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FULL-LENGTH REPORT

Confidence biases in problem gambling

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ABSTRACT

Background and aims: Subjective confidence plays an important role in guiding behaviour, especially when objective feedback is unavailable. Systematic misjudgements in confidence can foster maladaptive behaviours and have been linked to various psychiatric disorders. In this study, we adopted a transdiagnostic approach to examine confidence biases in problem gamblers across three levels: local decision confidence, global task performance confidence, and overall self-esteem. The importance of taking a transdiagnostic perspective is increasingly recognised, as it captures the dimensional nature of psychiatric symptoms that often cut across diagnostic boundaries. Accordingly, we investigated if any observed confidence biases could be explained by transdiagnostic symptom dimensions of Anxiety-Depression and Compulsive Behaviour and Intrusive Thought. This approach allows us to gain a more comprehensive understanding of the role of metacognitive processes in problem gambling, beyond the constraints of traditional diagnostic categories. *Methods:* Thirty-eight problem gamblers and 38 demographically matched control participants engaged in a gamified metacognition task and completed self-report questionnaires assessing transdiagnostic symptom dimensions. *Results:* Compared to controls, problem gamblers displayed significantly elevated confidence at the local decision and global task levels, independent of their actual task performance. This elevated confidence was observed even after controlling for the heightened symptom levels of Anxiety-Depression and Compulsive Behaviour and Intrusive Thought among the problem gamblers. *Discussion:* The results reveal a notable disparity in confidence levels between problem gamblers and control participants, not fully accounted for by the symptom dimensions Anxiety-Depression and Compulsive Behaviour and Intrusive Thought. This suggests the contribution of other factors, perhaps linked to gambling-specific cognitive distortions, to the observed confidence biases. *Conclusion:* The findings highlight the intricate link between metacognitive confidence and psychiatric symptoms in the context of problem gambling. It underscores the need for further research into metacognitive biases, which could enhance therapeutic approaches for individuals with psychiatric conditions.

KEYWORDS

problem gambling, metacognition, confidence, transdiagnostic psychiatry

INTRODUCTION

Decision-making often requires assessing the utility of one's choices without immediate external feedback, relying instead on an internal sense of confidence (Desender, Boldt, & Yeung, 2018; Folke, Jacobsen, Fleming, & De Martino, 2016). Inaccuracies in these internal evaluations are important as they can influence future behaviour, including the initiation or persistence of maladaptive behaviours. It is thought that in extreme cases, inaccurate metacognitive judgements could contribute to pathological behaviours, such as compulsive

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checking due to diminished confidence in memory (Boschen & Vuksanovic, 2007; Tolin et al., 2001), or delusional thinking stemming from overconfidence in false beliefs (Moritz, Woodward, Whitman, & Cuttler, 2005). Hence, a thorough understanding of metacognition — the monitoring of one's own thoughts and behaviours — may advance our understanding of several psychiatric disorders (David, Bedford, Wiffen, & Gilleen, 2014; Sharma, Sagar, Kaloiya, & Mehta, 2022; Sun, Zhu, & So, 2017).

The current study aimed to probe the nature and extent of biased metacognition within a sample of problem gamblers. Gambling disorder is a condition classified as a substance-related and addictive disorder by the DSM-5 (American Psychiatric Association, 2013). It is characterised by persistent and recurrent problematic gambling behaviour leading to substantial impairment or distress. Previous investigations into confidence levels in problem gamblers have pointed towards a tendency for heightened confidence among these individuals (Brevers et al., 2014; Goodie, 2005; Hoven, de Boer, et al., 2022; Lakey, Goodie, & Campbell, 2007). However, these studies have had limitations; some have not controlled for objective performance differences and others have lacked a demographically matched control group. A second limitation to existing work is that it has not examined how alterations in confidence in problem gamblers might be captured using a dimensional and transdiagnostic framework.

