Confidence biases in problem gambling

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Abstract

Subjective confidence plays an important role in guiding behaviour, especially when objective feedback is unavailable. Systematic misjudgements in confidence can lead to maladaptive behaviours and have been linked to various psychiatric disorders. This study investigated confidence biases in problem gamblers compared to demographically matched control participants. Confidence was examined across different hierarchical levels of metacognition, encompassing local decision confidence, global task performance confidence, and overarching self-esteem. The

problem gamblers demonstrated significantly higher local trial and global task confidence compared to control participants, despite lower self-esteem levels and after controlling for objective task performance. This overconfidence bias persisted even after controlling for the transdiagnostic symptom dimensions Anxiety-Depression and Compulsive Behaviour and Intrusive Thought, on which problem gamblers scored higher compared to control participants. The findings suggest a contrast in problem gamblers between elevated confidence in individual decisions and overall lowered self-esteem. Additionally, the findings indicate that these features cannot be solely attributed to increased Compulsive Behaviour and Intrusive Thought and Anxiety-Depression levels. Factors such as diminished sensitivity to objective evidence, cognitive distortions, and cognitive inflexibility in problem gamblers might fuel overconfidence, thereby triggering the cycle of escalating gambling behaviours.

Introduction

One fundamental aspect of decision-making involves evaluating the utility of our choices, often in the absence of immediate external feedback. In such situations, we typically depend on an internally generated sense of confidence to guide our actions [1, 2]. However, a distorted sense of confidence can be problematic. If our self-perception does not align with our actual performance, it may lead us to persevere with damaging choices or behaviours, thereby undermining our ability to adapt effectively. In extreme cases, inaccurate confidence judgements that do not mirror reality can be linked to pathological behaviours. This can, for instance, manifest as extensive checking due to diminished confidence in memory [3, 4], or delusional

thinking stemming from overconfidence in false beliefs [5]. Hence, a thorough understanding of metacognition — the monitoring and control of our own thoughts and behaviours — and its deficiencies plays a crucial role in the study and treatment of various psychiatric disorders [6, 7, 8].

Case-control studies have uncovered distinct patterns of alterations in metacognition across several psychiatric disorders. For example, alterations have been observed in depression [9, 10, 11], obsessive-compulsive disorder (OCD; [12, 13, 14], and psychosis [15, 16, 17, 5]; for a review, see [18]. However, given the high heterogeneity within and comorbidity between disorders, the nascent field of transdiagnostic psychiatry proposes that cognitive, affective, and neurobiological processes that govern complex behaviour may correspond more closely with transdiagnostic symptom dimensions rather than conventional diagnostic categories [19]. This approach transcends traditional diagnostic classifications, such as those found in the Diagnostic and Statistical Manual of Mental Disorders (DSM; [20], and potentially offers a more nuanced understanding of psychiatric conditions [21, 22]).

A study by Rouault et al. [23] leveraged this transdiagnostic approach to investigate the relationship between confidence and psychiatric symptomatology in a non-clinical sample. Participants performed a perceptual decision-making task and completed a series of self-report questionnaires capturing a broad spectrum of psychiatric symptoms, including depression, general anxiety, schizotypy, impulsivity, OCD, social anxiety, eating disorders, apathy, and alcohol dependency. The researchers performed a factor analysis to determine a concise latent structure that best explained the variance at the questionnaire item level, leading to the identification of three symptom dimensions: Anxiety-Depression, Compulsive Behaviour and Intrusive

Thought, and Social Withdrawal. These dimensions were consistent with the factor structure first identified by Gillan et al. [24] using the same set of psychiatric symptom questionnaires. The Anxiety-Depression dimension, which primarily links apathy, anxiety, and depression features, showed a significant correlation with lower mean confidence and higher metacognitive efficiency (the ability to distinguish between one's own correct and incorrect judgements given a certain level of task performance). In contrast, the Compulsive Behaviour and Intrusive Thought dimension, characterised predominantly by elements of impulsivity, OCD, schizotypy, addiction, and eating disorders, was linked with higher mean confidence and lower metacognitive efficiency.

These diametrically opposed associations between the Anxiety-Depression and Compulsive Behaviour and Intrusive Thought dimensions with confidence – whereby Anxiety-Depression is linked to decreased confidence and Compulsive Behaviour and Intrusive Thought to increased confidence – have been replicated in numerous studies [18, 25, 23, 26, 27]. Importantly, these associations do not emerge when only looking at individual questionnaire data, underscoring the merit of employing a transdiagnostic framework to account for existing comorbidities in psychopathologies. For instance, patients diagnosed with OCD may not only exhibit symptoms of compulsivity but also anxiety to a greater or lesser extent [28, 29], which could obscure findings related to the underlying cognitive processes when considering solely the traditional DSM disorder categories. This was also demonstrated in a study by Gillan et al. [30], finding that the Compulsive Behaviour and Intrusive Thought dimension was a significant predictor of deficits in goal-directed planning, whereas a diagnosis of OCD alone was not.

The seemingly paradoxical phenomenon, whereby the symptom dimensions of Anxiety-Depression and Compulsive Behaviour and Intrusive Thought demonstrate opposing associations with confidence yet are positively correlated, suggests that confidence is likely influenced by multiple cognitive processes. In order to unpack this idea, it is useful to consider multiple hierarchical levels at which metacognition operates, spanning from confidence in individual decisions (local confidence), to confidence in overall task performance (global confidence), to even higher-order attributes such as self-esteem [31]. Indeed, it has been suggested that the confidence biases may be driven by two distinct mechanisms; reduced confidence related to Anxiety-Depression may originate from global self-beliefs like self-esteem, whereas overconfidence related to Compulsive Behaviour and Intrusive Thought could be a consequence of difficulties in constructing an accurate mental model of one's own performance [31]. Supporting this idea, Hoven et al. [18] found a negative association between Anxiety-Depression and self-esteem but not local confidence, whereas Compulsive Behaviour and Intrusive Thought was positively linked with local confidence but negatively with self-esteem.

Within this framework, more globally-held beliefs are formed over extended periods of time, integrating information gleaned from a multitude of lower-level experiences. Consequently, metacognitive information obtained from monitoring lower-level activities can be employed as feedback to infer higher-order self-beliefs, such as selfefficacy and mastery, which may in turn influence our approach to life and our perceived control over it [32, 33]. These beliefs are important determinants of mental health [34, 35]. Conversely, the prevailing set of more globally held selfbeliefs may also shape an individual's local confidence in specific decisions. This process of monitoring our actions and cognitive processes on multiple levels may also manifest

itself in metacognitive control operating at different levels and on different time-scales. For instance, at the local level, local confidence may inform information seeking choices for individual decisions [1], whereas at the global level, global confidence may guide the selection of tasks to perform [36, 37]. These examples underscore the dynamic interplay between different levels of metacognition in shaping our beliefs and behaviour [18].

