the alternative or 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, task engagement 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 anecdotal, was generally in favor of the null hypothesis.

Table 3. Bayesian repeated-measures ANOVAs between variables of interest.

	RMMSD	
Effects	**BF_{incl}**	**Figure**
Time	0.694	
Severity	0.793	
Time x Severity	0.464	
Time	0.698	
Negative urgency	0.286	
Time x Negative Urgency	0.792	
Time	0.718	
Positive urgency	**11.377**	
Time x Positive Urgency	**0.072**	
Time	0.703	
Cognitive Reappraisal	0.301	
Time x Cognitive reappraisal	**0.066**	
Time	0.689	
Expressive suppression	1.467	
Time x Expressive suppression	5.484	
Time	0.688	
Craving	0.305	
Time x Craving	0.115	

Grey and black lines represents scores under and above the median, respectively.

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 x suppression interaction indicates that such a difference starts to show up in B2 (so that differences are more clearly related to time-on-task).

Linear regressions

Summary results for these analyses can be found in **Table 4** and **Table 5**.

The first analysis examined the relationship between SOGS gambling problems' severity and ERQ expressive suppression. Main effects analysis (across matched models) showed anecdotal evidence supporting the influence of gender and age (BF_{inc} = 1.343 and 1.394, respectively) on expressive suppression, while gambling problems' severity remained 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 anecdotally 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.

When positive urgency was included in the regression model, in place of negative urgency, the results provided merely anecdotal 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/anecdotal (BF_{inc} = 0.946, and BF_{inc} = 0.437, respectively).

In the same vein, we examined the relationship between gambling problems' severity and cognitive reappraisal. Main effects analysis showed again anecdotal 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 anecdotal 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 anecdotal evidence (BF_{inc} = 0.432) against an interaction effect of gambling problems' severity with negative urgency.

The inclusion of positive urgency in place of negative urgency in the model yielded negligibly anecdotal evidence (BFinc = 1.079) in favor of a main effect of gambling problems' severity, and anecdotal evidence against any main or interactive effect of positive urgency (BF_{inc} = 0.396 and 0.447, 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).

Table 4. Results of Bayesian linear regression analyses to examine gambling severity as a predictor of dispositional use of intentional emotion regulation strategies.

	Dependent variable					
	Expressive Suppression			Cognitive Reappraisal		
		95% Credible Interval			95% Credible Interval	
Coefficient	**$BF_{inclusion}$**	**Lower**	**Upper**	**$BF_{inclusion}$**	**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 UN	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

NU *Negative urgency*, PU *Positive urgency*. Sex and age were introduced as control variables.

Table 5. Results of Bayesian linear regression analyses to examine gambling severity as a predictor of changes in several HRV measures.

	RMSSD		
		95% Credible Interval	
Coefficient	$BF_{inclusion}$	Lower	Upper
Gambling severity	0.288	-0.025	0.006
Gambling Severity	0.271	-0.060	0.022
UN	0.268	-0.119	0.110
Gambling severity x UN	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
Reappraisal	0.245	-0.060	0.045
Gambling Severity x Reappraisal	0.485	0.000	0.000
Gambling Severity	0.281	-0.028	0.016
Suppression	0.306	-0.013	0.071
Gambling Severity x Suppression	0.499	-5.122×10^{-4}	0.003

Sex, Age and Counterbalance are used as control variables. UN negative urgency, PU positive urgency, RMSSD root mean square successive difference, HF high frequency.

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 negligibly anecdotal evidence against the severity x negative urgency interaction effect (BF_{inc} = 0.987).

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, anecdotal 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).

Discussion

The main objective of this study was to assess the associations of gambling-related problems and constructs with several measures of intentional emotion regulation 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 in the task. 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) showed no association with gambling-related problems or craving in the expected direction. In other words, in the range of severity explored in the present work, we found little or no evidence that altered strategic or intentional emotion regulation plays any role in problematic gambling or its manifestations. Concerning 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 associated with 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 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 anecdotal 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 et al., 2023) has corroborated this differential association and suggested a significant mediational role of gambling craving in the relationship between positive urgency and gambling problems that is 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 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 is, by itself, strong evidence against the more prototypical association in the opposite direction, but can also be taken at face value. As noted in the introduction, the more usual, and less counterintuitive finding is an association in the opposite direction, i.e. a negative relationship between the use of reappraisal and gambling problems (Bonnaire et al., 2022; Rogier et al., 2019; Pace et al., 2015), as it has been reported for most other mental health conditions (Aldao, Nolen-Hoeksema, & Schweizer, 2010; Lincoln, Schulze, & Renneberg, 2022). However, there are also exceptions to this trend that are worthy of note. For instance, Neophytou and cols. (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, Navas and Perales (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 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 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 that measure. 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 et al. (2018) 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 associations of dispositional emotion regulation and gambling-related variables with success in the reappraisal task is also worthy of note. Navas 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 association 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 et al., 2019), and subjective estimates of mental workload, in turn, increase with the fatigue that accumulates with increasing time on task (Luque-Casado et al., 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 heart rate variability (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 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 et al.'s (2017) fMRI results, that participants with more severe gambling problems, and specially 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

Despite this lack of confirmation of our hypothesis, 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. Although these results could show a mere lack of sensitivity in the measures used, this seems unlikely in view that gambling problems and craving were found to be associated with urgency (and especially with positive urgency, replicating our previous results), and positive urgency and a frequent use of suppression were associated with a stronger effect of time-on-task on vmHRV.

These results actually 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 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 problems and craving than negative urgency. Unfortunately, the importance of mechanisms for the regulation of positive emotions has been mostly neglected (for similar arguments, see Zou et al., 2019; Weiss et al., 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, and to be reported elsewhere). Fitting the 64-electrode cap used for EEG recording took between 30 and 60 minutes 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.

Fourth, 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 anecdotal 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.

CHAPTER VII:

General Discussion

The general objective of this dissertation was to elucidate the role of model-free and model-based emotional regulation processes in the severity of problematic gambling symptoms, as well as to understand the incidence of alterations in the mechanisms underlying both modes in the loss of behavioral control. Additionally, we aimed to address some gaps in current research, specifically related to the operationalization of compulsivity in behavioral addictions and the etiology of gambling-related biases.

In this section, we will recap the main findings of the five studies described in the previous four chapters and discuss them within the context of current and emerging experimental and theoretical evidence. Furthermore, a tentative theoretical proposal will be presented, integrating the findings of this dissertation and aiming to broaden and expand upon previous etiological models. Finally, we will reflect on the practical and clinical implications of our study results and outline future research directions that could emerge from this work and the current state of the field.

Summary of findings

In **Study** I, we aimed to explore the potential association (or lack thereof) between abstract and probabilistic reasoning abilities and gambling-related distortions. Additionally, to determine if this relationship depended on the participants' level of gambling involvement, analyses were conducted on two samples of gamblers with different levels of gambling severity (i.e., non-problematic gamblers and patients diagnosed with gambling disorder). These analyses also examined the relationship between gambling-related cognitions and the severity of the disorder.

First, a Multivariate Analysis of Covariance (MANCOVA) was conducted to examine whether the two samples differed in the manifestation of cognitive distortions based on general domain reasoning measures, which were introduced as continuous predictors. The results indicated significant differences between the groups in the dimensions of the Gambling Related Cognitions Scale (GRCS). Subsequent Analyses of Covariance (ANCOVA) for each GRCS dimension allowed us to rule out that these differences were not attributable to variations in general reasoning abilities. In other words, the results suggest that the observed differences in gambling-related cognitions between individuals with gambling disorder and non-problematic gamblers are robust but independent of their reasoning test scores.

Additional analyses were conducted to calculate the correlations between reasoning abilities and distorted cognitions for the two groups separately, thereby reinforcing the aforementioned findings. The results were mostly null, although some weak evidence of positive correlations was observed in the non-problematic gamblers group. Specifically, these correlations were between probabilistic reasoning abilities and gambling expectations cognitions, inability to stop gambling, and, to a lesser extent, interpretative bias.

Study II aimed to deepen the understanding and operationalization of compulsivity in the realm of behavioral addictions. To this end, a systematic review methodology was employed in accordance with PRISMA guidelines. This process involved an extensive search and analysis of specialized literature to identify the presence of compulsivity through the items included in the psychometric tools employed in this field of study. Initially, after screening 4,194 records, 330 articles were selected that described self-report instruments associated with the most studied putative behavioral addictions and incorporated terms theoretically related to the construct of interest. This preliminary selection permitted the identification of 138 psychometric instruments containing at least one item with the potential to be interpreted as indicative of compulsivity.

To refine the identification of items related to compulsivity, several specific criteria were established and applied, related to various characterizations of the construct retrieved from the scientific literature. This rigorous approach led to the identification of 586 items, out of a total of 2,693, considered relevant for exploring the construct. Subsequently, a detailed content analysis of the selected items was conducted to examine whether they could be grouped into different operationalizations of compulsivity, thus reflecting various conceptualizations or interpretations of the term. This thematic analysis yielded six distinct operationalizations of the term: (1) automatic or habitual behaviors, (2) behaviors insensitive to negative consequences, (3) overwhelming desire to initiate the activity, or urgency, (4) inability to interrupt the behavior once initiated, (5) attentional capture or cognitive hijacking, and (6) stereotyped behaviors or inflexible rules.

To conduct a thorough and specialized analysis, 15 representative items were selected for each of the identified operationalizations, resulting in a total of 90 items. This set of items was subjected to expert scrutiny in the field, who evaluated the clarity, precision, and adequacy of the delimitation of each specific operationalization of compulsive behavior. This evaluation process aimed to ensure that each operationalization accurately reflected different facets of compulsivity, thereby providing a solid foundation for the understanding and measurement of this complex construct in the field of behavioral addictions. The experts also provided recommendations for the wording of items that could be included in future measures of compulsivity, largely aimed at refining their wording to enhance their discriminative capacity. In summary, it was established as a necessary criterion that the items should explicitly refer to specific overt or covert behaviors, excluding those focused on thoughts or emotions that motivate the behaviors. Additionally, the formulation of the items should explicitly incorporate the manifestation of lack of control and the net disutility or disregard for instrumental goals.

Study III implements the findings of Study II and utilizes them to develop and validate a compulsivity scale (GRACC90; the Granada Assessment for Cross-domain Compulsivity) in two domains of behaviors recognized as potential behavioral addictions. Firstly, the 90 items were reformulated following the recommendations provided by the experts. Subsequently, the item set was administered to a convenience sample of individuals involved in gambling and video gaming activities, encompassing a broad spectrum of severity, whether within or outside clinical significance thresholds.

Structural equation modeling revealed that the construct of compulsivity fits better into a unidimensional model within the analyzed behavioral addiction domains, challenging the idea that it might be multifactorial or vary significantly across domains. Its structure remained consistent across different samples, as evidenced by variance analyses and high correlations between item loadings for both scales. Convergence analyses showed a higher correlation between compulsivity and gambling behavior severity compared to video gaming, although these differences were subtle. Significantly, compulsivity negatively correlated with measures of quality of life and positively with negative affect in both samples, suggesting a generalized impact on well-being regardless of the type of behavioral addiction.

To construct a shorter version of the scale (GRACC18), the 18 items with the highest factor loadings were selected. Interestingly, most items in this set referred to the dimensions of persisting in the behavior despite being aware of negative consequences (5 items), attentional capture or cognitive hijacking (5 items), and urgency (5 items). Two items referred to the dimension of automaticity or habitual behaviors, and one item to the operationalization of compulsivity as binging. The structure of the reduced scale was more distinctly unidimensional, which did not alter its ability to predict quality of life or negative affect.

Study IV aimed to replicate and expand upon the findings of a previous study (Quintero et al., 2020), delve into the role of model-free emotional regulation processes and generalized emotional dysregulation in problematic gambling symptoms, and establish a triadic association between behavioral markers, psychometric indicators, and psychophysiological markers of emotional regulation. Specifically, this study examined whether differences among gamblers in terms of generalized emotional dysregulation (positive and negative urgency) and craving influenced the acquisition and extinction of conditioned emotional associations, and how these variables interrelated with the severity of gambling symptoms. Several noteworthy findings emerged from this study.

First, and as expected, the results showed significant correlations between positive urgency, negative urgency, craving, and the severity of gambling symptoms. Of particular interest was the finding that positive urgency correlated more strongly with craving than negative urgency, suggesting that, at least in our sample, craving might be primarily driven by appetitive cues. This hypothesis was further supported by regression analysis and mediation analysis. The latter provided particularly intriguing data. In our study, the influence of positive urgency on gambling severity appeared to operate through craving (i.e., positive urgency increases craving, which in turn heightens gambling severity), but not directly. In contrast, negative urgency showed a direct impact on symptom severity. This suggest that difficulties in regulating positive emotions might play a significant role in increasing the desire to gamble, which has direct implications for the development of problematic gambling.

Secondly, it was found that positive urgency (but not negative urgency) was associated with a slower extinction of conditioned associations between neutral stimuli and affect-laden images. Post-hoc analyses revealed that this effect depended on the gamblers' preference for skill-based gambling, such as sports betting or card games. In our sample, the vast majority of gamblers had this preference, which could explain the rest of the findings and their contrast with the Quintero et al. study.

In conclusion, our findings indicate that higher scores on the positive urgency scale are associated with greater resistance to the extinction of emotionally conditioned cues, which in turn indicates a malfunction in model-free emotional regulation. The fact that positive urgency, rather than negative urgency, is responsible for the alteration of the underlying mechanisms of this type of regulation may be attributed to the specific phenotype of gamblers in our sample. This suggests that different etiological mechanisms may be involved in the development of gambling problems based on the profile of the gamblers. Finally, it is noteworthy that the analysis of electroencephalographic recordings showed no relationship between brain activity during task execution and performance, neither during the acquisition phase nor the extinction phase.

Finally, **Study V** sought to elucidate the underlying mechanisms of model-based emotional regulation in a sample of community gamblers. The purpose of this study was to specifically explore potential differences in the success of emotional regulation during a cognitive reappraisal task, as well as to identify psychometric markers associated with better or worse performance in this task. Additionally, this study sought to explore the existence (and, if applicable, the utility) of psychophysiological markers that could reflect the cognitive effort associated with task performance, following the conclusions of the study by Navas et al. (2017). Although the findings of our study did not show significant results, being mostly null, they offered a reasonably coherent view.

Neither dispositional use (as measured through psychometric tools) nor situational use (as measured through the cognitive reappraisal task) of emotional regulation was related to differences in craving scores or differences in the severity of problematic gambling symptoms. Nor were they related to the different indices of heart rate variability (HRV) recorded during the task. However, the relationship between the severity of gambling problems and craving with both negative and positive urgency was confirmed, aligning with previous research. We also observed a relationship between dispositional use of expressive suppression and positive urgency with a greater impact of task time on heart rate variability, suggesting that these forms of emotional regulation might influence the mental fatigue associated with task performance, leading to disengagement from the task.