The emerging field of transdiagnostic psychiatry suggests that cognitive, affective, and neurobiological mechanisms underlying complex behaviours might align more closely with symptom dimensions that cut across traditional diagnostic boundaries (Huys, Maia, & Frank, 2016; Stephan & Mathys, 2014; Wise, Robinson, & Gillan, 2023). A study by Rouault, Seow, Gillan, and Fleming (2018) leveraged this transdiagnostic approach to investigate the relationship between metacognitive confidence and psychiatric symptomatology in a non-clinical sample. A transdiagnostic symptom dimension Anxiety-Depression, which primarily links apathy, anxiety, and depression features, showed a significant negative correlation with confidence in a perceptual decision-making task. In contrast, a Compulsive Behaviour and Intrusive Thought symptom dimension, characterised predominantly by elements of impulsivity, OCD, schizotypy, addiction, and eating disorders, had a positive correlation with confidence. These transdiagnostic associations have been replicated in numerous studies (Benwell, Mohr, Wallberg, Kouadio, & Ince, 2022; Fox, Lee, et al., 2023; Hoven, Luigjes, Denys, Rouault, & van Holst, 2023; Rouault et al., 2018; Seow & Gillan, 2020), and have been shown to capture variation in confidence more strongly than questionnaires that pertain to discrete disorders like OCD or depression.

Seow, Rouault, Gillan, and Fleming (2021) suggested that these confidence biases may be driven by two distinct mechanisms operating at different hierarchical levels of metacognition. Here, local decision confidence refers to the certainty an individual feels about the accuracy of each specific decision made. It is the most immediate level of metacognitive evaluation, directly influenced by the task at hand. In contrast, global task performance confidence encompasses an individual's overall assessment of their capability across the entire task, reflecting a more generalised judgement than that made at the local level. Lastly, overarching self-esteem is a higher-order attribute that reflects global self-beliefs about one's worth and capabilities, extending beyond specific tasks to influence broader perceptions of the self. Reduced confidence related to Anxiety-Depression may originate from these global self-beliefs like self-esteem, whereas heightened confidence related to Compulsive Behaviour and Intrusive Thought could be a consequence of difficulties in constructing an accurate mental model of one's own performance, affecting confidence first at the more 'local' decision level. Supporting this idea, Hoven et al. (2023) found that when self-esteem was accounted for, Anxiety-Depression was no longer negatively associated with local decision confidence, whereas Compulsive Behaviour and Intrusive Thought remained positively associated with local confidence. These findings suggest that different levels of the metacognitive hierarchy are implicated in Anxiety-Depression versus Compulsivity.

As problem gambling is typified by compulsive behaviour, yet also demonstrates high comorbidity rates with anxiety and depression (Dannon, Lowengrub, Aizer, & Kotler, 2006; Dowling et al., 2015; Jauregui, Urbiola, & Estevez, 2016; Lorains, Cowlishaw, & Thomas, 2011), it is unclear how metacognitive biases might manifest in this condition. Therefore, the present study aimed to examine whether problem gamblers exhibit biases in confidence at the local decision level, global task performance level, and overarching self-esteem level, compared to a demographically matched control group. This assessment is conducted using a gold-standard task to assess metacognition independently of any differences in objective task performance (Rouault et al., 2018). Moreover, we sought to investigate how these biases in confidence relate to the transdiagnostic symptom dimensions of Compulsive Behaviour and Intrusive Thought and Anxiety-Depression. Specifically, we hypothesised that problem gamblers would display elevated confidence at the local decision and global task levels, compared to controls, and that these differences might be partially explained by the transdiagnostic symptom dimensions. Additionally, we hypothesised an interrelationship among local decision confidence, global task performance confidence, and self-esteem, and that this relationship may vary between problem gamblers and control participants. By investigating these dynamics, this study aims to elucidate the intricate interplay between metacognitive processes and psychiatric symptoms, contributing to a more nuanced understanding of problem gambling.

METHODS

Procedure

Problem gamblers and healthy comparison participants (final $N = 38$ per group) were recruited via posters displayed