The current study aimed to probe the nature and extent of maladaptive metacognition within a sample of problem gamblers. Gambling disorder is a condition currently classified as a substance-related and addictive disorder by the DSM-5 [38]. This classification highlights the similarities between gambling disorder and substance use disorders, with shared features that include chronic progression, high rate of relapse, and fundamental changes in the brain's reward and motivational systems [39]. Gambling disorder is characterised by persistent and recurrent problematic gambling behaviour leading to substantial impairment or distress. Of specific interest in this study was whether the double-dissociation observed in the general population, wherein the Anxiety-Depression dimension predicts underconfidence and the Compulsive Behaviour and Intrusive Thought dimension predicts overconfidence, is also prevalent among problem gamblers. Furthermore, we aimed to examine how these associations may manifest at different levels of the metacognitive hierarchy.

Problem gamblers present a particularly interesting case study given that problem gambling is typified by compulsive behaviour, yet also demonstrates high comorbidity rates with anxiety and depression [40, 41, 42, 43]. Building on the findings described above, we hypothesised that Anxiety-Depression would correlate

with reduced confidence at the self-esteem level, whereas Compulsive Behaviour and Intrusive Thought would be associated with elevated confidence at the local decision level, such that higher symptom severity might trigger a dissociation of the different levels of the metacognitive hierarchy. Previous investigations into confidence levels in problem gamblers have pointed towards a tendency for overconfidence among these individuals [44, 45, 46]. However, these studies failed to adequately control for performance differences, thus rendering definitive conclusions about confidence biases difficult to substantiate. In a recent study by Hoven et al. [47], problem gamblers also showed elevated confidence relative to healthy controls, though systemic differences in gender across groups present a potential confound to interpretation because males have been observed to generally exhibit higher levels of confidence [48, 49]. In light of these complexities, comparing problem gamblers to a demographically matched group of control participants and adopting a transdiagnostic approach to examine variations in symptoms could offer more robust insights into potential abnormalities at different levels of the metacognitive hierarchy associated with problem gambling.

Methods

Participants. After applying all exclusion criteria, the sample consisted of 38 problem gamblers and 38 control participants. The exclusion criteria were delineated as follows: Participants were excluded if, in the metacognition task, they consistently opted for the same side (either left or right) in over 95% of trials; if their average accuracy in the metacognition task either fell below 60% or exceeded 85%; if there were disparities in the data provided for participants'

gender, country of residence, or age within a range of ± 1 year between the preliminary screening survey and the data compiled from the Neureka app in which participants completed the metacognition task; if the participant was not residing in the United Kingdom, Ireland, or the United States; or finally, if participants, being potential controls, were females under the age of 21. This last criterion was adopted to ensure a demographic match between control participants and problem gamblers.

Table 1 depicts the demographic and psychological measures of problem gamblers and control participants as well as between-groups comparisons. Participants were compensated with a e10 gift card upon full completion of the task. Recruitment was done via online forums, posters displayed near gambling venues, university mailing lists, and word of mouth. The study was approved by the School of Psychology Research Ethics Committee, Trinity College Dublin.

Procedure. *Problem Gambling Severity Index.* Study volunteers were initially screened via the Problem Gambling Severity Index (PGSI) to be included as problem gamblers (PGSI ≥ 8) or control participants (PGSI = 0). The PGSI, a 9-item refined version of the Canadian Problem Gambling Index (CPGI; [50], is a nonclinical assessment survey for problem gambling and has been used worldwide in population-level survey research [51, 52, 53, 54, 55, 56, 57]. The survey asks participants to self-assess their gambling behaviour over the past 12 months by rating their agreement with statements such as '*Have you borrowed money or sold anything to gamble?*' or '*Have you needed to gamble with larger amounts of money to get the same feeling of excitement?*'. The PGSI employs a scoring system to categorise gamblers based on their behaviour and the

consequences of their gambling. A score of zero is assigned to non-gamblers or those who gamble without negative consequences. Scores of 1-2 represent individuals who encounter a low level of problems with no or only minimal negative repercussions. Those scoring between 3 and 7 are considered to be experiencing a moderate level of problems, which are associated with certain negative consequences. Finally, individuals scoring 8 or above are typically facing severe gambling issues, characterised by adverse outcomes and a potential loss of control.

Rosenberg Self-Esteem Scale. Following the PGSI, participants were asked to complete the Rosenberg Self-Esteem Scale (RSES; [58]. The RSES is a widely used instrument designed to measure self-esteem, consisting of ten statements related to overall feelings of self-worth or self-acceptance. The statements are designed to be answered using a 4-point Likert scale ranging from '*strongly agree*' to '*strongly disagree*'. Half of these statements have positively worded propositions (e.g., '*I feel that I'm a person of worth, at least on an equal plane with others.*'), whereas the other half contain negatively worded ones (e.g., '*I feel we do not have much to be proud of.*'). The scores from these ten items are summed up to form a total selfesteem score which can range from 0 to 30. Higher scores indicate higher self-esteem, whereas lower scores suggest lower self-esteem.

Metacognition Task. After completing the PGSI and the RSES, participants were asked to download the Neureka app (https://www.neureka.ie/). The Neureka app, developed by the Gillan Lab at Trinity College Dublin, features a collection of gamified versions of commonly-used psychological tasks and questionnaires. Within this app, participants were asked to complete the Metamind task (see

Figure 1). The Metamind task is a gamified version of the Dot Discrimination Task, a perceptual decision-task frequently used to measure metacognition [23, 59]. In comparing Metamind to the traditional dots-task, it has been shown to have adequate validity and excellent reliability [60]. In Metamind, participants are given the task of controlling a spaceship traversing through space. Upon the appearance of two objects, the challenge is to navigate the spaceship to the object containing more dots. Participants make their selection by tapping either the left or right side of their smartphone screen, corresponding to their chosen object. Following this, participants indicate how confident they are in the accuracy of their choice on a 6-point scale. Following 20 practice trials, participants perform 80 trials divided into four blocks. After every block of 20 trials, participants are asked to report their confidence in their performance in that block on a 6-point scale. Task performance is kept at ca. 72% accuracy by using a two-down-one-up log-adaptive staircasing procedure, whereby the difference in the number of dots increases (the task becomes easier) after an incorrect response and decreases (the task becomes more difficult) after two consecutive correct responses. For a full description of the task parameters and settings, see [60]. In this task, metacognitive bias is operationalised as mean confidence. We focus on mean confidence in this study because the quantification of metacognitive sensitivity and efficiency remains a contested question. Current measures provide sub-optimal validity and reliability, and require higher trial numbers than we had available in the metacognition task employed in this study [61, 62, 63, 64, 60].