Overall, our findings seem to indicate that model-based emotional regulation (or more specifically, those intentional and considered adaptive regulation strategies) may not play a decisive role in the severity of gambling problems in community gamblers. However, this does not rule out the possibility that general domain neurocognitive alterations might be relevant in clinical populations or gamblers with severe gambling problems.

General Discussion

This thesis is based on various streams of research that delve into different aspects of gambling. These investigations converge on exploring the role of alterations in various emotional regulation mechanisms in problem gambling. The contributions of our studies to these fields, as well as their theoretical implications, are detailed below.

What is the etiology of gambling-related cognitions and what role do they play?

In the Introduction section, we questioned the etiology and role of gambling-related cognitions in problem gambling. The relationship between these cognitions and gambling behavior appears clear, but the nature and causal direction of this relationship remain poorly understood due to inconsistent research findings. It is still debated whether cognitive distortions arise from general reasoning deficits, dysfunctional use of intact reasoning skills, gambling exposure or result from other distinct factors.

Through **Study I**, we explored this relationship by examining abstract and probabilistic reasoning in non-problem gamblers and those diagnosed with gambling disorder. The primary findings of this study are twofold, generally suggesting no connection between general reasoning abilities and the manifestation of gambling-related cognitions, while confirming a higher presence of such cognitions in gamblers who were located at the more severe end of the spectrum.

Convergence of our results with other studies

Regarding the hypothesis of the disconnection between reasoning ability and distorted cognitions, our results align with some studies. Lambos and Delfabbro (2012) found that pathological gamblers exhibited significantly more cognitive biases than regular or infrequent gamblers. More importantly, they found that these biases were not due to differences in probabilistic or numerical reasoning abilities between the groups. Indirectly, Delfabbro, Lahn, & Grabosky (2006) also found that problem gamblers tended to be more irrational in some gambling perceptions (e.g., illusion of control or increased perception of their skills) when compared to non-problem gamblers, despite showing no poorer understanding of objective probabilities than the latter.

Indirectly related, interventions aimed at improving probabilistic reasoning, combating erroneous gambling beliefs, and eliminating related biases and superstitious cognitions have not always significantly reduced erroneous gambling beliefs or improved probabilistic reasoning in at-risk or problem gamblers (although they have done so in non-problem gamblers; Donati, Primi & Chiesi, 2014). This result may confirm the difficulty in changing gamblers' erroneous beliefs, as they continue to perceive gambling as a matter of individual skill, even after being provided evidence of its incorrectness. Likewise, interventions on various aspects of gambling (randomness concept, awareness, and correction of erroneous beliefs and perceptions) in pathological gamblers reduced gambling severity and desire, but not gambling-related cognitions (Ladouceur et al., 1999). When intervention samples have not consisted entirely of gamblers (and where a minimal percentage were regular gamblers), there has been success in increasing resistance to gambling fallacies (Williams & Connolly, 2006) or in conferring various mediation roles to distorted cognitions and probabilistic reasoning in gambling severity and risk decision-making (Donati et al., 2014; 2018, respectively).

Also indirectly, a recent study found that a higher IQ, particularly the numerical ability subcomponent (though not the verbal or spatial subcomponent), positively predicted participation and spending in online horse betting, as well as a preference for complex betting formats (Suhonen et al., 2022). These findings resonate with the results of our study, where we found anecdotal to substantial support for positive associations between probabilistic reasoning (or numerical skills, measured through the BNT; Cockely et al., 2012) and gambling expectations, inability to stop, and interpretative bias in the sample of non-problem gamblers.

Of particular interest are the findings of Shaw et al. (2023), where the authors delved into the relationship between reasoning and statistical understanding, intelligence, other cognitive abilities, and gambling fallacies, measured by the Gambling Fallacies Measure (GFM; Leonard & Williams, 2016). They found that higher scores on abstract (Raven's Advanced Progressive Matrices; Raven, 2003) and probabilistic reasoning measures

(Cognitive Reflection Test; Toplak et al., 2011) correlated with higher GFM scores (thus indicating greater resistance to gambling fallacies). These scores also correlated with a reflective (vs. intuitive) and rational (vs. experiential) thinking style. Mathematical ability did not significantly correlate with the manifestation of fallacies. Regression analysis showed that a rational and reflective thinking style and higher probabilistic reasoning scores predicted resistance to gambling fallacies (while abstract reasoning did not significantly contribute). Although these findings are relevant, they are not directly comparable to ours since the sample consisted of students (not gamblers), specifically evaluated gambling fallacies (using a different psychometric tool), and the results were based on a general score from this questionnaire (leaving unknown which specific gambling fallacies contributed to the relationships between variables).

In summary, our results support previous literature, suggesting no necessary connection between probabilistic and abstract reasoning (or fluid intelligence) and gambling-related cognitions, at least regarding regular gamblers. In fact, if such a connection exists, it may indicate a greater ability rather than a deficit in these capacities. The fact that the studies which attempt to make these cognitions explicit or correct them, appear to have some short-term effect in reducing gambling involvement but do not eliminate the biases, seems to reinforce this proposal.

Gambling-related cognitions as ego-protective and emotional adjustment mechanisms: hiding the loss of control?

As previously suggested in the Introduction, if general domain reasoning alteration is not the basis of distorted cognitions, then, according to an alternative hypothesis, these cognitions would stem from the individual's interaction with gambling and its progression over time. Thus, cognitive distortions would emerge as a consequence of the emotional and motivational dynamics inherent in gambling-related problems. According to this proposal (e.g., see Navas et al., 2019; Ruiz de Lara, Navas & Perales, 2019; Buen & Flack, 2021; Jara-Rizzo et al., 2019), these distortions would function as defense mechanisms that conceal the inability to control behavior and disguise the adverse repercussions it entails.

Relationship between distorted cognitions and dispositional measures of emotional regulation. In the same line with the above, it could be suggested that gambling-related cognitions may result from mechanisms involved in the intentional regulation of emotions in response to gambling outcomes, thus influencing the mitigation of emotions experienced due to monetary losses. For example, cognitive reappraisal could be efficient but counterproductive if it targets inappropriate events (Troy, Shallcross & Mauss, 2013). Similarly, Ruiz de Lara, Navas & Perales (2019) observed that pathological gamblers might use this same strategy to maintain their distorted cognitions and justify their gambling behavior. Therefore, even those gamblers situated at the highest severity of the spectrum should maintain their ability to explicitly regulate emotions, as suggested by **Study V**. If so, gambling-related cognitions should directly relate to a greater capacity to execute intentional emotional regulation strategies, something the literature seems to confirm.

Ruiz de Lara, Navas & Perales (2019) found that reappraisal independently and significantly predicted gambling-related cognitions such as the illusion of control, predictive control, or interpretative bias. Other maladaptive strategies such as "rumination" or "other-blame" similarly predicted predictive control or the bulk of gambling-related cognitions measured by the GRCS, respectively. Jara-Rizzo et al. (2019) also found that cognitive reappraisal, measured with the ERQ, was positively and significantly associated with the intensity of gambling-related cognitions in a generalized manner, affecting all dimensions measured by the GRCS similarly. Tan & Tam (2023) found that gambling-related cognitions moderated the relationship between cognitive reappraisal and gambling severity. Specifically, they found that greater cognitive reappraisal capacity was associated with more severe gambling problems in the presence of gambling-related cognitions. When individuals did not exhibit these cognitions, cognitive reappraisal had no impact on gambling problems. Thus, they propose that reappraisal skills could exacerbate gambling problems among players prone to self-deception or self-justification. In contrast to this last study, Buen & Flack (2022) found that difficulties in emotional regulation influenced gambling problems through the mediation of cognitive distortions. They also found that emotional dysregulation did not mediate the relationship between gambling beliefs and gambling severity. Thus, they propose that emotional dysregulation could serve as a precursor to the development of cognitive distortions, while directly influencing gambling problems.

Distorted cognitions as an adjustment mechanism for the emotional impact of (monetary) losses. Beyond findings through dispositional measures, it is known that gamblers also reduce the negative emotional impact of losses directly during gambling. There is a tendency to interpret near-miss trials as evidence of mastering the game or as near-wins (Clark et al., 2009). In fact, these trials are processed psychophysiologically and cerebrally in a comparable way to real wins (Clark et al., 2009; Chase & Clark, 2010; Wu, van Dijk & Clark, 2014). Subjectively re-framing losses as a sign of imminent victory, as a near win or as evidence of control over the game, can condition the subjective experience of losses and maintain the desire to continue gambling (Griffiths, 1991; Barton et al., 2017; Clark et al., 2009; Billieux et al., 2012). These types of events are intensely and specifically related to interpretative bias and predictive control. Billieux et al. (2012) found that these two gambling-related cognitions (proposing them as a single factor of skill-oriented cognitions) predicted higher subjective scores of gambling desire after near-miss events, as well as predicting the subjective motivational effects of near-misses on gambling desire. Similarly, Ariyabuddhiphongs & Phengphol (2008) found that the gambler's fallacy increased the likelihood that after a near-miss, gamblers would decide to keep betting, reinforced by the belief that a win was imminent after several consecutive losses.

***Gambling-related cognitions as motivated* reasoning.** Within this context, the gambler's fallacy or the hot-hand fallacy is a type of predictive control that could also trigger these adjustment processes. Although both types of beliefs seem mutually exclusive, they usually coexist in the gambler's worldview and alternate according to their needs to fit gambling outcomes. As indicated in the Introduction, gamblers perceive that a sequence of events generated by humans or non-random devices tends to continue (positive recency, hot-hand belief), while they expect sequences generated by random mechanisms to stop (negative recency, gambler's fallacy), suggesting that perceived intentionality in the agent influences these expectations (Aton & Fischer, 2004; Clark, 2017;

Tyszka et al., 2008). Additionally, the desire to observe a specific outcome can bias reasoning towards strategies that reinforce the desired belief, be it the continuation or cessation of a streak (Braga et al., 2016; Caruso et al., 2010).

These beliefs and emotional biases associated with gambling, such as the gambler's fallacy and the hot-hand belief, can function as self-deception mechanisms that allow gamblers to reduce the emotional impact of losses and justify continued gambling. These processes, influenced by motivation rather than intellectual capacity, reflect motivated reasoning that distorts the perception of reality to align it with preexisting desires (Kunda, 1990; Navas et al., 2019).

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Although some etiological models link cognitive biases with the conditioning process that promotes the progressive pathologization of gambling, both the available data and our research partially challenge this hypothesis. It appears that gambling-related cognitions may not be the primary cause of gambling problems; rather, they emerge as a result of these problems and, over time, may contribute to their perpetuation. In other words, these cognitions, which are linked to—and idiosyncratic of—problem gambling, would evolve alongside the transition from functional or goal-directed gambling behavior to compulsive gambling behavior.

In fact, analyzing these elements has allowed us to better understand the nature of cognitive biases as phenomena accompanying the problem and how they may actively contribute to the development of problematic gambling patterns. For example, it is plausible to consider that gambling-related cognitions, by altering emotional experiences, could eventually be seen as a subtype of emotional regulation that facilitates continued gambling despite adverse consequences. Moreover, considering how these cognitive mechanisms activated during, before, or after gambling can interact with, or even enhance, the underlying and core processes of disordered gambling is essential. In this sense, addressing the role of cognitions in gambling has prepared us to explore more deeply the progressive pathologization of gambling behavior.

As suggested at the beginning of this thesis, it is the learning and conditioning processes, altered and influenced by the structural characteristics of gambling devices, that seem to underpin the transition from goal-directed gambling to one characterized by compulsivity. These processes are the main factors leading to the development of an uncontrollable desire to gamble, known as craving. Therefore, the central problem of disordered gambling would lie in the progressive acquisition of compulsivity.

To explore this proposal, and taking into consideration that the root of gambling problems and gambling disorder may lie in compulsivity, we set out to delve into the characterization of this construct to explore its nature in detail.

How is compulsivity characterized in problematic gambling and video game use?

In **Chapter IV** of our research (**Studies II** and **III**), we aimed to explore the nature of compulsivity in behavioral addictions, particularly in problematic gambling and problematic video game use. The findings of **Study III** revealed that the three fundamental components characterizing compulsivity in both domains partially align with those described in the specialized literature. Specifically, by selecting the most discriminative items of the GRACC90 (i.e., those with the highest factor loadings in both samples) to offer a brief version of the questionnaire, we discovered that most of them belonged to three of the operationalizations of compulsivity proposed in **Study II**: (1) *Cognitive/attentional hijacking or interference caused by activity-related thoughts or images* (e.g., “Anything related to playing immediately catches my attention and interferes with what I’m doing at that moment”), (2) *Insuperable urge compelling the individual towards the activity that jeopardizes the ability to control it* (e.g., “I feel an uncontrollable desire to play even right after I’m done”), and (3) *Behavior continuance despite awareness of imbalance between harm and reward* (e.g., “I continue to play even though I’m fully aware that I have increased the risks in certain aspects of my life so much that it’s not worth it”).

It is notable that these operationalizations (henceforth *cognitive hijacking*, *irresistible urge*, and *harmful persistence*, respectively) partially overlap with what has been documented in previous studies as characteristic properties of incentivized stimuli and manifestations of a multifaceted craving response (e.g., Meyer et al., 2012; Berridge & Aldridge, 2009; Ciccarelli et al., 2016; Berridge & Robinson, 2016; Anselme & Robinson, 2020; Zhang & Clark, 2020; see also Introduction). They also align with the diagnostic criteria for gambling disorder and video game use disorder in the 11th edition of the International Classification of Diseases (World Health Organization, 2022). It should not be surprising that these three aspects are considered central axes in the characterization of each construct (which are deeply interrelated). From the scientific literature reviewed and our studies, it can be derived that incentive sensitization constitutes the fundamental core of craving (e.g., Robinson & Berridge, 1993), which serves as the fuel for the compulsive behavior that underlies and drives addictive behavior and loss of behavioral control (e.g., Lüscher, Robbins & Everitt, 2020).

Tentatively, we propose that the three mentioned “ingredients” could be central to characterizing the compulsive behavior underlying established behavioral addictions (i.e., those examined in this thesis). However, we must be cautious before making this step. The following sections will present some points in favor of this hypothesis, which, we anticipate, will remain open. Subsequently, we will dissect the most important implications of our work strategy and our data concerning the current state of knowledge in this field. Nonetheless, we believe that the approaches and methodologies adopted in our studies have allowed us to bypass the limitations and contradictions of previous etiological models, avoiding, in our view, the pitfalls inherent in extensional and confirmatory approaches. This, in turn, has enabled us to conduct a thorough examination of our data interpretation, not devoid of limitations and criticisms.