near gambling venues, gambling support group networks, university mailing lists and from online forums. All study volunteers were pre-screened online using the self-reported Problem Gambling Severity Index (PGSI) (Ferris & Wynne, 2001), and at this time they also completed the Rosenberg Self-Esteem scale (RSES) (Rosenberg, 1965) as well as some basic demographic information (age, gender, highest education level, and country of residence). We invited those who scored ≥8 on the PGSI to participate in the full study as part of the problem gambling group and those who scored 0 as healthy controls. Participants who scored >0 and <8 were not included in the current study. Once invited to participate, all participants were sent instructions via email on how to download the Neureka app. The Neureka app is a citizen science smartphone application for conducting large scale brain health research. It was developed by the Gillan Lab at Trinity College Dublin and features a collection of gamified versions of commonly used psychological tasks and questionnaires. Within this app, participants were asked to complete the Metamind section (Fig. 1), comprising a gamified metacognition task and survey items from which the transdiagnostic symptom dimensions Anxiety-Depression and Compulsivity and Intrusive Thought can be calculated. Additional healthy control participants were drawn from a parallel study that aimed to validate the metacognition task in comparison to a more traditional browser-based version, and which has been published separately and followed the same procedures as the present study (Fox et al., 2024). In this partially overlapping study, half of the participants were randomised to receive the smartphone game first (traditional task second) and of those, participants with a PGSI score of 0 and who met our inclusion criteria (below) were included as healthy controls in the present study. All participants were compensated with a €10 gift card upon full completion of the study.

Participants

The final sample consisted of 38 problem gamblers (34 male; mean age: 31.2, SD = 6.9) and 38 control participants (28 male; mean age 28.8, SD = 10.7). Table 1 depicts the full demographic profile and questionnaire scores of problem gamblers and control participants as well as between-groups comparisons.

Inclusion criteria. Participants were included in the present study if they were based in the UK, Ireland, or the US. To support the demographic matching of the control group and the gambler group, we included healthy control participants from the parallel validation study (Fox et al., 2024), if they were either male or above the age of 20. In the final sample analysed in this study, 18.4% were drawn Fox et al. (2024).

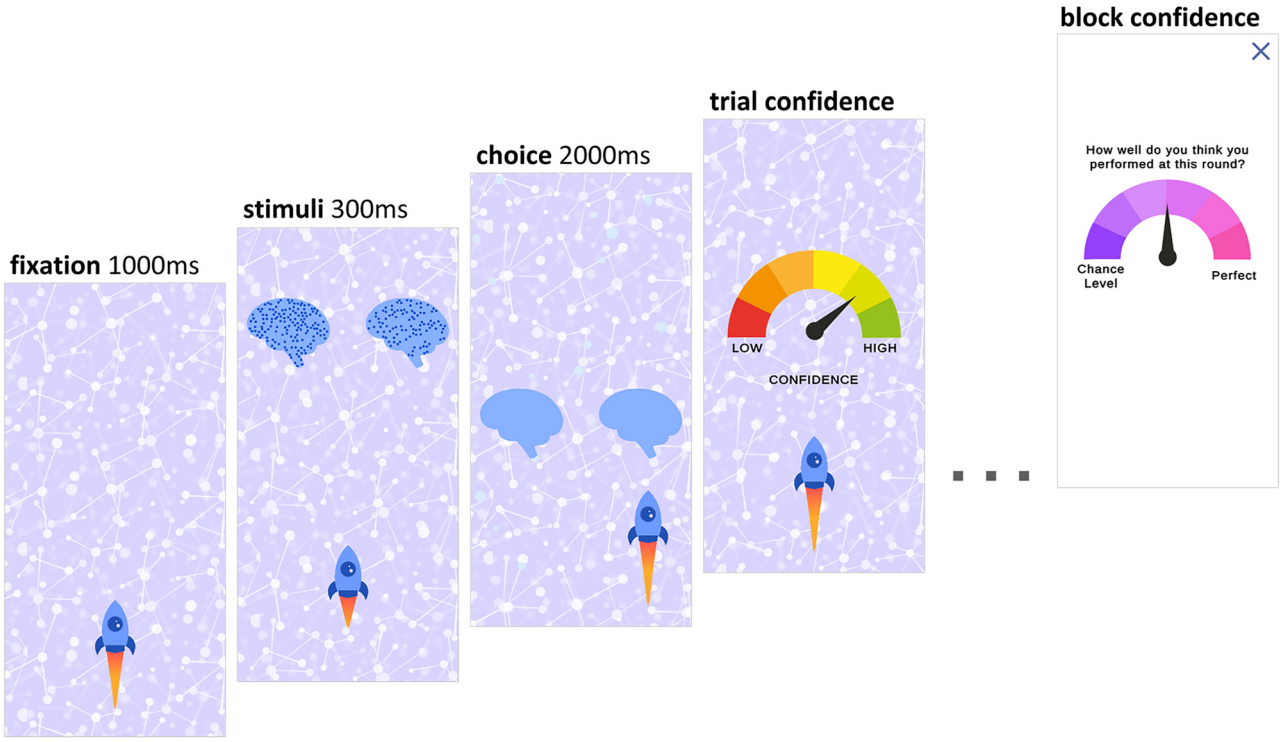

Fig. 1. Illustration of Metamind's task structure — a smartphone game designed to evaluate metacognition. Participants were placed in control of a spaceship voyaging through space. When two objects appeared, the task was to steer the spaceship towards the object displaying a greater number of dots. This 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