Characteristic	PG	CP	$\chi^2/t(df)$	p
Gender, *n*(%)			2.19 (1)	.139
Male	34 (89.5)	28 (73.7)		
Female	4 (10.5)	10 (26.3)		
Country of residence, *n*(%)			2.83 (2)	.243
Ireland	18 (47.4)	25 (65.8)		
United Kingdom	2 (5.3)	2 (5.3)		
United States	18 (47.4)	11 (28.9)		
Highest education level, *n*(%)			2.33 (2)	.312
Secondary school	3 (7.9)	2 (5.3)		
University degree or equiv.	33 (86.8)	36 (94.7)		
PhD or equiv.	2 (5.3)	0 (0.0)		
Age, *M*(*SD*)	31.2 (6.9)	28.8 (10.7)	1.15 (63.1)	.256
RSES, *M*(*SD*)	14.50 (4.6)	16.79 (6.6)	1.75 (66.6)	.084
AD, *M*(*SD*)	0.09 (0.9)	-0.37 (0.9)	2.26 (73.9)	< .05
CIT, *M*(*SD*)	0.92 (0.9)	0.04 (0.9)	4.42 (74.0)	< .0001
PGSI, *M*(*SD*)	15.7 (4.8)	0.0 (0.0)	20.22 (37.0)	< .0001

Table 1: Demographic (gender, country of residence, highest education level, age) and psychological (Rosenberg Self-Esteem Scale (RSES), Anxiety-Depression (AD), Compulsive Behaviour and Intrusive Thought (CIT), Problem Gambling Severity Index (PGSI) measures for problem gamblers (PG) and control participants (CP).

Transdiagnostic Symptom Dimensions. Finally, participants were asked to complete a range of psychiatric measures in order to derive Anxiety-Depression and Compulsive Behaviour and Intrusive Thought scores, two of the three transdiagnostic factors identified by Gillan et al. [24]. To measure these factors more efficiently, we used a reduced set of questions that has been shown to provide an accurate approximation of the true factor scores [65]. We included only those questionnaires that pertain specifically to the Anxiety-Depression and Compulsive Behaviour and Intrusive Thought dimensions. Accordingly, participants completed the following questionnaires: Apathy Evaluation Scale (AES, [66], Barrett's Impulsivity Scale (BIS [67], Eating Attitudes Test (EAT, [68], Obsessive Compulsive Inventory (OCI, [69], Selfrating Depression Scale (SDS, [70], and State Trait Anxiety Inventory (STAI, [71]. Anxiety-Depression and Compulsive Behaviour and Intrusive Thought scores were derived by using the factor weights as per Wise and Dolan [65]. Anxiety-Depression and Compulsive Behaviour and Intrusive Thought scores are scaled around 0, with higher scores corresponding to higher symptom levels.

To provide insight into what the Anxiety-Depression factor assesses, consider the three highest scoring items from this dimension: The first is derived from the AES, which inquires about participants' thoughts, emotions, and activities over the preceding four weeks. The statement is '*I have motivation*' and is coded in reverse. The second item stems from the SDS, requesting participants to express how they felt or behaved in the past few days. The statement is '*I feel that we am useful and needed*' and it is also reverse-coded. The third item is extracted from the STAI, probing into how participants generally feel. The statement is '*I feel satisfied with myself* ' and is coded in reverse as well. For the Compulsive Behaviour and Intrusive Thought dimension, the three highest scoring items are as follows: The first two are

from the OCI, which asks participants how much they have been distressed or bothered by a particular experience in the previous month. The statements are '*I find it difficult to control my own thoughts*' and '*I am upset by unpleasant thoughts that come into my mind against my will*'. The third item comes from the EAT and reads, '*I am terrified about being overweight*'.

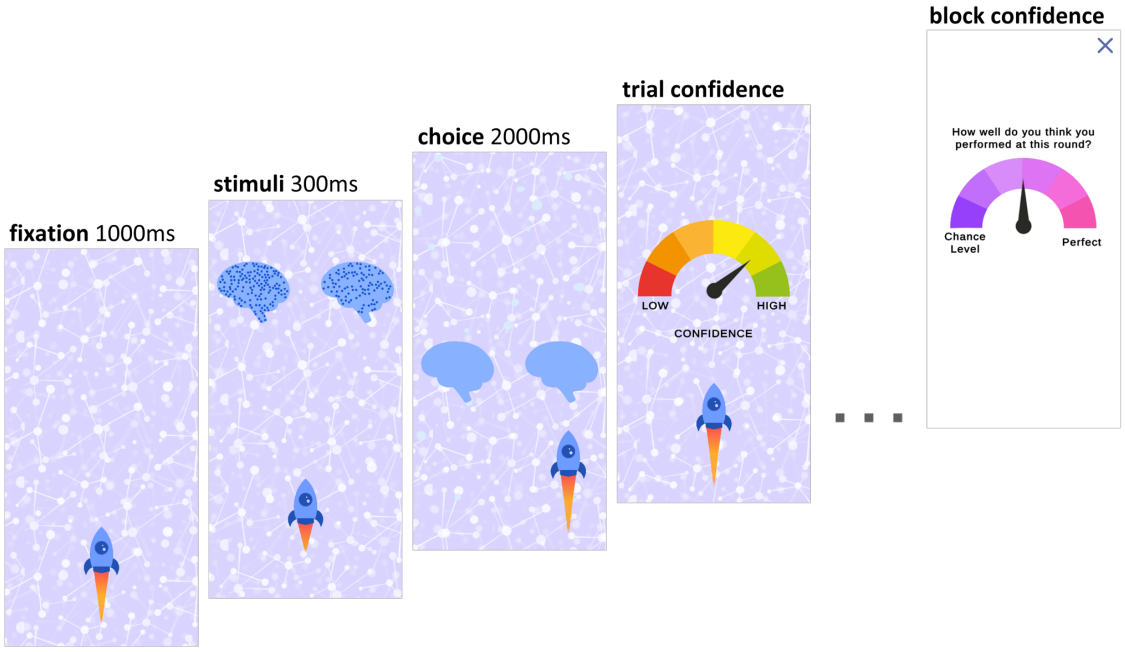

Figure 1: Illustration of Metamind's task structure — a smartphone game designed to evaluate metacognition. Participants were placed in control of a spaceship voyaging through space. When two objects appeared, the task was to steer the spaceship towards the object displaying a greater number of dots. This was achieved by tapping the left or right side of the smartphone screen, corresponding to the object of choice. Subsequently, participants were prompted to report their confidence in the accuracy of their choice on a 6-point scale. After the completion of every set of 20 trials, participants were further asked to report their confidence in their overall performance across the preceding block of 20 trials on a 6-point scale.