Towards an intensional proposal for characterizing compulsivity

As mentioned, our proposal should be taken with caution, pending future research providing relevant evidence on this hypothesis. Specifically, as defended in **Study III**, we speculate that *cognitive/attentional hijacking* and the *irresistible urge* to gamble/play represent two symptomatic aspects of the same phenomenon: craving. The first aspect would reflect its more cognitive dimension (e.g., the cognitive elaboration of desire; May, Kavanagh & Andrade, 2015; Cornil et al., 2018, 2019), and the second would encompass its more motivational and affective elements (a "wanting" or irresistible desire independent of the expected hedonic satisfaction from the activity; Robinson & Berridge, 1993; 2008). Both aspects, if sufficiently intense, would lead to a loss of behavioral control, despite awareness of its futility and the disadvantages of "giving in" to these impulses. In other words, *cognitive hijacking* and *irresistible urge* (understood as manifestations of craving) would constitute the core elements of compulsivity, and the maintenance or increase in behavior (despite negative consequences) or *harmful persistence* would be the consequence or the observable sign.

Avoiding a component model of compulsivity. Our hypothesis can be examined in light of new intensional proposals about the consideration of the "addictive" phenomenon, emerging as critiques of the structural validity of the component model (e.g., Charlton, 2002; Charlton & Danforth, 2007; Deleuze et al., 2018; Fournier et al., 2023). One of these new approaches proposes that, in the realm of behavioral addictions, there are central components (i.e., constitutive of pathology) and peripheral components (i.e., traits or characteristics whose presence is not useful for distinguishing between pathological and non-pathological behaviors; Charlton, 2002; Charlton & Danforth, 2007). We understand that this approach, intended to discriminate between the essential and secondary components that define a behavior as "addictive" (in an effort to avoid overdiagnosis and determine its etiological causes), can be equally valuable for identifying relevant components to establish a behavior/component as constitutive of "compulsivity" or not. Following this line, our data could suggest that dimensions with items that have a higher factor load (i.e., that contribute most to the construct being measured) would be central to compulsivity in the examined behavioral addictions (in our case, *irresistible urge*, *cognitive hijacking*, and *harmful persistence* despite negative consequences). Similarly, dimensions whose items obtain lower loads could be considered peripheral components related to compulsive behavior (in our case, *purely habitual or automatic behaviors*, "*binges*," and *inflexible ritual behaviors*).

We will compare our proposal based on the results of seminal and more recent studies that have laid the foundation for the mentioned approach. For example, Charlton & Danforth (2007) conducted an exploratory factor analysis of the (six) component model in the realm of online video games. They found that the components loaded into two clearly differentiated factors. The first factor, termed "engagement" (i.e., peripheral components), included items related to *euphoria* (similar to *mood modification*; Griffiths, 2005), *salience* (comparable to attentional capture or *cognitive hijacking*; Griffiths, 2005), and *tolerance*. The second factor, "addiction" (i.e., central components), comprised items referring to *relapse* (assimilable to *intense urge*, *urgency*, or loss of behavioral control; Billieux et al., 2019), *conflict* (equivalent to *harmful persistence* despite negative consequences; Billieux et al., 2019), and *withdrawal*. This work highlighted that high involvement in an activity does not necessarily imply addiction, but rather an intense commitment to it without negative consequences for the individual (Charlton & Danforth, 2007). Fournier et al. (2023) similarly explored the psychometric validity of the component model in the domain of "addictive" social media use. Their results presented a similar panorama, with the difference that the *mood modification* component was integrated into the "addiction" factor, while *salience* and *tolerance* continued behaving as peripheral components (see also Amendola, 2023, and

Fournier et al., 2024, for an in-depth analysis of the robustness of the data). More closely related to our data, a study by Deleuze et al. (2018) with video game players revealed that *conflict*, *relapse*, and *withdrawal* (along with *salience*, to a lesser extent) were strongly associated with a factor similar to "addiction" (i.e., obsessive passion), while *salience*, *mood modification*, and *tolerance* aligned more with a factor equivalent to "engagement" (i.e., harmonious passion).

While we remain skeptical about the potential overlap between our categories and the constructs evaluated in previous studies, our data coincide in that *irresistible urge* (i.e., *relapse*) and *harmful persistence* (i.e., *conflict*) would be essential criteria for characterizing behavior as constitutive of compulsivity (this is noteworthy in itself, as we have reached the same conclusions with different methodologies). However, the centrality of the other side of craving, *cognitive hijacking* (i.e., cognitive *salience*), does not fully align with the results of the reviewed studies (except in the case of video games, where this relationship is quite mild, and the study methodology is relatively different). Nonetheless, the inclusion of *salience*/*cognitive hijacking* as a central component in our proposal can be justified, at least, by two arguments.

First, cognitive capture, attentional bias, or neural reactivity to cues have been vigorously studied in their relationship with craving in the context of problematic gambling and also in video games (Franken et al., 2000, 2003; Brevers et al., 2011, 2019; Limbrick-Oldfield et al., 2017; Wulfert, Maxson & Jardin, 2009; van Holst et al., 2012; for two systematic reviews, see García-Castro, Cancela & Cárdaba, 2022; Starcke et al., 2018). Second, as Fournier et al. (2023) noted, components may have different implications depending on the domain where they are situated and how they are characterized (i.e., how the items representing the construct of interest are operationalized). For example, as inferred from their study, the *mood modification* component could be central to "addictive" social media use when used to escape personal problems, but not in problematic video game use, where the construct is described slightly differently (i.e., *euphoria*), implying excitement seeking (Charlton & Danforth, 2007).

This last point acquires particular relevance, given that the lack of rigor in operationalizing scale items derived from extensional models has often been questioned. This ambiguity in item wording could lead to a theoretically essential component for addictive behavior being defined so broadly that practically any individual involved in the activity would be reflected in it. Similarly, different components may manifest as central or peripheral depending on the study domain.

The importance of domain heterogeneity and item operationalization: towards a satisfactory model. Two key issues emerge from the previous paragraphs. The first refers to the likelihood that compulsive behavior is characterized differently in various behavioral addictions, suggesting that there may not be a uniform characterization for disorders supported by this diagnostic label. Currently, a wide range of potential behavioral addictions is recognized, some well-established and others considered putative or even “moot” addictions (Petry, Zajac & Ginley, 2018; Rumpf et al., 2019; Petry & Petry, 2016; Perales et al., 2020; Griffiths, 2019; Billieux et al., 2019). Therefore, it is crucial to consider specific research domains, as different "addictions" may present different central problems, diverse etiological trajectories, and distinct relationships with other convergent measures. Similarly, the construct of compulsivity may manifest differently in various activities, as well as in different sub-profiles of individuals who engage in them (e.g., gamblers with preferences for different gambling modalities).

With this in mind, the GRACC90 was validated in two different samples, corresponding to two representative domains of two different behavioral addictions. While **Study III** suggests that both addictions share similarities in how loss of behavioral control manifests, it is important to note that this does not imply that the etiological causes of compulsivity in problematic gamblers and video gamers are the same. In other words, the common presence of similar symptoms or signs of compulsivity should not be interpreted as evidence that these play the same role or, if they do, that they stem from the same underlying mechanisms.

The second issue is that, before labeling components as central or peripheral, it is necessary to make a precise effort in item wording and a meticulous analysis of their functioning before testing them. Item and component operationalization is crucial, as these should serve to discriminate between specific internal or external behaviors that are constitutive of pathology or not.

As seen, it may happen that some components traditionally aimed at defining addictive disorders might not be discriminative of such a condition, representing simply a high degree of involvement in potentially addictive activities. An exchange of views between Billieux et al. (2019) and Griffiths (2019) illustrates this issue well. For Billieux et al., *cognitive salience* is operationalized in some psychometric instruments in a way that could reflect harmonious passion rather than a correlate of addictive behavior. In contrast, Griffiths argues that if the same construct is operationalized according to the original definition, it should clearly focus on negative aspects (e.g., when the activity becomes something that dominates thoughts and leads to behavior deterioration), thus meeting the criteria for a central and necessary component.

In **Study II**, we attempted to address this issue carefully. The development of items representing the different conceptualizations of compulsivity followed an iterative process: initially selected based on preliminary categories, discrepancies and overlaps in their content were identified, and the categories were redefined based on the information obtained from the items themselves. Subsequently, a draft of the GRACC90 was reviewed by a panel of experts who judged whether the items adequately represented compulsivity, assigned them to different operationalizations blindly, and reported delimitation issues in capturing the construct. For example, they pointed out that some items might reflect overvaluation of goals rather than compulsivity, that others did not refer to loss of control, or were insensitive to the behavior's futility (e.g., when assessing insensitivity to negative consequences, it was necessary to expand the item by mentioning that such consequences contradicted the activity's rewarding outcomes and making it explicit that the individual was aware of this). In another case, it was observed that the category "Automatic or habitual behavior occurring in absence of conscious instrumental goals" had items that, although adequately operationalized, could refer to a lack of positive attention or "flow state," which might be more representative of harmonious passion or high commitment to the activity than compulsive behavior (Barberis et al., 2021).

Through these and other cases, we ensured that the items were measuring the constructs of interest as accurately as possible.

Beyond a definition based on central and peripheral components. All the steps taken thus far lead to an attempt to define compulsivity based on its characterization in gambling and video games. To this end, we followed recommendations from several authors advocating for an intensional and transdiagnostic approach to the process (e.g., Kardefelt-Winther et al., 2017; Karhulahti et al., 2023). Besides defining the construct of interest appropriately, it is necessary to seek strong evidence of construct validity. In this sense, our scales' scores (original and brief) correlate intensely with the severity of symptoms in gamblers and video gamers.

Moreover, beyond the components and scores on scales assessing activity severity, labeling a behavior as compulsive/addictive requires an additional criterion: its manifestation involves significant and recognizable functional impairment in various aspects of the individual's life (Kardefelt-Winther et al., 2017; Billieux et al., 2019). To this end, we evaluated the relationship between our instruments' scores with a Negative Affect scale and a Quality of Life scale. The scores correlated (positively and negatively, respectively) significantly, which can be interpreted to indicate that compulsivity, as measured by the developed psychometric tools, is related to a general dimension of psychological distress and a negative perception of physical well-being and health.

Finally, it is worth noting that the severity scales used in convergent validity analyses, as discussed in this thesis, have notable limitations, especially in their ability to differentiate between high involvement in an activity and problematic behaviors. Among the intensional approaches highlighted at the beginning of this section, the Dualistic Model of Passion attempts to correct this limitation (Vallerand et al., 2003; Curran et al., 2015). Briefly, the concept of passion is presented as a strong inclination towards an activity considered important by the individual, in which time and resources are invested (Vallerand et al., 2003; Vallerand, 2010, 2015). Based on this, the concept diverges into two distinct types. Harmonious passion facilitates a free and controlled commitment to the activity, integrating it harmoniously with other life aspects without leading to negative consequences, and is associated with positive emotions, flow states, and greater adaptability. Conversely, obsessive passion is characterized by an uncontrollable drive towards the activity, leading to loss of control and generating conflicts with other areas of the individual's life. It manifests as inflexible engagement in the activity, resulting in negative affect and numerous adverse consequences (Vallerand et al., 2003; Curran et al., 2015; Orosz et al., 2016).

Empirical studies delving into putative behavioral addictions from this framework (e.g., internet addiction or problematic use, video games, social networks, or compulsive TV series watching) consistently show that both forms of passion correlate significantly with severity measures. However, only obsessive passion is associated with trait compulsivity measures (e.g., urgency), negative cognitions, adverse consequences, and other indicators of functional impairment (Vallerand et al., 2003; Burnay et al., 2015; Billieux et al., 2015; Orosz et al., 2016; Deleuze et al., 2018). Thus, it seems that individuals with high engagement or excessive involvement (but harmonious) manage to maintain behavioral control. However, the development of obsessive passion is associated with unfavorable consequences and an uncontrollable, compulsive use, presenting itself as a manifestation or a pathway to behavioral addiction (Andreassen, 2015; Holding et al., 2021). Although not part of this thesis' work, it is noteworthy that in our validation study of the brief scale (in preparation), using similar convergent validity measures (such as positive and negative urgency), we found that these measures similarly relate to the compulsivity scores measured by the GRACC18, which could support that it captures genuinely compulsive/addictive behaviors and not merely high engagement with gambling and video games.

Craving as the driver of compulsivity

Compulsivity appears to be understood as a heterogeneous yet unidimensional construct. Depending on the study area, different aspects of compulsivity may be more predominant, but the various dimensions defining it (both internal and external behaviors and clinical signs or symptoms) are so interrelated that opting for a clearly multidimensional model is difficult. From **Studies II** and **III**, we conclude that craving, in its multiple forms, lies at the center of compulsivity in behavioral addictions.

In this sense, understanding craving as a multidimensional construct composed of several sub-facets is not unprecedented. Previous theoretical proposals suggested that craving is not a unitary process but the emergent consequence of the interaction between distinct subcomponents specific to the craving experience (Flaudias et al., 2019). These could be related to different neural and cognitive systems (Noël, Brevers & Bechara, 2013). Similarly to our results, two of the subcomponents of this triadic neurocognitive model (automatic craving and physiological craving) partially coincide in their description with the two components prevailing in our studies (Flaudias et al., 2019). The first is related to cue reactivity and attentional biases towards craving-related cues, proposed to depend on the automatic/habitual and affective system, thus resembling our facet of attentional hijacking. This description aligns with other approaches like the Elaborated Intrusion Theory (May, Kavanagh & Andrade, 2015), which defines craving as affectively charged cognitive events where attention remains focused on the object of desire, successfully investigated in the context of gambling (Cornil et al., 2018, 2019). The second relates to the interoceptive system, sensations associated with withdrawal symptoms, and their translation into impulses, which could be similar to our category of irresistible urge (overlapping with the previously discussed withdrawal component). The third subcomponent would be cognitive craving, proposed to depend on the reflective system and be related to high-level cognitive abilities. Following this description and considering the results of **Study I**, we tentatively suggest that it might also be related to gambling-related cognitions as a "reflective" response to loss of behavioral control.

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Throughout this subsection, we have aimed to provide an exhaustive analysis of the methodology used to characterize compulsivity from an intensional approach. This approach has served as a support point to enrich, complement, and debate the analysis of our data. However, as mentioned in the Objectives, Justifications, and Hypotheses section, our approach would not be complete without analyzing the underlying mechanisms seemingly linked to the manifestation of craving, the fundamental core of compulsive behavior.

As outlined in the Introduction, craving is frequently described in the scientific literature as an intense emotional experience. Therefore, its manifestation could arise from deficiencies in emotional regulation processes. **Studies IV** and **V** aimed to verify whether dysfunctions in various emotional regulation mechanisms could intensify craving and exacerbate problematic gambling symptoms. Therefore, in the next subsection, we will examine our findings based on this premise.

What is the role of alterations in the mechanisms of emotional regulation in the severity of gambling and the manifestation of craving?

In **Studies IV** and **V** (**Chapters V** and **VI**), we set out to investigate whether alterations in the mechanisms underlying emotional regulation are foundational to uncontrolled or excessive craving. Our investigation aimed to determine whether the proper functioning of these mechanisms could keep craving under control or prevent its manifestation, thereby serving as a protective barrier against the symptoms of craving and their impact on the severity of gambling problems. By understanding craving as an affective state and a core component of compulsivity, we posited that disruptions in emotional regulation mechanisms could ultimately facilitate the transition from recreational gambling to addictive behavior, triggering the processes examined in earlier sections.