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)

Characteristic	PG	CP	χ^2/t (*df*)	*p*
Gender, *n* (%)			2.19 (1)	0.139
Male	34 (89.5)	28 (73.7)		
Female	4 (10.5)	10 (26.3)		
Country of residence, *n* (%)			2.83 (2)	0.243
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)	0.312
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)	0.256
RSES, *M*(*SD*)	14.50 (4.6)	16.79 (6.6)	1.75 (66.6)	0.084
AD, *M*(*SD*)	0.09 (0.9)	−0.37 (0.9)	2.26 (73.9)	<0.05
CIT, *M*(*SD*)	0.92 (0.9)	0.04 (0.9)	4.42 (74.0)	<0.0001
PGSI, *M*(*SD*)	15.7 (4.8)	0.0 (0.0)	20.22 (37.0)	<0.0001

Exclusion criteria. Participants were excluded if there was evidence of disingenuous responding. Specifically, we excluded subjects with disparities between the preliminary screening survey and the data they provided to the Neureka app in their self-reported gender or country of residence, or if the age they reported at the two timepoints differed by more than 1 year ($N = 49$). Consistent with prior work using this task, we excluded participants if the staircase procedure of the metacognition task failed to produce accuracies in the 0.60–0.85 range ($N = 1$) (Fox et al., 2024).

Measures

Problem Gambling Severity Index. The PGSI, a 9-item refined version of the Canadian Problem Gambling Index (CPGI; Ferris & Wynne, 2001), is a non-clinical assessment survey for problem gambling and has been used worldwide in population-level survey research (Dunne, Flynn, & Sholdis, 2017; Kavli & Berntsen, 2005; Kristiansen & Jensen, 2011; Meyer, Hayer, & Griffiths, 2009; Volberg & Bernhard, 2006; Wardle et al., 2007; Young & Stevens, 2008). 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; Rosenberg, 1965). 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 self-esteem score which can range from 0 to 30. Higher scores indicate higher self-esteem, whereas lower scores suggest lower self-esteem.

Metacognition task. The Metamind task is a gamified version of the Dot Discrimination Task, a perceptual decision-task frequently used to measure metacognition (Boldt & Yeung, 2015; Rouault et al., 2018). The smartphone task was recently validated in a separate study and it has moderate convergent validity with a longer traditional browser-based version ($r\ (50) = 0.64$, $p < 0.001$) as well as excellent split-half reliability ($r\ (50) = 0.91$, $p < 0.001$) and very high test-retest reliability (ICC = 0.86, $N = 110$) (Fox et al., 2024). In Metamind, participants are given the task of controlling a spaceship traversing the brain. 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. The median completion time for the Metamind task in this study was 8.43 min.

For a full description of the task parameters and settings, see Fox et al. (2024). 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. This is because current measures provide suboptimal validity and reliability, and require higher trial numbers than we had available in the metacognition task employed in this study (Arnold, Johnston, Adie, & Yarrow, 2023; Desender, Vermeylen, & Verguts, 2022; Fox et al., 2024; Guggenmos, 2021; Rahnev, 2023).

Transdiagnostic symptom dimensions. As part of the smartphone-based task, 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, Kosinski, Whelan, Phelps, and Daw (2016). 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 (Wise & Dolan, 2020). 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, Marin, Biedrzycki, & Firinciogullari, 1991), Barrett's Impulsivity Scale (BIS Patton, Stanford, & Barratt, 1995), Eating Attitudes Test (EAT, Garner, Olmsted, Bohr, & Garfinkel, 1982), Obsessive Compulsive Inventory (OCI, Foa et al., 2002), Self-rating Depression Scale (SDS, Zung, 1965), and State Trait Anxiety Inventory (STAI, Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983). Anxiety-Depression and Compulsive Behaviour and Intrusive Thought scores were derived by using the factor weights as per Wise and Dolan (2020). 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*'.