Results

The characteristics of the participants are presented Table 1. There were no significant differences between the groups regarding the distribution of gender, country of residence, level of education, or age. This suggests successful matching of the control participants and problem gamblers with regards to demographic variables. The problem gamblers exhibited significantly higher Anxiety-Depression and Compulsive Behaviour and Intrusive Thought scores compared to the control participants (see Figure 2). Within the problem gamblers, problem gambling severity was positively, albeit non-significantly, associated with Compulsive Behaviour and Intrusive Thought symptoms (r = 0.21,p = .213), but showed no association with Anxiety-Depression symptom levels (r = 0.00,p = .996; Figure 3). Despite the staircasing procedure, control participants performed at a slightly higher mean accuracy of 73.2% (±0.03, range = 68.8 — 77.5) compared to problem gamblers at 71.7% (±0.04, range = 62.5 — 77.5; t(74) = 2.1,p < .05). To account for potential effects of task accuracy as well as age and gender, these parameters are included as covariates in subsequent analyses where relevant. For a comprehensive understanding of all descriptive and between-group comparison statistics, refer to Table 1.

The primary research question in this study was whether problem gamblers would show differences in confidence bias relative to controls. To address this question, linear regression analyses were performed to test for group differences in local confidence and global confidence, while controlling for gender, age and mean task accuracy, as well as for self-esteem, while controlling for age and gender. These analyses revealed significant effects of group on local confidence (β = 0.91,SE =

0.20,p < .0001), whereby problem gamblers reported significantly higher confidence at the trial-level compared to control participants, and on global confidence (β = 1.08,SE = 0.28,p < .001), whereby problem gamblers reported significantly higher confidence at the block-level compared to control participants (see Figure 4 A & B). There were no significant effects of gender, age or mean task accuracy on local and global confidence (all p > .27). The higher confidence was not reflected in any significant difference between mean reaction times between problem gamblers (M = 0.91 seconds) and control participants (M = 0.94 seconds; t(74) = 0.90,p = .373; Figure 4 D). In contrast to the finding of elevated local and global confidence, we observed that self-esteem was lower for problem gamblers compared to control participants (M = 14.50 vs. M = 16.79). However, this group effect on self-esteem was not significant when controlling for gender and age (β = −2.4,SE = 1.33,p = .072, Figure 4 C). There were no significant effects of gender or age on self-esteem (both p > .12).

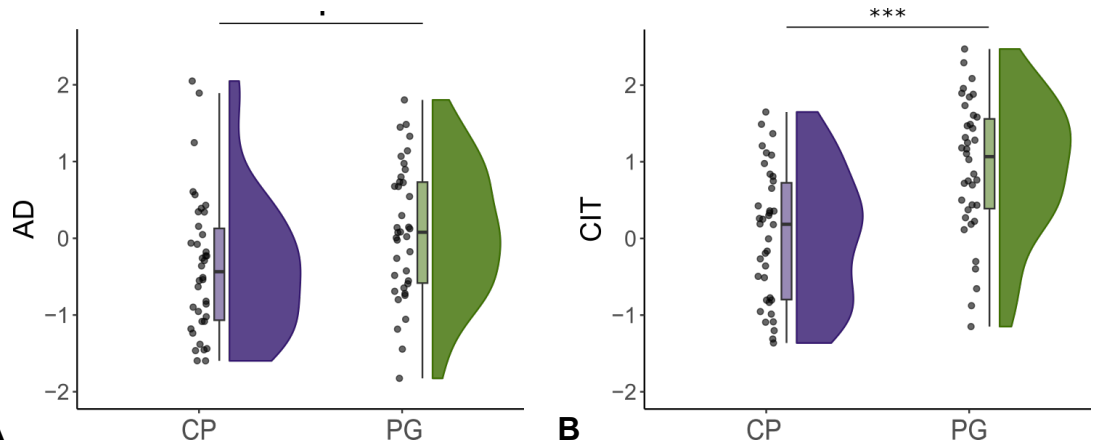

Figure 2: **A.** Anxiety-Depression (AD) and **B.** Compulsive Behaviour and Intrusive Thought (CIT) scores for control participants (CP) and problem gamblers (PG). Dots show data from individual participants. Violin and box plots show the distributions of participant means. · p < .05, *p < .01, **p < .001, ***p < .0001 in two-sample T-test.

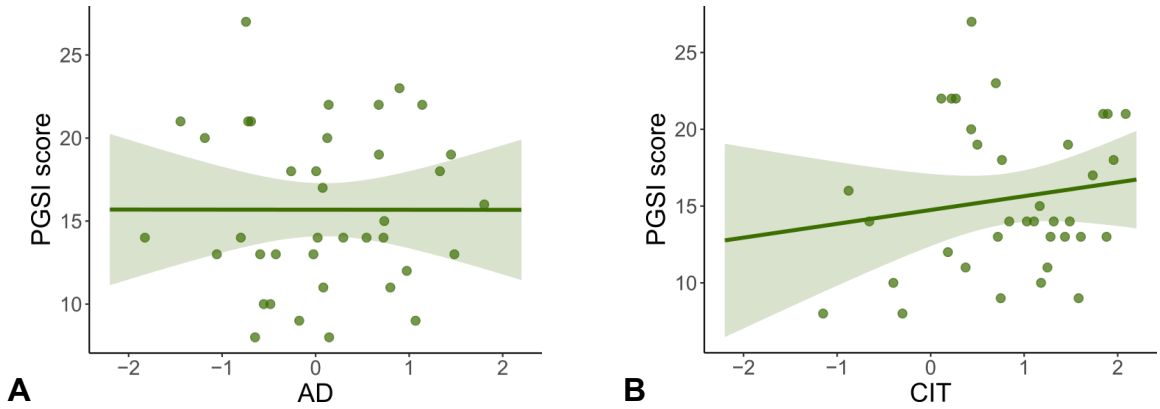

Figure 3: Relationship of **A.** Anxiety-Depression (AD) and **B.** Compulsive Behaviour and Intrusive Thought (CIT) with Problem Gambling Severity Index (PGSI) score in problem gamblers.