It is noteworthy that most of the evidence in this area comes from dispositional measures. While these measures allow us to compare our results with other studies and propose an integrated explanation of the findings, they must be interpreted with caution. Our objective extended beyond dispositional measures of emotional regulation to include the identification of reliable proxies for its functioning. Furthermore, exploring the expression of these mechanisms through laboratory tasks and psychophysiological markers was imperative for establishing a causal explanation of addictive behavior and constructing a comprehensive narrative supporting our intentional approach.

Our studies also provided insights into the affective nature of craving, enabling us to discuss whether it manifests as an emotional state with aversive or appetitive characteristics. Additionally, we hypothesized that the different manifestations of these elements might correspond to different domains of study, whether in the context of various behavioral addictions or distinct gambler profiles. The results of our studies are situated within the framework of the emerging profile of young gamblers who prefer skill-based games, a demographic that predominantly comprises our study samples.

Discussing the Role of Model-Free Emotional Regulation Mechanisms

In **Study IV**, we explored the influence of urgency as an indicator of generalized model-free dysregulation on craving and symptoms of problem gambling. Our findings corroborate existing literature that links affective impulsivity with gambling craving and problem gambling symptoms (e.g. López-Guerrero et al., 2023; Quintero et al., 2020; Kim et al., 2018), and also confirm its association with difficulties in extinguishing conditioned associations between initially neutral stimuli and emotionally charged images (e.g., Quintero et al., 2020). However, our results suggest distinct roles for the generalized failure to regulate positive and negative emotions in the manifestation of craving and the emergence of gambling-related symptoms.

Specifically, our results indicate that both positive urgency and negative urgency are correlated with the severity of disordered gambling symptoms.

However, while negative urgency remains a significant predictor after controlling for craving, indicating a direct effect on severity, the effect of positive urgency appears to be mediated through craving. These findings have several important implications.

Firstly, they suggest that craving mediates the relationship between positive urgency and the severity of gambling problems. This implies that urgency reflects a difficulty in regulating emotions, including the regulation of craving. It also supports the view that craving is related to incentives, at least in certain subpopulations of gamblers, aligning with several studies (Wilson et al., 2022; Mansueto et al., 2019; Cornil et al., 2017; Robinson & Berridge, 1993, 2001; Kavanagh, Andrade & May, 2005).

Secondly, the absence of an effect of negative urgency on craving, alongside its direct effect on gambling severity, supports the notion that negative urgency is a complicating factor in behavioral dysregulation and addiction (Navas et al., 2019; Perales et al., 2020). However, it is not central to the etiology of gambling problems, assuming we accept that craving is the primary driver of these issues. The impact of negative urgency on severity may be exerted through complicating factors or comorbidities with a basis in negative affect or externalization (though different perspectives exist, e.g., Marmorstein, 2016). In this regard, and as previously hypothesized, the transdiagnostic nature of negative urgency could make individuals with disordered gambling more susceptible to other conditions, thereby increasing the risk of clinical complications not necessarily caused by gambling itself (Zorrilla & Koob, 2019; Um et al., 2019).

Convergence of our results with other studies. The pattern of results described may be specific to the behavioral domain of gambling as well as other areas within behavioral addictions. The evidence in this regard is relatively consistent. For instance, while Quintero et al. (2020) found that craving mediated the effect of negative urgency on gambling problems (using a methodology nearly identical to our study and also involving a convenience sample of predominantly non-pathological gamblers), a reanalysis of the mediation model that included positive urgency revealed that positive urgency had an indirect effect on severity through craving, eliminating the (direct or indirect) effect of negative urgency on severity (López-Guerrero et al., 2023). Thus, we "replicated" the indirect link of positive urgency on severity observed in the study we aimed to replicate.

Furthermore, a study by Rivero et al. (2023) in two culturally differentiated samples of video gamers found a pattern that completely coincided with ours (with craving mediating the effect of positive urgency on Internet Gaming Disorder symptoms and a direct effect of negative urgency on the same symptoms). This result adds evidence in support of the findings from **Study III**, regarding the possibility of a common etiological pathway in the mechanisms involved in the loss of behavioral control in both gamblers and video gamers. Additionally, gamblers who prefer skill-based games appear to have a profile similar to that of video gamers (Grubbs et al., 2024; Clark et al., 2014).

Lastly, it is worth highlighting the results of a recent comprehensive review by López-Guerrero et al. (2023), which allows us to reinterpret the findings of **Study IV**. In their study, they sought to determine whether positive or negative urgency played a more significant role in the manifestation of craving and the severity of addictive behaviors. After accessing the raw scores of urgency, craving, and severity measures from some of the records that survived the inclusion process, they conducted mediation analyses similar to our study. Consistent with our results, most studies (4 out of 5) on which this model could be executed revealed a significant indirect effect of positive urgency on the severity of symptoms through craving. However, the direct link between negative urgency and severity (independent of craving) only appeared in studies conducted by our team (**Study IV** and Rivero et al., 2023), suggesting that our findings regarding the direct effect of negative urgency on severity may be more the exception than the rule. This issue could be explained by a higher percentage of gamblers and video gamers in our studies who are situated on the more severe end of the severity spectrum. This makes sense considering the disappearance of this effect in the study by Quintero et al. (2020), whose sample presented slightly lower levels of severity and included gamblers participating in gaming modalities that we excluded from our study (e.g., lottery) as well as some non-gamblers.

Interestingly, the analysis of one of the registered study samples (Cornil et al., 2019) found a contrasting pattern to ours, i.e., a direct effect of positive urgency on severity and an indirect effect of negative urgency through craving. The direct effect of positive urgency on severity was also found (along with an indirect effect of positive urgency) in another data set. This could be interpreted as indicating that positive urgency (and not just negative urgency) may also influence the development of addictive behaviors independently of craving. This difference may result from the assessment of craving using different scales. While the studies by Rivero et al. (2023), Quintero et al. (2020), and **Study IV** used the same craving scale, finding the same pattern of results, the study by Cornil et al. (2019) used an adapted (and validated) version for gambling of the Craving Experience Questionnaire (g-CEQ; Cornil et al., 2019), theoretically anchored in the Elaborated Intrusion Theory (EIT), which assesses craving more related to cognitive constructs (e.g., intrusive thoughts, mental imagery). Similarly to the study by Quintero et al., most gamblers in this study (almost half) gambled only a few times a year, with an overall preference for scratch cards and lotteries, so the profile of the gamblers could also explain the differences found, highlighting the need to characterize gambling problems considering the heterogeneity of gamblers, preferences for different gambling modalities, and the severity spectrum on which they are situated.

Different urgencies, different roles?. Considered together, the results suggest the existence of other factors beyond the behavioral domain that could explain the different roles of positive and negative urgency in craving and problematic gambling severity. One possibility is a hypothetical "escalation" from a predominant role of positive urgency in the early stages, with non-pathological levels of severity, to a predominant role of negative urgency in later, more severe stages. Following the reflection of Gullo, Loxton & Dawe (2014), positive urgency may play a more prominent role in predicting early gambling problems, while negative urgency may have a stronger predictive role after dependence symptoms emerge. For instance, gambling is likely to lead to significant financial losses in advanced stages and promote negative affect, which may result in using gambling as a coping strategy to deal with adverse emotional states, thereby facilitating problematic behaviors like chasing losses under intense emotional conditions (Bonnaire et al., 2022). It may also promote positive affect in situations of winning or the anticipation of such, with evidence suggesting that dysregulation of positive emotions is associated with problematic gambling behaviors (Rogier et al., 2022).

This possibility, however, is not supported by available research in our field of interest, as few studies have systematically investigated variations in the triadic association patterns between urgencies, craving, and gambling problems across domains, along with severity levels, using comparable methods (with the only attempt, to our knowledge, being the work of López-Guerrero et al., 2023).

Utility of discriminating positive and negative urgency. Despite the emerging evidence from our findings, which seem to attribute differentiated roles to negative and positive urgency, divergences persist in the literature regarding whether the emotional component of impulsivity constitutes a unitary construct, or whether the valence of urgency gives rise to two distinct constructs—positive and negative (Johnson et al., 2020). This debate remains unresolved. Some studies suggest that the valence of urgency plays a secondary role in influencing behavior; they argue that the central issue is the inability to maintain control during intense emotional states (Johnson et al., 2020). In other words, the disruption of control management is more critical than the emotional valence of impulsive behavior itself (Willie et al., 2022).

On one hand, evidence from psychometric research suggests that urgency should be considered a single factor. Studies using component analysis (Sperry, Lynam & Kwapil, 2017) or network analysis (Billieux et al., 2021) show that items from both constructs merge into a single general urgency factor in both clinical and non-clinical samples. Other studies indicate that, depending on the community detection algorithm used, network analyses might treat positive and negative urgency as distinct clusters or as a single cluster (Eben et al., 2023). It is hypothesized that differences in scores for positive or negative urgency could be due to respondents' baseline or contextual levels of positive or negative affect (Billieux et al., 2021).

Conversely, different research advocates for distinguishing between the two constructs (Cyders & Smith, 2007, 2009; Whiteside & Lynam, 2001). Reconciliatory proposals suggest that both constructs could be separate, though strongly related, "subprocesses" within a broader dimension encompassing responses to intense emotion (Berg et al., 2015). This approach emphasizes that considering both dimensions can facilitate understanding how emotional impulsivity manifests in different contexts, while also warning that distinguishing between the two might lead researchers to overlook their similarities, thus losing valuable information about their shared etiology (Berg et al., 2015).

Another argument regarding the distinction between the two constructs involves their ability to discriminate in the dynamics of problem gambling and other pathologies (e.g., Birkley & Smith, 2011; Stautz et al., 2017; Bold et al., 2017; Jara-Rizzo et al., 2019; Ruiz de Lara, Navas & Perales, 2019; see Berg et al., 2015 for a meta-analytic review). For example, some studies have found that negative urgency is associated with reckless behaviors under negative mood states, while positive urgency is linked to risky behaviors under positive mood states (Cyders & Smith, 2007). Additionally, longitudinal studies have demonstrated that positive urgency predicts an increase in alcohol consumption among college students, mediated by positive expectations about its effects, whereas negative urgency influences consumption as a way to manage distress (Settles, Cyders & Smith, 2010).

Nevertheless, some studies support the hypothesis that urgency is a construct that responds to distress triggered by the intrusion of intense emotions, regardless of valence, and experienced as aversive. These investigations find that positive urgency is associated with increased negative affect and decreased positive affect, indistinguishable from the correlation patterns of negative urgency (Sperry, Lynam & Kwapil, 2017). De Castro et al. (2007) found that gambling craving was inversely correlated with positive affect, and alcohol craving was directly correlated with negative affect. Both were also related to an unpleasant state of arousal. Borges et al. (2017) found that both positive and negative urgency were related to distress intolerance. These findings challenge whether we can consider the existence of different natures of craving (appetitive vs. aversive; **Study IV**), although they do not refute that urgency traits contribute to compulsive engagement in addictive behaviors (Birkley & Smith, 2011).

Finally, it is necessary to reflect on the utility of urgency as a dispositional measure. Generally, the literature has primarily used a single measurement method to assess the construct of emotion-based impulsivity; that is, using dispositional self-report measures (e.g., Lynam et al., 2006; Carver et al., 2011). However, urgency implies a conditional process (i.e., if I experience intense positive/negative emotions, then I will engage in risky behaviors) that self-reports only capture indirectly (Sperry, Sharpe & Wright, 2021). Implementing other experimental methodologies, such as ecological momentary assessment (EMA), could enrich our understanding of these dynamic processes (Wright &

Hopwood, 2016) and their relationship with gambling problems. Indeed, when this approach has been used in everyday contexts, it has been shown that negative affect predicts impulsive behavior, but negative urgency does not moderate this effect (Feil et al., 2020). This serves as an example that, at least in some circumstances, discrepancies may exist between the theoretical dynamic nature of affect-based impulsivity and dispositional measures of urgency, although some studies have been more successful in relating both measures in alcohol consumption (e.g., Wonderlich, Molina & Pedersen, 2022). These issues have practical implications for this thesis and will be addressed later.

In conclusion, we consider that the two positions examined at the beginning need not be entirely discrepant. In our area of interest, intense emotions in gamblers with model-free emotional regulation problems could trigger the manifestation of craving and problematic gambling behaviors regardless of valence. However, it is also possible that appetitive or aversive tendencies are relevant at different severity stages or depending on preferences for different gambling modalities, and that the nature of craving responds to these differences. Additionally, problem gambling need not be solely a consequence of trait impulsivity (self-reported), but could also be influenced by personal gambling history and the structural characteristics of gambling devices (e.g., Torres et al., 2013). Therefore, while urgency may be considered a single construct in some contexts, in our study, both dimensions provide crucial and differentiated information.

UP, UN, and extinction. The results of Quintero et al. (2020) and **Study IV** echo the previous reflection. The contrast regarding the relationship between urgency and the slowing of extinction has been explained by differences in the participant samples between the two studies. We found that the effect of positive urgency on extinction was strongly modulated by preferences for casino and skill-based games, whereas the effect of positive urgency on extinction tended to disappear in participants who preferred pure chance games. However, we have not been able to verify whether this possibility could explain the results of Quintero et al. Both urgencies, therefore, seem to be associated with a slowing of extinction processes, possibly depending on other underlying characteristics of the gamblers.

In fact, the objective of using the acquisition-extinction predictive task in **Study IV** was to find an emotional regulation paradigm useful in the study of problem gambling, and a more reliable alternative to dispositional self-report measures—such as negative urgency—that may serve as indirect proxies for these processes. Resistance to extinction is a commonly used index of behavioral perseveration (Robbins, Banca & Belin, 2024). Persistence in gambling under extinction conditions (i.e., when winning outcomes are no longer obtained) has also been used as a behavioral index of gambling propensity and has been related to gambling-related cognitions, such as skill-based beliefs (Bonnaire et al., 2022; Billieux et al., 2012) and the belief that financial losses can be recovered by continuing to gamble (Banerjee et al., 2023). Preferences for chance-based games also seem to explain the chasing of losses, which could be attributed to structural characteristics of gambling products, such as chronic exposure to intermittent reinforcement schedules, more pronounced in fast-paced games (e.g., slots; Banerjee et al., 2023; Horsley et al., 2012).

All points considered, new lines of research that contemplate these possibilities could be interesting, as they could open the door to understanding how model-free emotional dysregulation and extinction processes may be influenced by different phenotypes related to resistance to extinction processes (e.g., single-trackers vs. goal-trackers; Schad et al., 2020; Ahrens et al., 2016; Anselme & Robinson, 2020). However, it is still important to consider the possibility that model-free emotional dysregulation underlies different behavioral variables.