Statistical analyses

Group differences in demographic variables, problem gambling severity, and transdiagnostic symptom scores were examined through descriptive statistics and independent samples *t*-tests or chi-square tests. The relationship between problem gambling severity and symptom dimensions within the problem gambler group was quantified using Pearson correlation coefficients. To investigate the primary research question regarding differences in confidence bias, we conducted multiple regression models. These models predicted levels of local and global confidence, as well as self-esteem (dependent variables), from group status (problem gambler vs. control participant – independent variable) while adjusting for the demographic covariates gender and age. Mean task accuracy was also incorporated as a covariate in models evaluating local and global confidence but was not included for the self-esteem analysis due to its lack of direct relevance. To probe the influence of transdiagnostic symptom dimensions on confidence biases, we introduced symptom dimension scores as independent variables in subsequent models, replacing group status. This approach aimed to discern the individual contribution of these symptom dimensions to variations in local confidence, global confidence, and self-esteem. In a further analytical step, both group status and symptom dimension scores were concurrently included as independent variables in the models. This dual inclusion enabled an assessment of their comparative explanatory power. Detailed regression tables for all analyses are provided in appendix. Lastly, the relationships between local trial confidence, global task performance confidence, and self-esteem were examined using Pearson correlation coefficients, with Fisher's *Z*-test applied to assess whether the strength of these correlations differed between problem gamblers and control participants.

Ethics

The study was approved by the School of Psychology Research Ethics Committee, Trinity College Dublin. All participants provided informed consent.

RESULTS

The characteristics of the participants are presented in 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 (Fig. 2A and B). Within the problem gamblers, problem gambling severity was positively, albeit non-significantly, associated with Compulsive Behaviour and Intrusive Thought symptoms ($r = 0.21$, $p = 0.213$), but showed no association with Anxiety-Depression symptom levels ($r = 0.00$, $p = 0.996$; Fig. 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, $p < 0.05$, Fig. 2C). 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, global confidence, and self-esteem. Gender, age and mean task accuracy were controlled for in analyses of local and global confidence. Gender and age were controlled for in the analysis of self-esteem. These analyses revealed significant effects of group on local confidence ($\beta = 0.91$, $SE = 0.20$, $p < 0.0001$), whereby problem