Next, we examined whether the observed group differences in confidence bias could be explained by the transdiagnostic symptom dimensions Compulsive Behaviour and Intrusive Thought and Anxiety-Depression (see Figure 5). Specifically, we predicted that Compulsive Behaviour and Intrusive Thought would correlate with elevated confidence, potentially explaining the higher confidence at the local trial and global task level in problem gamblers compared to control participants. Additionally, we predicted that Anxiety-Depression would correlate with reduced confidence, potentially accounting for lower self-esteem. Following the format of our previous analyses, we constructed three regression models to predict local confidence, global confidence, and self-esteem. Instead of group, Anxiety-Depression and Compulsive Behaviour and Intrusive Thought scores were used as predictors. As expected, there was a significant positive association between Compulsive Behaviour and Intrusive Thought and local confidence (β = 0.24,*SE* = 0.11,p < .05), but no effect of Anxiety-Depression on local confidence (β = 0.01,*SE* = 0.11,p = .928). These results were mirrored in the regression on global confidence, with a significant positive association between global

confidence and Compulsive Behaviour and Intrusive Thought (β = 0.34,*SE* = 0.15,p < .05), but no effect of Anxiety-Depression on global confidence (β = 0.02,*SE* = 0.15,p = .917). Contrary to local and global confidence, variations in self-esteem were not significantly associated with either Compulsive Behaviour and Intrusive Thought (β = −0.34,*SE* = 0.70,p = .628) or Anxiety-Depression (β = −0.66,*SE* = 0.69,p = .341). None of the covariates (gender, age, and task accuracy) were statistically significant in any of the three regression models (all p > .076).

Building on these findings, we again constructed three separate regression models to predict each of local confidence, global confidence, and self-esteem. This time, we included both group and the transdiagnostic symptom dimensions, Anxiety-Depression and Compulsive Behaviour and Intrusive Thought, as predictors to establish which among these was best at explaining the observed differences in confidence bias. Notably, the significant group effects on local confidence (β = 0.91,*SE* = 0.23,p < .001) and global confidence (β = 1.02,*SE* = 0.32,p < .005) remained despite including Anxiety-Depression and Compulsive Behaviour and Intrusive Thought as predictors in the regression models. Conversely, there was no longer a significant effect of Compulsive Behaviour and Intrusive Thought on local (β = 0.05,*SE* = 0.11,p = .654) and global (β = 0.12,*SE* = 0.16,p = .441) confidence. As before, the effects of Anxiety-Depression on local (β = −0.08,*SE* = 0.10,p = .408) and global (β = −0.09,*SE* = 0.14,p = .534) confidence were not significant in the regression models. In the case of self-esteem, there were no significant effects of any of group (β = −2.4,*SE* = 1.58,p = .135), Compulsive Behaviour and Intrusive Thought (β = 0.21,*SE* = 0.78,p = .791) or Anxiety-Depression (β = −0.44,*SE* = 0.70,p = .533). None of the covariates

(gender, age, and task accuracy) were significant in any of the three regression models (all $p > .15$).

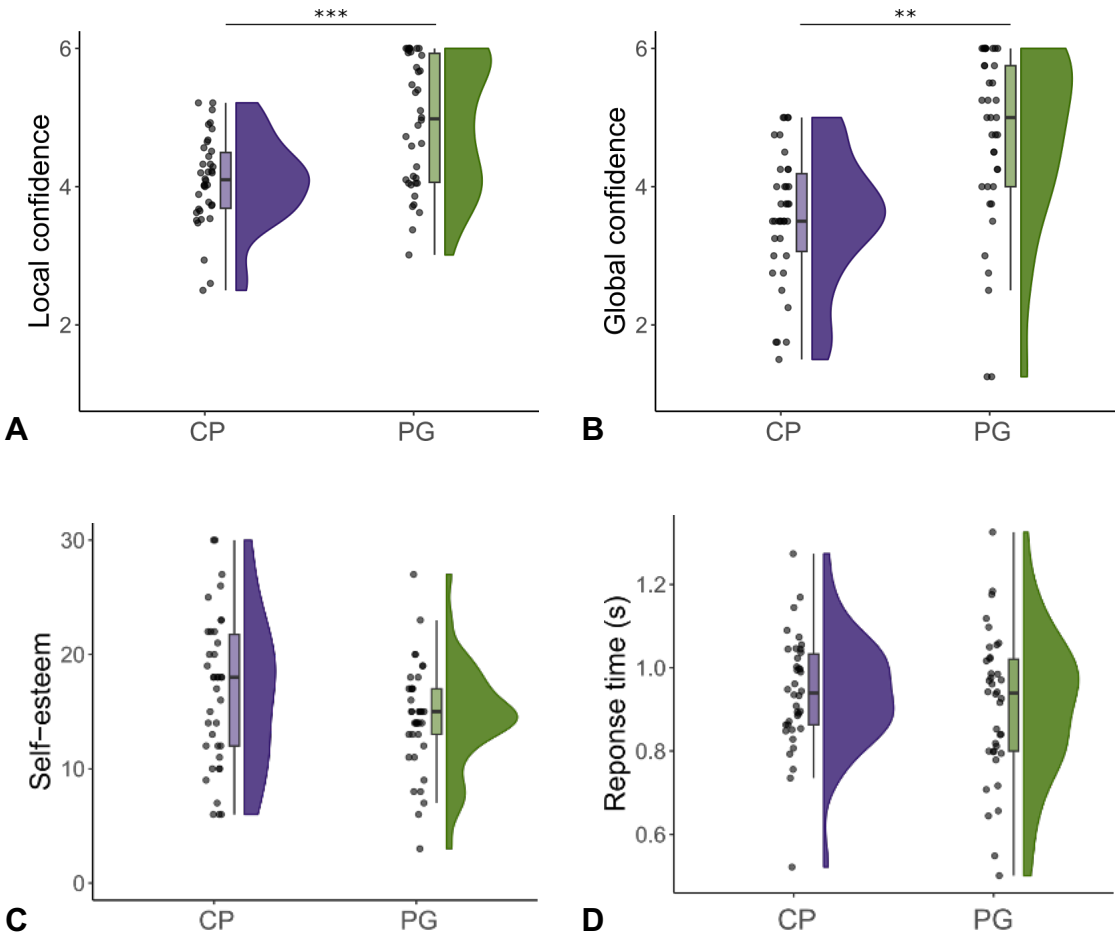

Figure 4: **A.** Local trial confidence, **B.** global task confidence, and **C.** self-esteem for control participants (CP) and problem gamblers (PG). Dots show data from individual participants. Violin and box plots show the distributions of participant means. *$p <$ .01, **$p <$ .001, ***$p <$ .0001 in linear regression with age, gender, and task accuracy as covariates. **D.** Mean reaction times in seconds for control participants (CP) and problem gamblers (PG)