Model-free mechanisms: a pre-appraisal regulation?. Finally, our results seem to confirm the hypothesis that model-free regulation, whether successful or not, operates before the individual becomes fully aware of their craving state. This, however, does not exclude the possibility that model-free emotional regulation processes intervene in subsequent temporal segments. It also does not exclude the possibility that other factors, besides urgency, may play a moderating role before the conscious manifestation of craving (e.g., stress, anxiety) or after the conscious manifestation of craving (intentional strategies to regulate craving once it is subjectively experienced).

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The discussion above emphasizes the early and potentially unconscious role of model-free emotional regulation in the development of craving. This insight leads us naturally to consider the potential contributions of model-based emotional regulation mechanisms. In the following section, we will explore how these model-based processes, which involve more deliberate and conscious strategies, may influence the course and management of gambling behaviors in expected and unexpected, or even counterintuitive, ways. Here, we aim to bridge the gap in understanding how both types of regulatory mechanisms interact and contribute to the pathology and treatment of gambling disorders.

Discussing the Role of Model-Based Emotional Regulation Mechanisms

Our research (**Study V**) did not find evidence supporting that deficits in intentional emotion regulation have a significant impact on craving or gambling problems in community gamblers. More in specific, we found little evidence that disruptions in model-based emotion regulation mechanisms play a major role in problematic gambling or its manifestations, at least not in the expected direction.

Our results revealed a lack of significant association between emotion regulation strategies and gambling problems across three levels of behavioral analysis: the use of emotion regulation strategies (dispositional, measured by the ERQ), situational (during a cognitive reappraisal laboratory task), and changes in HRV related to cognitive effort in implementing these strategies. Overall, few of these measures showed significant correlations with the severity of problematic gambling symptoms or levels of craving.

Nevertheless, we did observe supportive evidence for a positive association between dispositional cognitive reappraisal and the severity of gambling problems. Additionally, there was evidence of a relationship between dispositional use of expressive suppression and positive urgency with a greater impact of task time on HRV, cautiously suggesting that these forms of emotional regulation could influence the mental fatigue associated with reappraisal strategy execution.

As discussed in **Study V**, the relationship between cognitive reappraisal and the severity of gambling problems, as well as other general findings, contradicts some of the existing literature and may seem counterintuitive, although it consistently aligns with the results presented in this thesis. We reviewed previous research that generally links greater use of cognitive reappraisal with a lower incidence of gambling problems (e.g., Aldao, Nolen-Hoeksema & Schweizer, 2010; Bonnaire et al., 2022; Lincoln, Schulze & Renneberg, 2022; Pace et al., 2015; Rogier et al., 2019). However, some propositions in the literature suggest that cognitive reappraisal can lead to ambivalent outcomes and act as a double-edged sword in certain contexts, which could help better explain our results (Neophytou et al., 2023; Troy, Shallcross & Maus, 2013; Ruiz de Lara, Navas & Perales, 2019).

Our findings could be attributed to limitations in the use of dispositional measures and participants' ability to influence these measures, as well as their performance in laboratory tasks. Additionally, the heterogeneity of the gambler population studied could also contribute to the contradictory results observed in the literature. Regarding the first issue, we consider that our results are not affected by a lack of sensitivity in the measures used. This is supported by the fact that both gambling problems and craving are associated with urgency, particularly positive urgency, consistent with the findings of Study IV.

As for the second issue, the samples in **Studies IV** and **V** are similar and point to a subgroup of gamblers who maintain their ability to use intentional emotion regulation strategies. This regulation could act ambivalently in maintaining disordered gambling, alleviating cognitive dissonance from loss of control and mitigating the emotional impact of negative consequences, thus promoting illusory reasoning that perpetuates problematic behavior. Findings related to urgency and its link to craving and gambling problems indicate that these gamblers prefer skill-based games and tend to lose control under positive affective influences, facing greater difficulties in controlling their gambling behavior in the face of reward cues. Most participants in our sample showed a clear preference for this type of game. Additionally, the recruitment protocols and inclusion and exclusion criteria were identical in both studies, indicating that we likely accessed similar populations.

Model-free emotional regulation strategies: a "triple-edged" sword. In contrast to model-free emotion regulation, intentional emotion regulation strategies take place once craving is instantiated and in subsequent temporal segments (assuming a causal line from the exacerbated desire to gamble to problematic behavior and its negative consequences). In light of our findings and previous studies, we interpret that a preserved or even enhanced ability to implement these strategies can result in at least three distinct outcomes, depending on the purpose (conscious or not) of their use. Two of these outcomes relate directly to the development of gambling problems, while the third has significant implications for research in this field.

Firstly, (1) model-based emotion regulation strategies (e.g., reappraisal) could serve as an adaptive and protective mechanism against the development of problematic gambling. When effectively implemented and aimed at managing relevant emotions (e.g., craving), these strategies could function as a "barrier" or shield that prevents loss of control during gambling. By managing both negative and positive emotional states that trigger avoidance or reward-seeking behaviors through gambling, these strategies contribute to a functional adaptation of behavior, thus preventing significant deterioration.

Secondly, (2) some gamblers might use these theoretically adaptive strategies after engaging in problematic behaviors to justify their actions and minimize the perceived negative consequences. This approach may lead individuals to perceive their gambling behavior as less problematic than it actually is, preventing them from deciding to stop gambling. It also helps them manage the emotional difficulties resulting from gambling consequences and other threats to their self-concept. This proposal has been previously discussed in various studies (Tan & Tam, 2023; Ruiz de Lara, Navas & Perales, 2019; Navas et al., 2016). In this sense, and if we agree with Chicchetti, Ackerman & Izard's (1995) definition, this would represent a case of emotional dysregulation where the use of these strategies is preserved or even enhanced. In this context, model-based emotion regulation mechanisms remain intact but operate maladaptively, regulating emotions and behaviors toward inappropriate goals. Supporting this interpretation, **Study V** found a positive association between dispositional reappraisal use and the severity of gambling problems. Additionally, we did not observe differences in task performance based on the severity of the gamblers, suggesting that our sample might predominantly use these regulation strategies in this maladaptive manner. We also found evidence supporting a relationship between expressive suppression and the effect of task duration on heart rate variability (HRV). Our predominantly strategic gambler sample might also use gambling-related cognitions for the same purpose, consistent with findings associating this type of preference with greater use of these cognitions in specific gambling contexts.

Lastly, (3) the maladaptive (yet efficient) use of these strategies could undermine the value of dispositional and behavioral measures recorded in our research. Generally, the use of deliberate emotion regulation strategies such as reappraisal is inversely related to problematic gambling symptoms in most studies. However, as previously indicated, these strategies might not effectively protect gamblers from gambling-related problems but instead modify their perception of these problems. More specifically, gamblers who score high in dispositional reappraisal might use this ability to deceive themselves into believing their gambling problems are less severe than they actually are. In our studies, we measured gambling severity using questionnaires, which reflect what the gambler believes about their gambling behavior. If gamblers deny their gambling-related problems, they are likely to underestimate the actual problems in their responses. This tendency could also be observed in any task where gamblers control the scores of success or failure. For example, the subjective perception of performance in reappraisal tasks might not necessarily indicate the actual effectiveness of their execution. This phenomenon could explain the lack of correlation between performance in reappraisal tasks and dispositional emotion regulation measures, as well as the inconsistent results in the scientific literature on the relationship between model-based emotion regulation strategies and gambling severity. In the practical implications section, we will attempt to address a possible solution to this issue.

In summary, the data obtained from community gamblers evaluated in our studies (as well as many others) could challenge the widespread belief that neurocognitive deficits (including emotion regulation) play an imperative role in the etiology of pathological gambling and addictions in general. This conclusion leads us to review commonly accepted claims in the scientific literature regarding the relationship between addictive problems and deficits in emotion regulation, as well as other neuropsychological variables.

Apparent preservation of model-based emotion regulation mechanisms in (at least a subgroup of) problem gamblers. Our findings and their interpretation prompt us to reflect on the possibly overly generalized characterization of problematic gamblers. This analysis highlights the importance of recognizing the heterogeneity and distinctive characteristics of different gambling populations.

Addictive disorders have been widely associated with neuropsychological problems and neurocognitive deficits, a point supported by extensive evidence (e.g., Manning, Verdejo & Lubman, 2017; Bickel et al., 2017; Bowden et al., 2006; Yücel et al., 2006). Additionally, these disorders are linked to problems in using deliberate emotion regulation strategies (Garland et al., 2020; Stellern et al., 2022; Murphy, Taylor & Elliott, 2012), leading us to test these capacities in this thesis. However, given our results and other relevant literature, it is worth questioning whether model-based emotion regulation problems are universally part of the etiology of gambling problems, or if they are a correlate valid only for certain subgroups of gamblers.

While it seems reasonable to assume that if the structures underlying executive and goal-directed functions are damaged, those underlying goal-directed emotion regulation would also be impaired, and that these deficits would be detectable behaviorally, the literature on this is inconclusive. The reality likely lies somewhere in between and needs to be contextualized by considering different gambler populations in terms of game preferences, problem severity, and other factors.

Regarding neurocognitive problems in pathological gamblers, the literature reports deficits in response inhibition (i.e., motor impulsivity), cognitive flexibility, planning, and working memory, among others, and examines how these affect decision-making (Grant et al., 2012; Goudriaan et al., 2006; Marazziti et al., 2008; van Holst et al., 2010; Ledgerwood et al., 2011; Lawrence et al., 2009; Reid et al., 2012). These findings are supported by neuroimaging studies indicating alterations in frontal structures and neurobiological dysfunctions affecting executive functioning (Kalechstein et al., 2007). From these results, a common neurocognitive etiology has been proposed for both substance and non-substance addictive disorders. Similarly, emotional dysregulation problems in pathological gamblers are well-documented (Velotti et al., 2021; Rogier, Zobel, & Velotti, 2019; Rogier & Velotti, 2018; Estevez et al., 2020, 2022, 2023).

However, recent studies question previous findings on neurocognitive problems. For example, Kapsomenakis et al. (2018) observed that gamblers scored similarly or higher than controls on working memory, cognitive flexibility, processing speed, sustained attention, and other executive capacities, despite not exhibiting higher levels of impulsivity. Balodis (2020) investigated less studied aspects such as self-awareness, interoception, metacognition, and social cognition and found no evidence of widespread cognitive control impairment. Ledgerwood et al. (2009) found that while pathological gamblers tended to be more impulsive, there were no significant differences from controls in terms of response inhibition, attention, memory, or distress tolerance. These results also emphasized differences between pathological gamblers with and without substance use.

Regarding emotional dysregulation, both our findings in **Study V** and other studies (Barrault et al., 2017, 2018; Mestre-Bach et al., 2021; Williams et al., 2012) challenge the notion of a uniform deficit in these capacities across the gambler population. Consequently, the idea of generalized impairment in gamblers may seem inaccurate and presents a need to reevaluate generalized claims about emotional dysregulation in the context of pathological or problematic gambling.

The literature also reflects concern over this issue; it has been proposed that mixed findings are due to various factors. One proposition is the heterogeneity of alterations in gambling disorder, combined with the multidimensionality of employed tests, which can yield ambiguous results (Balodis, 2020). Pathological gamblers might indeed experience deficits in specific executive function components (Ledgerwood et al.), but it is unclear whether these deficits are independent of basic cognitive function deficits (Balconi, Angioletti & Delfini, 2021). Additionally, methodological limitations in existing studies include focusing on a single executive function, using small samples, and lacking evaluation or control of comorbid disorders and medication use, as well as the absence of clinical comparison groups. Sampling bias (i.e., including only treatment-seeking patients) and the fact that many problem gamblers seek treatment for a comorbid disorder rather than gambling itself are also cited as issues, as they often result in non-representative samples of gamblers isolated from other problems. Similarly, regarding observed frontal lobe abnormalities in gamblers, there is a debate on whether these correlates should be considered a primary phenomenon linked to the disorder's etiology or secondary to symptomatic features or comorbid psychopathological conditions (Balconi, Angioletti & Delfini, 2021). Finally, we question whether adopting an exclusively confirmatory philosophy in studying behavioral addictions might have negatively influenced research, steering it towards equating the neurobiological and psychological correlates of substance addictions with those of non-substance addictions.

This suggests that in the field of behavioral addictions, community participants across the severity continuum—though a significant percentage might score above clinical thresholds for diagnosis—are less likely to exhibit neuropsychological or neurocognitive complications typically observed in clinical samples (Christensen et al., 2023; 2024). Therefore, it is likely that the samples in our studies may not exhibit such problems.

In other words, evidence suggests that at least some profiles of gamblers do not show impairment in neurocognitive aspects or in their ability to implement emotion regulation strategies. In terms of our data, this profile seems to match the participants in our **Studies IV** and **V**. However, this does not imply that other gamblers do not face difficulties with emotional dysregulation. Etiological models like the Pathways Model and the Gambling Space Model support the existence of these variations (Blaszczynski & Nower, 2002; Navas et al., 2019).

As an illustration, a recent study by Baenas et al. (2024) significantly contributes to this discussion. In this study, they aimed to identify and compare groups of individuals with gambling disorder using sociodemographic, neuropsychological, and other gambling-related variables. They discovered that different gambler populations showed variations in relevant correlates for this debate, reflecting both existing literature and our own findings. One group, termed the “young reward-seeker” consisted mainly of young men who preferred strategic and online games. This group exhibited high trait impulsivity according to self-reports but showed little or no cognitive impairment. The other two groups had a higher percentage of women and older individuals, primarily involved in non-strategic games and showing lower neuropsychological performance. The third cluster, “cognitive inflexible,” showed the lowest neuropsychological performance, especially in cognitive flexibility, while the second cluster, “comorbid vulnerable coping-seeker,” reported poorer inhibitory control. This last group also featured poor emotion regulation and higher prevalence of comorbidities, according to self-reports.

Subgroup 1 bears great similarities to the representative player subtype in our samples from studies **IV** and **V**. This subgroup also aligns closely with the “type I” gambler described by Navas et al. (2016; preference for skill-based games and high reward sensitivity), as well as with the group of gamblers with low executive function impairment identified by Mallorquí-Bagué et al. (2017). Additionally, it resembles the “conditioned gambler” from the Pathways Model (Blaszczynski & Nower, 2002) and fits well within the dimensions of the Gambling Space Model (Navas et al., 2019). This profile is not only the most numerous in the studied sample but also shares demographic and gambling characteristics that represent the emerging gambler profile in recent years, including factors such as age, intelligence, education level, gender, and game preferences (Baenas et al., 2024; Navas et al., 2017, 2019; Griffiths et al., 2009; Myrseth et al., 2010).

In a global synthesis, a recent study by Mora-Maltas et al. (2024) highlights an ambiguous relationship between neuropsychological performance and the severity of gambling problems, emphasizing the influence of gambling-related cognitive distortions. The authors noted that among young strategic gamblers, better neuropsychological performance was linked to higher gambling severity. They hypothesized that more efficient executive functioning could facilitate a sharper perception of the statistical information in games, leading to a false sense of mastery or illusion of control. On the other hand, in less strategic gamblers, they observed that poor neuropsychological performance was related to gambling severity through higher trait impulsivity and more pronounced cognitive distortions These findings provide evidence for the dual role that neuropsychological performance can play in the severity of gambling disorder, depending on the gambler subtype, and help explain the mixed results observed in the literature.

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In summary, our studies along with recent literature, suggest that the presence of neurocognitive problems or model-based emotion regulation alterations is not a necessary condition for developing gambling problems. This finding has significant clinical implications, indicating that neither neurocognitive preservation nor a high capacity for successful intentional emotion regulation guarantees protection against gambling problems. Most research on addictive disorders has been conducted in clinical samples with high prevalence of comorbidities and other complications. However, our sample includes gamblers with severe gambling problems, as demonstrated by a significant percentage scoring above clinical thresholds on severity scales, but not showing equivalent levels of impairment in other various transdiagnostic constructs. This indicates that while these individuals face gambling problems, other areas of their neurocognitive functioning remain intact.

Our data also reveal that these gamblers do show model-free emotion regulation problems, particularly in relation to trait impulsivity (urgency) and its link to craving and gambling severity. However, no deficiencies were observed in intelligence, probabilistic reasoning, or the use of adaptive emotion regulation strategies. In fact, in some cases, gamblers seem to use these strategies more effectively, which paradoxically contributes to self-sabotage that exacerbates complications associated with gambling activity.

Clinical implications

As evidenced throughout this dissertation, gambling disorder is a complex and multifaceted condition that affects a diverse population, composed of individuals with varied personality traits as well as psychological and neurocognitive profiles. In **Chapter IV**, we argue that the heterogeneity observed among problem gamblers underscores the necessity for an individualized treatment approach, which not only considers the specific characteristics and context of each person but also their particular vulnerability factors.

Given this scenario, it is clear that the effectiveness of a single treatment, uniformly applied to all affected individuals, could be insufficient. The diversity of gambler profiles suggests that a standardized therapeutic package—i.e., a set of predetermined, non-specific interventions—may not be adequate to address the inherent complexity of each case. This reality reinforces the importance of exploring and developing multiple therapeutic strategies that are tailored to the individual needs of each gambler.

Despite being a relatively recent disorder, gambling disorder already boasts a wide array of therapeutic packages derived from various theoretical perspectives, each demonstrating varying degrees of efficacy in practical application (Pfund et al., 2024; Carlbring et al., 2009; Maynard et al., 2015; Yakovenko et al., 2015; Ribeiro, Afonso & Morgado, 2021). Cognitive-behavioral therapy (CBT), which remains the gold-standard evidence-based treatment, has shown efficacy in reducing the severity of the disorder in the short and medium term in several clinical trials (Gooding & Tarrier, 2009; Grant & Odlaug, 2012; Cowlishaw et al., 2012). However, it has limitations such as modest long-term efficacy, high dropout and relapse rates, and moderate effectiveness in patients with high impulsivity and affective regulation problems (Pfund et al., 2024; Echeburua et al., 2014; Ledgerwood & Petry, 2006). To enhance its efficacy, CBT has integrated tools from other therapies that have proven effective individually in addressing both global and specific aspects of problem gambling (Gooding & Tarrier, 2009; Petry et al., 2009; Wulfert et al., 2006; Carlbring et al., 2009; Grant et al., 2018; Maynard et al., 2015; Tolchard, 2015; McIntosh, 2017; Nastally & Dixon, 2017; Toneatto, Vettese & Nguyen, 2007). These therapies, emerging within the context of third-generation and contextual approaches — such as acceptance and commitment therapy (ACT) and mindfulness-based therapies (e.g., MBRP) — or as variants of CBT — like motivational interviewing (MI) — , include metacognitive strategies that can be useful in various scenarios.

The factors we suggest considering for the individualization of treatments refer to the variables studied in the different studies that comprise this thesis. Gambling-related cognitions, compulsivity and craving, and model-free and model-based emotional regulation problems are associated with different clinical characteristics of the varied populations of gamblers and could be addressed through different treatment techniques that also take into account other factors related to gambler phenotypes. This multidimensional approach not only addresses the manifestations of the disorder but also attends to the underlying processes and personality characteristics that increase the likelihood of maintaining problematic gambling.

It is crucial to recognize that while etiological models have sought to categorize gamblers into distinct phenotypic groups (e.g. Navas et al., 2019; Nower, Blaszczynski, & Anthony, 2022; Baenas et al., 2024; Jimenez-Murcia et al., 2020; Mallorquí-Bagué et al., 2018), the reality appears to be considerably more intricate. Identifying fixed subgroups of gamblers is not straightforward, as each gambler represents a reality that transcends a fixed characterization. For this reason, we will propose different therapeutic approaches based on the specific process to be intervened, and subsequently provide some insights into the idiosyncratic characteristics of the specific subgroup of gamblers that seems to have a greater prominence in this thesis and in contemporary society. We refer to the emerging profile of the gambler characterized, among other things, by their youth, preserved cognitive functioning, high sensitivity to the appetitive properties of games, strong cognitive distortions, a tendency to adapt adaptive emotional regulation strategies to justify their motivations, and preferences for skill or strategy games (Baenas et al., 2024; Navas et al., 2017, 2019; Griffiths et al., 2009; Myrseth et al., 2010).

Our studies, along with the reviewed literature, clearly evidence that gamblers who experience more intense craving face more severe gambling problems. Furthermore, it has been identified that craving, in general, acts as a central component of the compulsive behavior underlying gambling problems, playing a crucial role in its etiology, development, maintenance, and relapse episodes (Hasin et al., 2013; Rash et al., 2016). Therefore, it is essential that primary treatment efforts focus on mitigating craving.

In our studies, we have found that craving comprises at least two facets: a cognitive one (attentional capture) and an affective one (related to the intense desire to gamble). According to some research, intervening on the cognitive-affective components of craving may be key to reducing its incidence once established (Kavanagh et al., 2005; May et al., 2015). Beyond the strategies proposed by CBT, one of the interventions currently being researched and that could play an important role in reducing craving through a multifaceted approach is mindfulness-based therapies (Tapper, 2018; Tang et al., 2016). Their effectiveness lies in their integration of emotional regulation strategies that help manage the experiences generated by craving (May et al., 2015). On the one hand, mindfulness techniques foster attention and awareness in the present moment, allowing gamblers to discriminate the stimuli that trigger problematic behaviors and thereby helping them select alternative responses to the intense desire to gamble (Maynard et al., 2015). Non-critical observation of the process, without being carried away by the underlying motivation, would contribute to restructuring the sequence of automatic responses that emerge after its onset (O'Neill, 2017). Additionally, mindfulness promotes greater awareness of the cognitive-affective processes underlying craving and its acceptance, reducing the likelihood that intrusive thoughts will intensify associated stress, instead of suppressing it (May et al., 2015). Moreover, the components trained through this approach appear to impact brain areas involved in reward/loss processing, motivation, and executive control (Potenza et al., 2013). Other intervention packages incorporating related techniques such as awareness, visualization, and present-moment focus, emerging from approaches like ACT, dialectical behavior therapy (DBT), or mindfulness-based relapse prevention (MBRP), have proven effective in improving coping strategies for substance use impulses and tolerance of negative experiences (Dixon & Wilson, 2014; Linehan & Dimeff, 2001; Bowen, Chawla, & Marlatt, 2010; Toneatto, Vettese & Nguyen, 2007; Bowen et al., 2009), and could also be useful in treating gambling problems. Although these approaches address the mentioned dimensions of craving, it is also relevant to consider experimental approaches such as laboratory tasks that retrain attentional and approach biases, initially applied to alcohol use but promising in other contexts (van Deursen et al., 2013).

Our studies have also established that dispositional variables such as positive urgency significantly impact the severity of problem gambling, notably through craving. It is also related to model-free emotional regulation difficulties, underlying compulsive or stimulus-driven behavior. This implies several distinct therapeutic targets.

On the one hand, positive urgency is a relatively novel construct, so there is less research on addressing positive urgency-based maladaptive behaviors

(Zapolski et al., 2011). Tentatively, some authors suggest teaching adaptive techniques to enjoy positive moods, identifying safe alternative contexts for celebration, and learning to discriminate risk signals of maladaptive behaviors to optimize self-control under intense positive moods (Zapolski et al., 2011).

On the other hand, considering that positive urgency might be related to the disruption of model-free emotional regulation mechanisms (Study IV), these mechanisms should also be a priority therapeutic target. This approach is challenging, as they are automatic processes over which patients theoretically have no awareness or control (Etkin, Büchel, & Gross, 2015). Mindfulness-based approaches could be helpful, as they share characteristics with systematic desensitization (Hoppes, 2006). Additionally, the continuous practice of mindfulness could promote more automatic affect regulation responses through regular practice. By learning to observe emotions without immediately reacting to them, individuals can develop more automatic and emotionally regulated responses that do not require conscious analysis in each situation (Toneatto, Vettese & Nguyen, 2007; Wupperman et al., 2011). Similarly, albeit tentatively, some authors have proposed that through repeated practice and reinforcement of cognitive reappraisal in emotional situations, individuals might develop a more automatic response (a kind of “incidental reappraisal”) that does not require conscious deliberation (Gyurak, Gross, & Etkin, 2011). Controlled exposure techniques to gambling cues (signals that would trigger craving catalyzed by urgency traits) may also be useful (Bergeron et al., 2022), although they must be conducted with caution due to the potential risk of relapse underlying these interventions (Giroux et al., 2013; Smith et al., 2015).

Finally, the relationship between positive urgency and craving suggests an exacerbated desire to gamble, guided by the expectation of appetitive gambling rewards. It is likely that these gamblers exhibit excessive sensitivity to rewards, suggesting that behavioral interventions aimed at promoting reinforcing alternative behaviors to gambling would be beneficial. Approaches like functional behavior analysis could help identify which alternative sources of reinforcement are viable (Dixon et al., 2018). However, as discussed in the General Discussion, it is not entirely clear whether positive urgency is a response to distress triggered by the intrusion of positively characterized events. If this is the case, craving could be considered an aversive affective state. For gamblers who use gambling as a means to avoid or escape negative emotional states, including specific techniques to develop emotional coping skills could be helpful (Petry, Litt, Kadden, & Ledgerwood, 2007; Rychtarik & McGillicuddy, 2006), or dialectical behavior therapy aimed at distress tolerance (Dimeff & Linehan, 2001).

Some recent research has indicated that gamblers with a tendency towards impulsive behaviors under the influence of positive emotions also exhibit a greater propensity to manifest gambling-related cognitions (Ruiz de Lara, Navas & Perales, 2020). However, the discussion in **Study I** leads us to point out that these cognitions might not constitute the primary cause of gambling problems. Thus, CBT tools such as cognitive restructuring could have limited efficacy in these cases. In fact, in earlier sections, mixed results in the literature on the exclusive approach of cognitive biases to alleviate or reduce problem gambling symptoms have been discussed. If, as we argue, gambling-related cognitions are not part of the etiology of problem gambling but rather a consequence of it, addressing them would not resolve gambling problems, as compulsivity and associated issues would not be reduced (although there are studies that do not share this statement, for example, Li et al., 2018). This does not mean that distorted cognitions should not be addressed, but their approach should be undertaken after addressing other priority variables more closely linked to the development and maintenance of disordered gambling.

An alternative approach to CBT could be the use of metacognitive techniques (Wells, 2013; Lindberg, Fernie & Spada, 2011). The goal would be to increase awareness of the emotional and motivational basis of thought processes, and then modify them. The intervention, also supported by mindfulness tools, could aim to teach gamblers to monitor how gambling outcomes can automatically trigger emotional regulation strategies that subsequently feed reasoning processes aimed at fostering distorted beliefs about their abilities. The work of "realizing" these manifestations, from an external perspective that allows them to "observe" their own behavior and understand that their thoughts are intrinsically linked to their desires, along with other tools such as exposure in different contexts, could hinder the future development of gambling-related cognitions. This metacognitive approach would have the potential to address the emotional and motivational roots of cognitive distortions from their origin.

Furthermore, we have previously discussed that the strength of these cognitive distortions might represent preserved cognitive functioning (Navas et al., 2019; Perales et al., 2017). Therefore, although the importance of integrating emotional regulation training into therapeutic approaches for gambling disorder has been suggested (e.g., Chu & Clark, 2015), we must consider our results and discussion from Study V. At least a portion of problem gamblers seems to maintain intact their abilities to use deliberate emotional regulation strategies, so strengthening these skills alone, and at least in these cases, could be counterproductive. Strengthening model-based emotional regulation processes could promote better strategies for overestimating personal self-efficacy or minimizing the emotional impact of monetary losses. To avoid potential iatrogenic effects, we believe it is essential that intentional emotional regulation training and the approach to gambling-related cognitions be carried out jointly, contextualized, and considering metacognitive approaches when implementing the intervention.

Beyond addressing processes, though closely related to them, we suggest considering three final general issues:

Firstly, it seems that gamblers who combine all the characteristics seen so far tend to have less awareness of their gambling problems (Gainsbury, Hing, & Suhonen, 2014; Moreau, Chabrol, & Chauchard, 2016), reduced motivation to cease or reduce their gambling, and a higher likelihood of dropping out of therapy and not complying with treatment-assigned tasks (Jara-Rizzo et al., 2019; Aragay et al., 2015). We believe that, again, these tendencies are supported by motivated reasoning processes and distorted cognitions. Thus, the key would be to reduce the gambler's reactance, who has built a mental architecture to disregard arguments in favor of change. Motivational interviewing would allow the person to become aware that their cognitive tools serve to maintain dysfunctional behavior, and that in some way, they are actually defending their own self-concept. In this sense, Motivational Interviewing could be an effective way to help these gamblers move out of the precontemplation stage and help them initiate a comprehensive treatment for their gambling problem (Miller & Rollnick, 2012).

Secondly, we consider prevention efforts and public health initiatives crucial. The compulsive behavior underlying problematic and disordered gambling is fostered by the structural characteristics of gambling games and devices, which promote biases towards gambling and increase its addictive potential (Parke et al., 2016). Therefore, we believe that implementing restrictions on these structural characteristics, such as the frequency of near-miss events, multiline devices, and random ratio reinforcement schemes, is justified and should be regulated by competent institutions, always based on scientific evidence. Similarly, regulating advertisements and how sports betting and other gambling modes are advertised is also justified (López-Gonzalez et al., 2018). Psychoeducation efforts and other strategies aimed at raising public awareness about how gambling devices work can be particularly fruitful in preventing problems in gamblers who are already engaged in gambling. Finally, we believe it would be interesting to further explore how approaches such as ACT can provide skills to increase gambler awareness of the structural features of pathological gambling (Nastally & Dixon, 2012).