Lastly, we investigated the inter-relationship between local trial confidence, global task confidence, and self-esteem, with a particular focus on potential differences in these relationships between problem gamblers and control participants (see

Figure 6). Both the problem gamblers and control participants exhibited a strong association between local trial confidence and global task confidence (problem gamblers: $r = 0.71, p < .0001$; control participants: $r = 0.75, p < .0001$). Applying Fisher's Z-test to examine whether the strength of these correlations differed between the two groups showed that the correlation coefficients did not significantly differ ($Z = -0.33, p = .74$). In contrast, self-esteem appeared to be largely independent of local confidence in the control participants ($r = -0.08, p = .629$), but was positively associated with local confidence in the problem gamblers ($r = 0.33, p < .05$; $z = 1.78, p = .075$). Self-esteem was not significantly correlated with global confidence in either group (problem gamblers: $r = 0.19, p = .251$; control participants: $r = -0.11, p = .522$; $Z = 1.26, p = .208$).

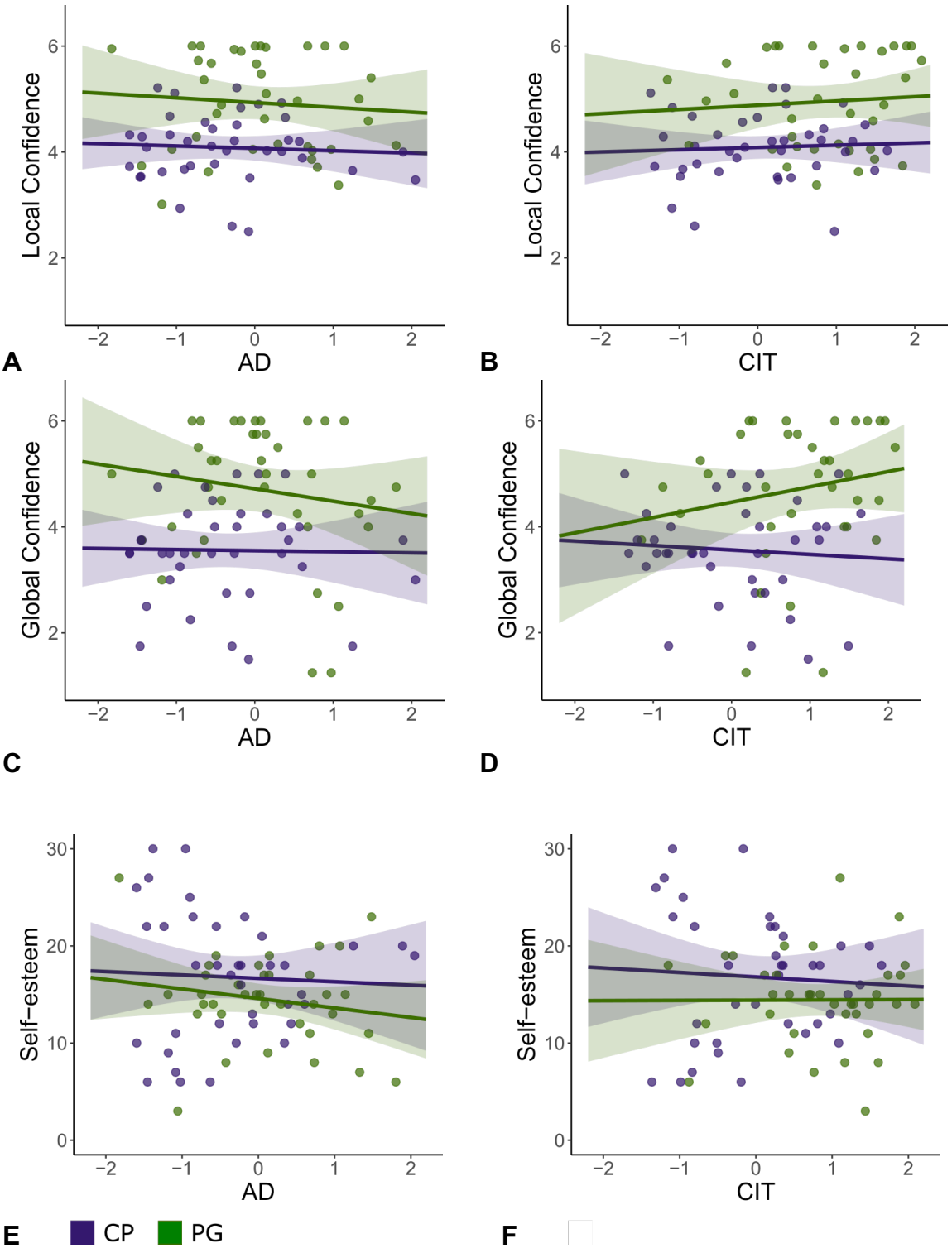

Figure 5: Relationship between the transdiagnostic symptom dimensions (Anxiety-Depression (AD) and Compulsive Behaviour and Intrusive Thought (CIT) and confidence at all levels of the metacognitive hierarchy (local confidence, global confidence, and self-esteem) for control participants (CP) and problem gamblers (PG).