Finally, it is crucial to recognize the suffering of those close to the gamblers and reflect on the impact that problem gambling has on family members and companions. We believe that they should have spaces, whether individualized or in the form of group therapy, to address aspects related to support and self-care. Additionally, including family members in the therapeutic context can offer significant advantages. Establishing systemic approaches that include the families or cohabitants of patients in the dynamics of treatment can lead to beneficial outcomes for gamblers (McComb, Lee & Sprenkle, 2009; Kourgiantakis, Saint-Jacques, & Tremblay, 2013). The participation of family members in treatment not only provides additional support to the patient but also helps mitigate the impact of problem gambling on the family environment, and possibly greater adherence to intervention proposals, thereby improving the overall efficacy of the therapeutic approach.

Limitations, Practical Implications, and Future Perspectives

Beyond the specific limitations of each of our investigations, which have been discussed in detail in the respective studies, there are overarching methodological constraints common to all our research. The following outlines these general limitations, delves into the particular restrictions of each study, and proposes future solutions to contribute to more robust evidence in subsequent research.

Firstly, the cross-sectional nature of our studies limits our ability to establish causal relationships between the studied variables, preventing us from inferring the direction of observed associations. Moreover, stratified sampling was not employed during participant recruitment, nor were other methods used to ensure population representativeness, which is crucial for generalizing the results.

For instance, the data from Study I were derived from previous samples used in other studies by our research group, potentially introducing overlap between the results and complicating their comparison and discussion with part of the cited literature. In Study III, recruitment was conducted via a Spanish online panel. While studies suggest that recruiting community samples through panels is a valid and generalizable method (Belliveau, Soucy & Yakovenko, 2022), there is concern that the severity levels detected may be overestimated (Pickering & Blaszczynski, 2021). This may affect data representativeness and result replicability. Participants in Studies IV and V were recruited through various methods, including social networks, flyer distribution, and snowball sampling. This diversity in methods might have limited the sample heterogeneity, influencing the similarity of results across these studies regarding the associations between dispositional variables. On the other hand, the strict and similar selection criteria across both studies aimed to control for concomitant psychopathology, potentially biasing gambler heterogeneity while reducing extraneous variables. It is also noteworthy that most of our data come from self-report instruments, which are susceptible to memory biases, social desirability, and self-perceptions that may not align with reality.

Finally, it should be noted that none of our studies were pre-registered; however, in all cases, the planned analytical strategies specified in the scientific-technical reports approved by the relevant institutions prior to the start of each study were followed.

Specific Limitations and Potential Solutions

Specific limitations related to the results obtained in our studies open the door to considering the practical implications of our findings and establishing future research perspectives to clarify unresolved questions.

The results of **Study I** seem to contradict the existence of a relationship between general domain reasoning and probabilistic reasoning and the etiology of gambling-related cognitions. Longitudinal studies could provide more reliable information on how these variables are related. For example, these methodologies could determine whether the frequency of exposure to gambling devices enhances cognitive distortions and, if so, identify the specific structural characteristics that cause them. This could have significant implications for establishing regulatory policies and harm reduction measures.

We also proposed in the discussion section that these cognitions, as modifiers of the emotional experience, could be considered a subtype of emotional regulation aimed at justifying continued gambling, either during gambling sessions or over time. Future research could explore whether these distorted cognitions are supported by motivated reasoning processes. Some recent studies discuss "justifications" or "gambling-justifying thoughts" aimed at making desirable decisions (Raymond & Clark, 2024). Therefore, what exactly are gambling-related cognitions? Are they a cause of other biases, a process of motivated reasoning or justification, or a tool for emotional regulation? Perhaps all at once? Future research delving into the roots of these cognitions would be highly interesting.

Additionally, regarding the “regulatory hypothesis”, investigating the relationship between cognitive biases and gambler profiles at different extremes of the cognitive spectrum could reveal differentiated etiologies, contributing to understanding how gambling-related cognitions manifest in different individuals.

Lastly, the studies analyzed in the discussion highlight the influence of prior beliefs and attributions in modulating recency effects, whether positive or negative, based on gambling outcomes. This observation suggests that emotional adjustment processes based on gambling outcomes may be more complex and require detailed exploration. To advance understanding of these mechanisms, we propose specific laboratory tasks to examine how justificatory elaborations based on gambling outcomes emerge. These tasks should simulate ecological gambling contexts, controlling the sequence of outcomes to observe their impact on gamblers' emotional and cognitive responses. Using previous methodologies like the "think-aloud method" would provide direct insight into the thoughts, intentions, impulses, and ideas driving behavior during gambling. This approach would also overcome the limitations of using merely dispositional variables, offering contextual and dynamic data that more accurately reflect the cognitive and emotional processes in action.

The findings of **Chapter IV** provide a crucial starting point for further exploring the nature of compulsivity and craving. These studies have been a first step toward developing a new instrument to evaluate compulsivity, considering the intensional components of addictive processes. Moreover, this instrument not only serve to measures dispositional compulsivity but also can assess state-level compulsivity in more ecological contexts.

Given this advantage, we find its utility in developing research lines compelling. For example, laboratory experiments inducing craving using audio-guided procedures, similar to those employed in previous studies (e.g., Cornil et al., 2019), could: (1) Validate and verify the accuracy and reliability of our assessment tool under experimental conditions, and (2) deepen the anatomical-functional characterization of compulsivity, identifying psychophysiological correlates accompanying the manifestation of craving.

Additionally, beyond purely experimental paradigms, the experience of craving has not been sufficiently explored from a phenomenological perspective in the existing literature, representing an outstanding task. Incorporating qualitative questionnaires with open-ended questions to capture subjective information about the affective, cognitive, and interoceptive aspects of craving could provide a deeper understanding of the core elements of addictive processes, facilitating a richer and more nuanced description of their experience.

Finally, and beyond purely experimental paradigms, the experience of craving has not been sufficiently explored from a phenomenological perspective in the existing literature, representing an outstanding task. Incorporating qualitative questionnaires with open-ended questions to capture subjective information about the affective, cognitive, and interoceptive aspects of craving could provide a deeper understanding of the core elements of addictive processes, facilitating a richer and more nuanced description of how they are experienced.

Study IV provides a valuable framework for future research in understanding the relationship between craving, emotional dysregulation, and gambling problems. It is necessary to replicate the scope of the mediational model resulting from our analyses in future studies. Although it appears that the mediation of craving for emotional dysregulation of positive emotions in linking with the severity of gambling problems responds to a general picture (López-Guerrero et al., 2023), future replication attempts will help systematize the findings and clarify any ambiguity in the proposed causal relationship. It would be helpful to systematize the use of dispositional measures in studies delving into these constructs. Establishing specific psychometric instruments to evaluate key constructs can improve precision and reduce variability due to different self-report methods. Additionally, applying these analyses to different subpopulations could identify how the association between various variables fits different gambler phenotypes, their severity spectrum, preferences for different gambling modalities, and other psychobiological, cultural, and demographic variables.

Actually, the proposed model emerges from a theoretical proposal based on the literature that presents a tentative causal chain of processes. Therefore, we suggest more ecological approaches that overcome the limitations of dispositional measurements and increase the validity of the findings. Momentary ecological assessment (EMA) methodologies are particularly interesting. Applying this methodology would allow collecting data on gamblers' behaviors and experiences in real-time and in their natural environments. This approach would not only reduce recall bias but also offer a more immediate and accurate perspective of the craving experience, whether appetitive or aversive. It can also facilitate studying dynamic interactions between personality traits, emotional experiences, and gambling behaviors. Along with longitudinal paradigms, this could help us understand whether certain traits, such as emotional impulsivity, are merely causal or also consequential concerning the individual's gambling history. In other words, whether personality traits act as causal factors in developing compulsive gambling behaviors, or if these traits are influenced by continuous exposure to the structural characteristics of gambling devices.

Finally, understanding the intriguing results of **Study V** remains a challenge. The diverse results found in the literature and the absence of robust replications prevent integrating various questions related to the foundations of our findings. It is crucial to understand the scope of the use of deliberative emotional regulation strategies aimed at maintaining gambling behavior and the practical implications this might have in the research field, as discussed in the Discussion section.

One important aspect is to delve into the relationship between the use of adaptive emotional regulation strategies and the severity of problematic gambling, which initially seems counterintuitive. A future research line could examine whether adaptive emotional regulation strategies effectively moderate the impact of craving on gambling severity — in the unexpected, but possible, direction. Such studies would face the same limitations as previous ones but could provide a preliminary and cost-effective advance through dispositional variables, laying the groundwork for subsequent experimental or prospective studies. Again, EMA paradigms could be useful for delving into the sequence of events from the manifestation of craving to the use of emotional regulation strategies in an adaptive or maladaptive manner. Monitoring this sequence could address several open questions in the literature, allowing for detailed and contextual analysis of how gamblers manage their emotions in real situations and providing both quantitative and qualitative data.

Finally, addressing the practical implications of using reappraisal or gambling-related cognitions in self-report questionnaires is essential. We believe there is a possibility that the underlying mechanisms involved in self-deception and re-evaluation of gambling's negative consequences also influence how gamblers perceive and report their gambling problems. This could result in self-reports of problematic gambling symptoms, craving intensity, or dispositional trait impulsivity and emotional regulation variables not being representative of the gambler's reality. Incorporating family members or partners of gamblers into the evaluation could provide a more objective perspective on the severity of gambling and other behavioral variables. Comparing these external perceptions with gamblers' self-assessments would help validate the accuracy of self-reports and better understand discrepancies between self-perception and external observations, distinguishing between incongruent results and those that might not be.

Finally, it is crucial to emphasize that all these considerations, aimed at further understanding the heterogeneity of gambling problems, must account for the diversity among gamblers when designing studies. This includes considering different gambler profiles based on criteria such as problem severity, gambling preferences, and socio-demographic or cultural variables. Adequately operationalizing these subpopulations in research will allow for more precise and relevant comparisons between groups, contributing to treatment and advancing knowledge.

General conclusions

Considering the limitations and within the general discussion framework on the results of the studies included in this thesis, the following general conclusions are suggested:

1. Probabilistic and abstract reasoning abilities are not related to the intensity of gambling-related cognitions. This finding suggests that cognitive biases do not play a causal role in the etiology of gambling problems. Consequently, a general lack of understanding of probability or low fluid intelligence is not the primary cause of gambling issues. Similarly, preserving these abilities would not protect

individuals from developing problematic gambling behavior; in some cases, they might even contribute to it.

2. Further research is required to test the hypothesis that these cognitions are a byproduct of the compulsivity underlying problematic and disordered gambling. Once established, these cognitions may contribute to the perpetuation of gambling problems. Specifically, they might result from motivated reasoning aimed at justifying the loss of control over gambling and serving as an ego-protective mechanism.
3. Compulsivity in recognized behavioral addictions, such as gambling disorder, manifests through various non-trivial facets. These facets can be categorized into at least six different operationalizations: “Cognitive/attentional hijacking or interference caused by activity-related thoughts or images", "insuperable urge compelling the individual towards the activity that jeopardizes the ability to control it", "continuation of behavior despite awareness of the imbalance between harm and reward", “inability to interrupt problematic behavior once initiated, resulting in sessions lasting longer than planned (binging)", “automatic behavior triggered by cues in the absence of declarative instrumental goals (habit)", “Inflexible or stereotyped behaviors or rituals regarding the completion or execution of parts of the activity". Despite their differences, disutility appears to be a common element, presenting unfavorable or counterproductive consequences for the gambler.
4. The three facets most closely related to compulsivity align with elements of a multifaceted craving response. These include cognitive

hijacking by gambling-related stimuli, an irresistible or uncontrollable urge to gamble, and the continuation of gambling behavior despite recognizing that negative consequences outweigh the positive ones. Therefore, craving is identified as the central element of compulsive behavior underpinning addictive conduct and loss of behavioral control.

5. Alterations in various emotional regulation mechanisms are differently associated with craving and the severity of problematic gambling.
6. Both positive urgency and negative urgency correlate with the severity of disordered gambling symptoms. However, while negative urgency has a direct effect on severity, the impact of positive urgency appears to be mediated through craving.
7. The mediating role of craving in the association between positive urgency and gambling severity suggests that positive urgency reflects a difficulty in regulating emotions, including craving regulation. This is supported by the association between positive urgency and resistance to the extinction of emotionally conditioned cues, further confirming its role as an indicator of model-free emotional dysregulation.

8. Model-based emotional regulation mechanisms do not seem to be impaired in at least some populations of gamblers. The positive relationship between the severity of problematic gambling and the dispositional use of adaptive emotional regulation strategies may indicate that these strategies could serve a role similar to that of gambling-related cognitions.

Appendix

Supplementary materials

(Study I)

Distribution of scores for all measurements of interests across groups

Figure A1 displays violin plots for distributions of age, education years, matrices scores, GRCS subscores, and SOGS severity scores, and frequency histogram for the number of correct responses in the BNT, across groups. Contrast statistics and BFs for the observed differences are reported in the main manuscript.

BNT and matrices effects controlling for age and education

The MANCOVAs described in the main analyses were re-run including either education or age as covariates, and allowing both covariates to interact with either BNT or Matrices (i.e. estimating the possible dependence of the effect of reasoning abilities on GRCS scores on age or education years). Table A1 shows the results for the four tested models.

In terms of significance, results were virtually identical to the ones described in the main text, with the addition of a significant multivariate effect of education on GRCS scores in the third model in Table A1. However, a number of other effects were close to significance, including the ones of matrices, matrices x age, and matrices x education. Marginal significance and the multiplicity of tests yield these effects virtually non-interpretable. Still, in order to visualize them, total predicted GRCS scores (the sum of the four GRCS dimensions) are displayed in Figure A2. In general, the relationship between education and biases trend in the positive direction, with younger individuals showing this pattern more clearly, and older ones showing a weaker one, or even a trend in the opposite (negative) direction. The potential relevance of these trends is presented in the discussion section of the main manuscript.

Full-sample analysis

In view of the tight association between disordered gambling symptoms' severity (SOGS scores) and the strength of gambling-related cognitions (GRCS), it could be argued that including group (PGD vs NPG) in main analyses could overshadow the impact of reasoning abilities on gambling-specific beliefs and biases.

Disregarding group when analyzing the putative effect of reasoning abilities would increase the likelihood that other variables correlating with group (i.e. any variables the two groups differ at, due to manipulation by selection) got confounded with reasoning abilities, artificially boosting the correlation between them and GRCS scores. Yet, for the sake of transparency and robustness, we have re-run the cross-sectional MANCOVAs described in the main text, but with reasoning abilities as the only independent variables (thus disregarding group), and GRCS scores as dependent variables, followed, by dimension-by-dimension Bayesian correlational analyses.

Despite the large sample size, neither the multivariate effect of matrices nor the one of BNT on GRCS scores were significant [Wilks' □□= 0.965, F (5, 129) = 0.949, p = 0.452; and Wilks' □ = 0.985, F (5, 129) = 0.402, p = 0.847].

Bayesian correlations did not change main conclusions either. As expected, increasing the range of severity (and given the large differences between groups in GRCS scores) also increased the strength of the correlations between SOGS and GRCS scores. Most importantly, although the sign of correlations between reasoning abilities and GRCS changed from positive to negative (relative to separate group analyses shown in the main text; see Table A2 and Figure A3), these correlations remained close to zero, and Bayes factors systematically supported the null hypothesis (except for the BF_{10} = 1.713 anecdotally supporting the correlation between matrices score and inability to stop).

Complementarily to these correlational whole-sample analyses, we also carried out Bayesian regression analyses for each one of the GRCS dimensions, with age and education years as covariates, and either BNT or matrices scores as main predictors (in all cases, the BF_{10} was computed pitching a null model including age and education years, against a comparison model that included either BNT or matrices upon the null model; BNT and matrices were never included in the same model to avoid competition between them). BF_{10} values were 1.288 and 0.331 for the effects of matrices and BNT scores on gambling expectancies, 0.706 and 0.324 on inability to stop, 0.344 and 0.332 on control illusion, 0.650 and 0.430 on predictive control, and 0.674 and 0.356. In other words, controlling for age and education years left results qualitatively unaltered.

Table A1. Results of separate MANCOVAs for multivariate effects of BNT and matrices effects on GRCS, with either age an education as covariates.

Model	***Effect***	***Pillai's trace***	***F***	***p***
BNT controlling for age				
	BNT	0.030	0.773	0.571
	Age	0.079	2.158	0.063
	Group	0.627	42.338	< *0.001*
	BNT x Age	0.047	1.243	0.293
BNT controlling for education				
	BNT	0.030	0.793	0.557
	Education	0.096	2.685	*0.024*
	Group	0.625	42.058	< *0.001*
	BNT x Education	0.055	1.467	0.205
Matrices controlling for age				
	Matrices	0.077	2.097	0.070
	Age	0.078	2.135	0.065
	Group	0.621	41.255	< *0.001*
	Matrices x Age	0.072	1.941	0.092
Matrices controlling for education				
	Matrices	0.075	2.042	0.077
	Education	0.079	2.168	0.062
	Group	0.609	39.322	< *0.001*
	Matrices x Education	0.074	2.005	0.082

Table A2. Bayesian correlation tests (bidirectional Bayes factors for Kendall's t) between for variables of interests in the full sample.

		Age	*Education*	*Matrices*	*BNT*	*EXP*	*IS*	*CI*	*PC*	*IB*
Education	t	-0.263								
	BF_{10}	> 100								
Matrices		0.026	0.308							
		0.124	> 100							
BNT		-0.171	0.385	0.32						
		8.341	> 100	> 100						
EXP		-0.026	-0.08	-0.121	-0.04					
		0.125	0.289	0.956	0.142					
IS		0.049	-0.126	-0.136	-0.068	0.634				
		0.159	1.153	1.713	0.224	> 100				
CI		-0.016	-0.115	-0.12	-0.053	0.539	0.519			
		0.117	0.788	0.927	0.171	> 100	> 100			
PC		-0.068	-0.062	-0.11	-0.058	0.652	0.641	0.628		
		0.223	0.198	0.654	0.186	> 100	> 100	> 100		
IB		-0.051	-0.08	-0.103	-0.063	0.68	0.671	0.594	0.748	
		0.164	0.285	0.527	0.2	> 100	> 100	> 100	> 100	
SOGS		0.034	-0.166	-0.146	-0.104	0.513	0.625	0.436	0.547	0.582
		0.133	6.559	2.603	0.544	> 100	> 100	> 100	> 100	> 100

Figure A1. Violin/box plots for age, education years, matrices scores, GRCS subscores, and SOGS severity scores, and frequency histogram for the number of correct responses in the BNT, across groups (PGD: patients with gambling disorder; NPG: Individuals in non-problematic gambling).

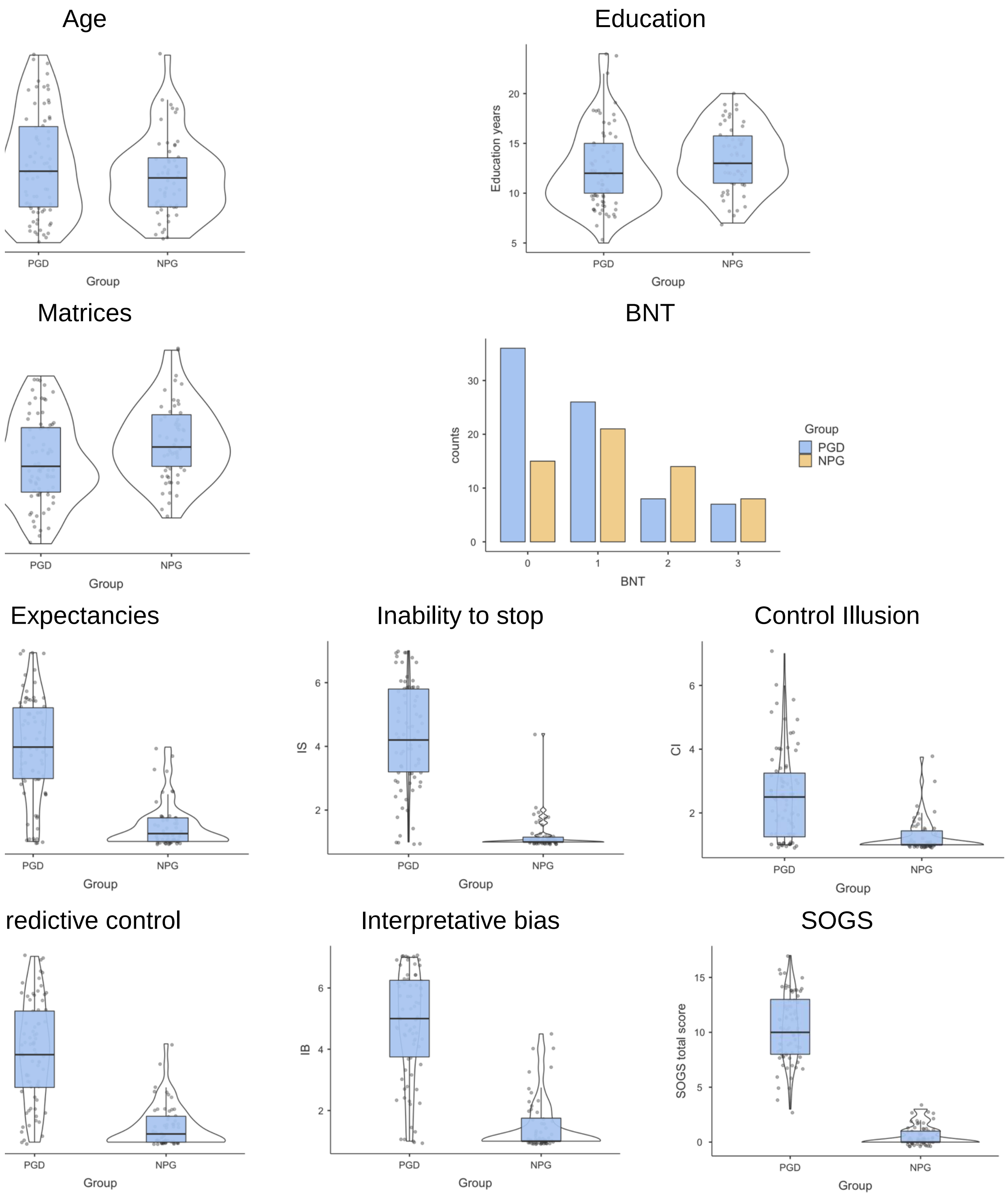
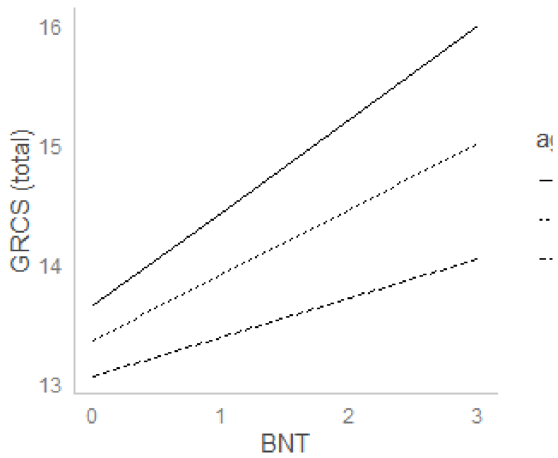
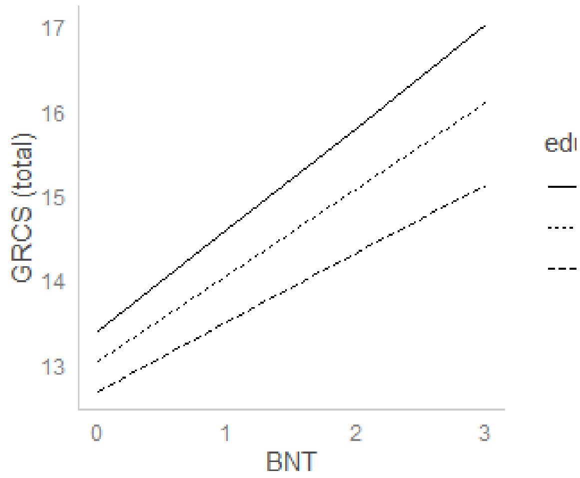


Figure A2. Predicted total GRCS scores as a function of BNT scores, matrices scores, age and education. Reference values for age and education years were selected as +1, 0, and -1 standard deviations.

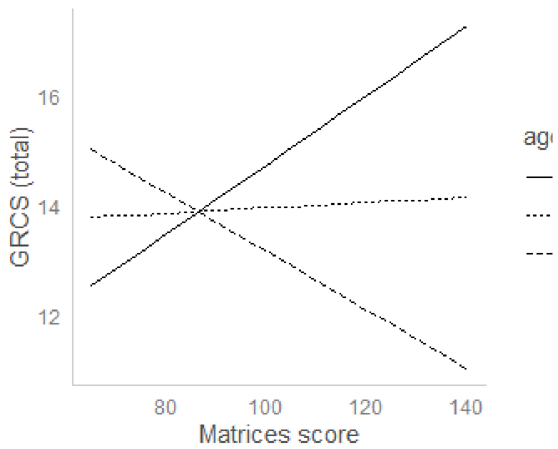
BNT interaction with age



BNT interaction with education



Matrices interaction with age



Matrices interaction with education

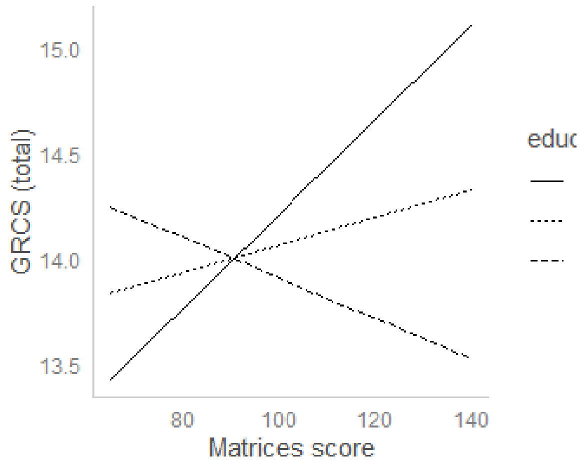
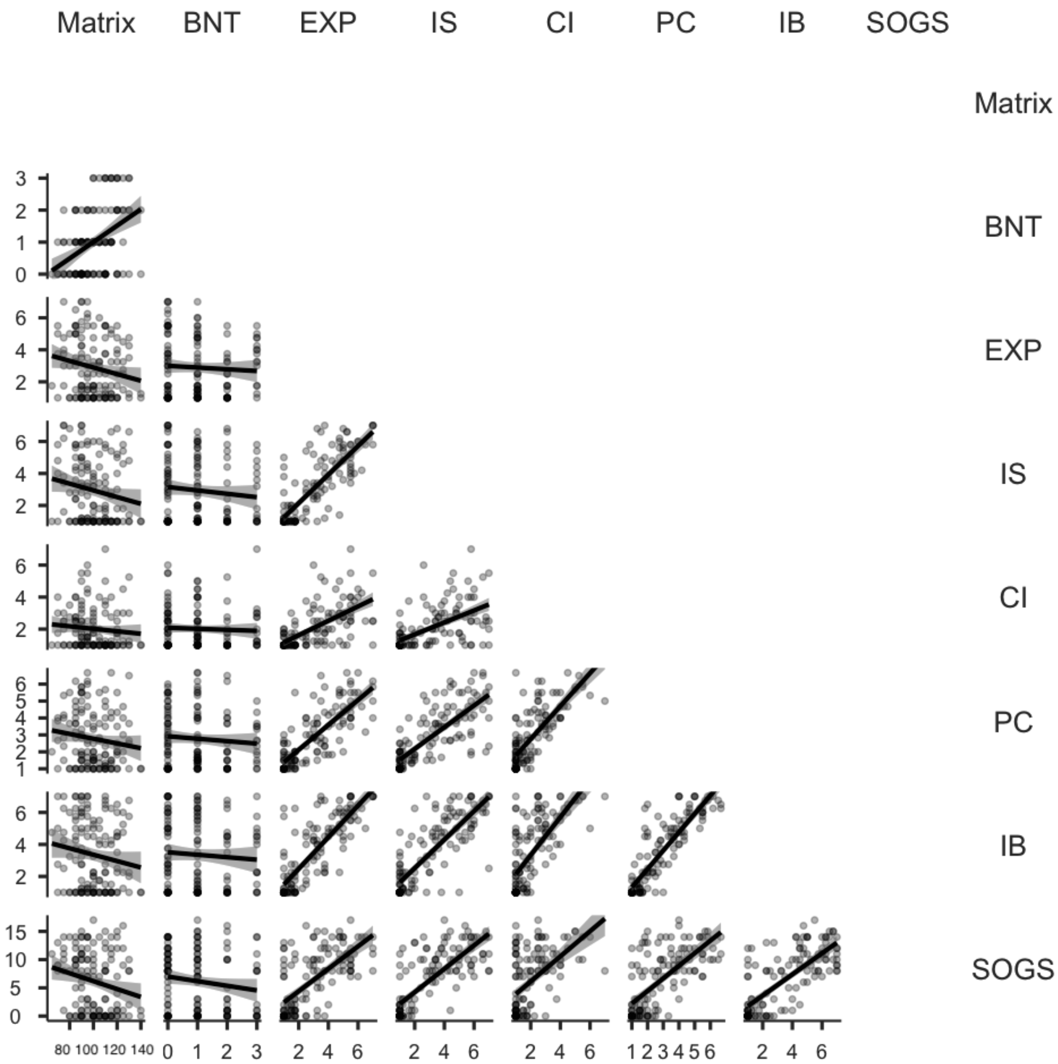


Figure A3. Graphic depiction of the correlation matrix for all variables of interest, collapsing groups (Matrix: WAIS matrices scores, BNT: Berlin Numeracy Test, EXP: Gambling Expectancies, IS: Inability to Stop, CI: Control Illusion, PC: Predictive Control, IB: Interpretative Bias, SOGS: Gambling severity).



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