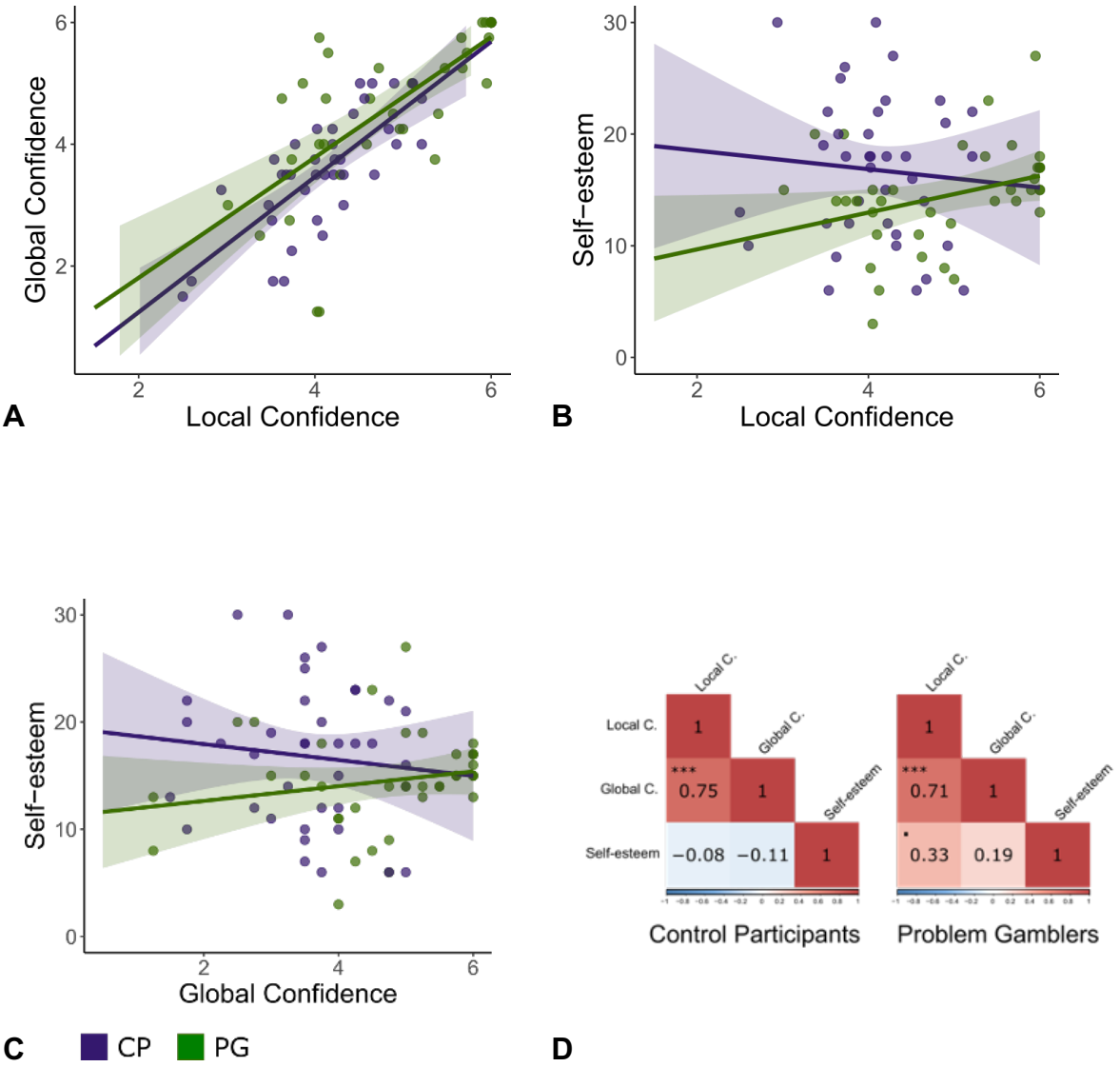

Figure 6: **A.-C.** Relationship between local trial confidence, global task confidence, and self-esteem for control participants (CP) and problem gamblers (PG). **D.** Correlation matrix for local trial confidence, global task confidence, and self-esteem for control participants and problem gamblers. · $p < .05$, *$p < .01$, **$p < .001$, ***$p < .0001$

Discussion

Our internal sense of confidence plays a crucial role in guiding our behaviours, particularly when external feedback is lacking. Misjudgements in confidence can result in maladaptive behaviours, and systematic aberrations have been

associated with psychiatric disorders. The transdiagnostic approach, which characterises symptoms across diagnostic boundaries rather than adhering to traditional diagnostic categories, has shown that a symptom dimension of Anxiety-Depression is associated with reduced confidence, whereas a Compulsive Behaviour and Intrusive Thought dimension is associated with elevated confidence [23]. This study sought to investigate how these confidence alterations manifest at different hierarchical levels of metacognition (local confidence, global confidence, self-esteem) in problem gamblers, a group often displaying symptoms of both Anxiety-Depression and Compulsive Behaviour and Intrusive Thought, compared to control participants.

The findings demonstrated that a group of problem gamblers showed significantly higher local trial-by-trial and global task confidence compared to control participants, even after controlling for gender, age, and objective task accuracy. However, despite the problem gamblers' elevated confidence on trial and task levels, their overall self-esteem was generally lower than that of the control participant group (albeit not significantly so). We hypothesised that the heightened confidence within the problem gamblers might be attributable to elevated Compulsive Behaviour and Intrusive Thought levels in problem gamblers, whereas the diminished self-esteem might be associated with increased levels of Anxiety-Depression in this group. Although we observed the expected significant association of Compulsive Behaviour and Intrusive Thought with elevated local and global confidence across groups, this effect diminished when controlling for group. Moreover, there was no significant effect of Anxiety-Depression on confidence at any level of the metacognitive hierarchy. The group effect on elevated confidence on the other hand remained significant even when controlling for the transdiagnostic symptom dimensions, Anxiety-Depression and

Compulsive Behaviour and Intrusive Thought. This suggests that there are differences between the problem gamblers and control participants driving elevated decision confidence that are not captured by the transdiagnostic symptom dimensions.

The observation of significantly higher levels of local and global confidence in the problem gamblers in comparison to the control participants, even after accounting for elevated levels of Compulsive Behaviour and Intrusive Thought and Anxiety-Depression, and despite lower self-esteem, raises intriguing questions about the underlying mechanisms contributing to heightened decision confidence in this group. Research conducted by Hoven et al. [47] found that problem gamblers displayed a reduced integration of evidence into their confidence judgements for correct choices. This was observed when compared to both healthy controls and OCD patients, a comparison that underlines the presence of additional processes specific to problem gamblers, given that OCD patients also display high Compulsive Behaviour and Intrusive Thought symptom levels. This diminished sensitivity towards objective evidence might align with cognitive distortions that are a common occurrence in problem gamblers. These distortions may include biases like interpretive bias (perceived ability to interpret or control ambiguous events), illusion of control (overestimation of ability to control events), or predictive control (reflecting probability errors such as the gamblers' fallacy; [72, 73, 44, 74, 75, 76]. Moreover, problem gamblers often display cognitive inflexibility, which may include a reduced capacity to shift attention and could make them less receptive to objective evidence that contradicts their beliefs, thereby fostering overconfidence [77, 78]. Possibly supporting the notion of a lack of sensitivity to belief-contradicting evidence, a study by Wyckmans et al. [79] found that individuals with problem gambling disorder demonstrated impaired model-based

476 learning, especially after non-rewarded outcomes. These individuals also
477 exhibited faster reaction times compared to control participants following
478 nonrewarded decisions. This lack of reduced speed in response after a loss in
479 problem gamblers was also observed by Goudriaan et al. [80]. Such behaviour
480 has also been associated with increased impulsive responding often observed in
481 problem gamblers [81]. However, results in the current study did not reveal any
482 differences in mean reaction times between the problem gamblers and control
483 participants. This lack of a reaction time difference suggests that impulsivity, as
484 measured by response times, may not have been a direct contributor to the
485 observed overconfidence in problem gamblers in the current study.

486 Although group effects persisted even after accounting for Anxiety-Depression and
487 Compulsive Behaviour and Intrusive Thought, these effects were smaller than those
488 found when not accounting for the transdiagnostic dimensions. This finding indicates
489 that, although the differences in confidence levels and self-esteem between problem
490 gamblers and control participants are not exhaustively captured by the Anxiety-
491 Depression and Compulsive Behaviour and Intrusive Thought symptom dimensions,
492 these factors do explain some of the observed variance. Moreover, a regression
493 model not including group as a predictor showed significant effects of Compulsive
494 Behaviour and Intrusive Thought on elevated local and global confidence.
495 Overconfidence linked to Compulsive Behaviour and Intrusive Thought has been
496 suggested to reflect difficulties in developing an accurate cognitive map or model of
497 the task environment [24]. Evidence for this comes from Seow and Gillan [25], who
498 demonstrated that individuals with higher Compulsive Behaviour and Intrusive
499 Thought were less likely to use evidence to inform their confidence evaluations,
500 exhibiting overall inflated confidence estimates and an inability to adequately utilise

unexpected outcomes, belief uncertainty, and positive feedback to appropriately inform their confidence levels. This begs the question, if environmental evidence is not informing confidence in those high in Compulsive Behaviour and Intrusive Thought, what is? One speculative answer to this question may lie in an individual's prior expectations. Individuals with higher Compulsive Behaviour and Intrusive Thought symptoms could be basing their confidence on a distorted prior expectation of success, and thus not adequately use objective evidence available in the task environment to update their beliefs.

The lack of a clear effect of Anxiety-Depression on confidence may need to be considered in light of the effect sizes of the associations between Anxiety-Depression and reduced confidence, and Compulsive Behaviour and Intrusive Thought and elevated confidence reported in previous studies [25, 23], and even in the same task as used in the present study [60]. Power analyses (assuming a power of 0.80 and a two-tailed alpha of 0.05) indicated that a sample size of 280 would have been needed to reliably detect an association between confidence and Anxiety-Depression scores in general population samples. It is also important to consider that findings from the general population may not always be generalisable to patient populations. A recent study comparing non-clinical highly compulsive individuals to OCD patients found that whereas highly compulsive individuals did indeed display local and global overconfidence, OCD patients exhibited underconfidence across all three levels of the metacognitive hierarchy [82]. This implies that confidence manifestations can significantly vary, even among populations sharing compulsive tendencies. Hence, drawing inferences from general population studies, such as Rouault et al. [23], about the way in which the transdiagnostic dimensions impact on a clinical group like problem

gamblers should be done with caution. Although the symptom dimensions may be associated with confidence biases in such individuals, there could also be distinct aspects inherent to problem gamblers that modify the extent and manifestation of these biases.

Exploring the relationships between local trial confidence, global task confidence, and self-esteem, we found a strong association between local and global confidence, with no significant differences between the problem gamblers and control participants. This suggests that although problem gamblers are biased in their local confidence judgements for individual decisions, this information is then integrated into a global confidence judgement on a task level without further distortion. However, considering that global confidence was probed after each block of trials, and via a similar 6-point scale, it may not be surprising that this measure closely aligns with trial-level confidence. Interestingly, self-esteem appeared to be disconnected from both local and global confidence in the control participants, indicating a decoupling across the metacognitive hierarchy. In contrast to the control participants, there was a significant correlation between self-esteem and local confidence within the problem gamblers. Notably, the fact that the decoupling of self-esteem from local confidence was observed in the control participants is in contrast to our original hypothesis. This finding suggests that the dissociation is not likely driven by counteracting impacts of Compulsive Behaviour and Intrusive Thought on local confidence, and Anxiety-Depression on self-esteem. If this were the case, we would expect a stronger dissociation at higher symptom levels, i.e., in the problem gamblers. The observed independence of self-esteem from local and global confidence in control participants contrasts with recent research that revealed a positive association between individual confidence and self-esteem [83]. Rouault et

al. [84] compared low and high self-esteem groups and discovered that, despite no significant performance disparity, the low self-esteem group consistently reported lower global confidence ratings. Corroborating this, Hoven et al. [18] found that higher-order self-beliefs were positively correlated with confidence and overconfidence at both local and global levels, independent of objective performance. The apparent divergence of these findings from our results underscores the necessity for additional comprehensive, long-term studies, which would provide a more comprehensive understanding of the relationship between these variables and how they evolve over time.

It is noteworthy that although the transdiagnostic dimensions probed in this study have been validated repeatedly, the questionnaire items that constitute these dimensions do not comprehensively represent all forms of psychopathology. Other transdiagnostic symptom structures that may capture a more extensive array of cognitive/metacognitive alterations have been suggested [85, 86, 87]. Furthermore, another fundamental question concerns the relationship between abnormalities in metacognitive processes and psychiatric disorders. These abnormalities might be intricately linked with, or even underpin, psychiatric symptoms, or they could arise as a consequence of the disorder. Alternatively, they might be inconsequential by-products that have no significant influence on symptom presentation. In this context, Fox et al. [27] found that the underconfidence bias related to Anxiety-Depression showed significant improvement along with reductions in Anxiety-Depression severity following cognitive-behavioural therapy or antidepressant medication. Although this finding does not clarify whether metacognitive abnormalities are a cause or consequence of the disorder, it offers valuable insight into their dynamic nature. Specifically, it

suggests that metacognitive biases may not be enduring, static traits, but rather state-dependent variables susceptible to change as psychiatric symptoms evolve. However, more research is needed to fully understand the relationship between metacognitive abnormalities and psychiatric disorders.

Given that overconfidence in problem gamblers can lead to excessive risk-taking, increased financial loss, and a destructive cycle of continued gambling, a better understanding of the driving forces behind this overconfidence is needed to inform therapeutic interventions aimed at mitigating its adverse effects. The current study established that problem gamblers exhibit significantly higher levels of local and global decision confidence compared to a control group. Notably, this heightened decision confidence persists despite lower overall self-esteem and is not fully explained by the transdiagnostic symptom dimensions Compulsive Behaviour and Intrusive Thought and Anxiety-Depression. A future direction of this research might include a more comprehensive examination of cognitive flexibility and decision-making processes in problem gamblers using gamified versions of other cognitive tasks. These tasks could provide additional insights into the cognitive profile of problem gamblers, contributing to a more nuanced understanding of the cognitive biases and distortions that may fuel overconfidence and persistent gambling behaviours in this group.

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