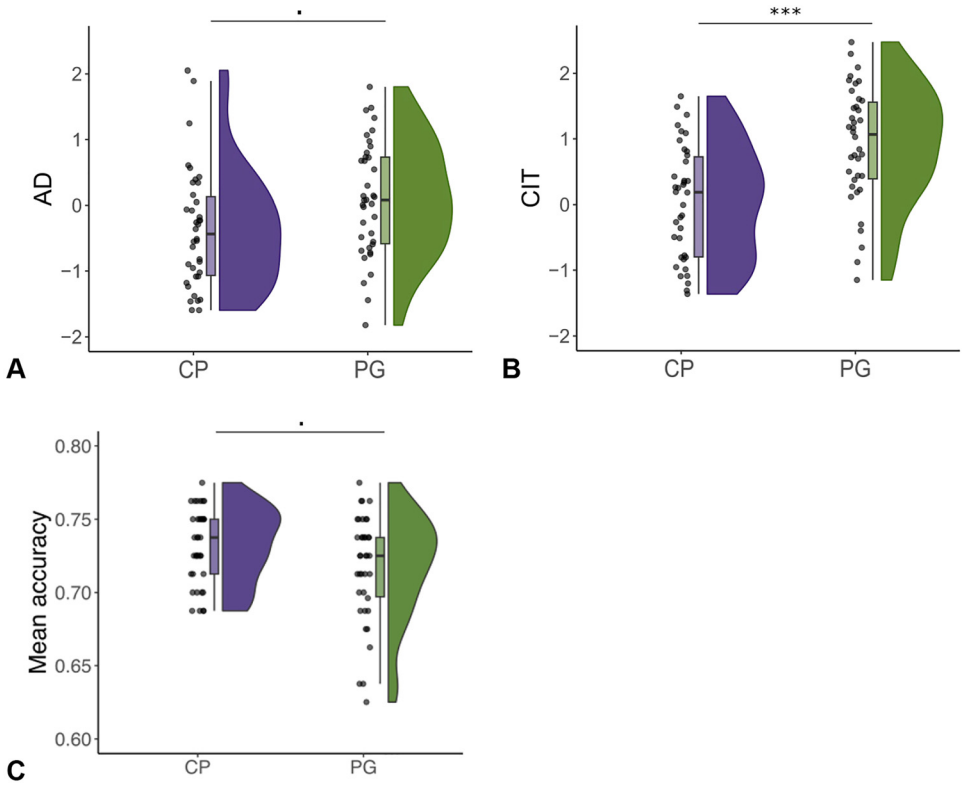

Fig. 2. **A.** Anxiety-Depression (AD), **B.** Compulsive Behaviour and Intrusive Thought (CIT) scores, and **C.** mean accuracy for $N = 38$ control participants (CP) and $N = 38$ problem gamblers (PG). Dots show data from individual participants. Violin and box plots show the distributions of participant means. · $p < 0.05$, $^{*}p < 0.01$, $^{**}p < 0.001$, $^{***}p < 0.0001$ in two-sample T-test

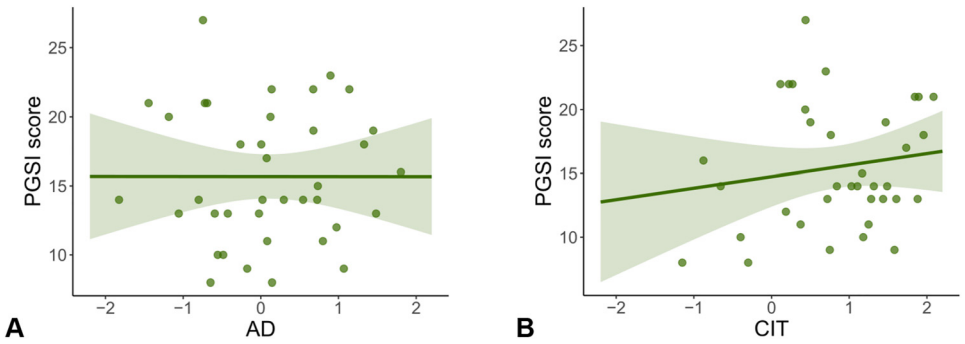

Fig. 3. Relationship of **A.** Anxiety-Depression (AD) and **B.** Compulsive Behaviour and Intrusive Thought (CIT) with Problem Gambling Severity Index (PGSI) score in $N = 38$ problem gamblers

gamblers reported significantly higher confidence at the trial-level compared to control participants, and on global confidence ($\beta = 1.08$, $SE = 0.28$, $p < 0.001$), whereby problem gamblers reported significantly higher confidence at the block-level compared to control participants (Fig. 4A and B). There were no significant effects of gender, age or mean task accuracy on local and global confidence (all $p > 0.27$). The higher confidence was not reflected in any significant difference between mean reaction times between problem gamblers ($M = 0.91$ s) and control participants ($M = 0.94$ s; $t(74) = 0.90$, $p = 0.373$; Fig. 4D). 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 difference in self-esteem was not significant when controlling for gender and age ($\beta = -2.4$, $SE = 1.33$, $p = 0.072$, Fig. 4C). There were no significant effects of gender or age on self-esteem (both $p > 0.12$).

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 (Fig. 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 ($\beta = 0.24$, $SE = 0.11$, $p < 0.05$), but no effect of Anxiety-Depression on local confidence ($\beta = 0.01$, $SE = 0.11$, $p = 0.928$). These results were mirrored in the regression on global confidence, with a significant positive association between global confidence and Compulsive Behaviour and Intrusive Thought ($\beta = 0.34$, $SE = 0.15$, $p < 0.05$), but no effect of Anxiety-Depression on global confidence ($\beta = 0.02$, $SE = 0.15$, $p = 0.917$). Contrary to local and global confidence, variations in self-esteem were not significantly associated with either Compulsive Behaviour and Intrusive Thought ($\beta = -0.34$, $SE = 0.70$, $p = 0.628$) or Anxiety-Depression ($\beta = -0.66$, $SE = 0.69$, $p = 0.341$). None of the covariates (gender, age, and task accuracy) were statistically significant in any of the three regression models (all $p > 0.076$).

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

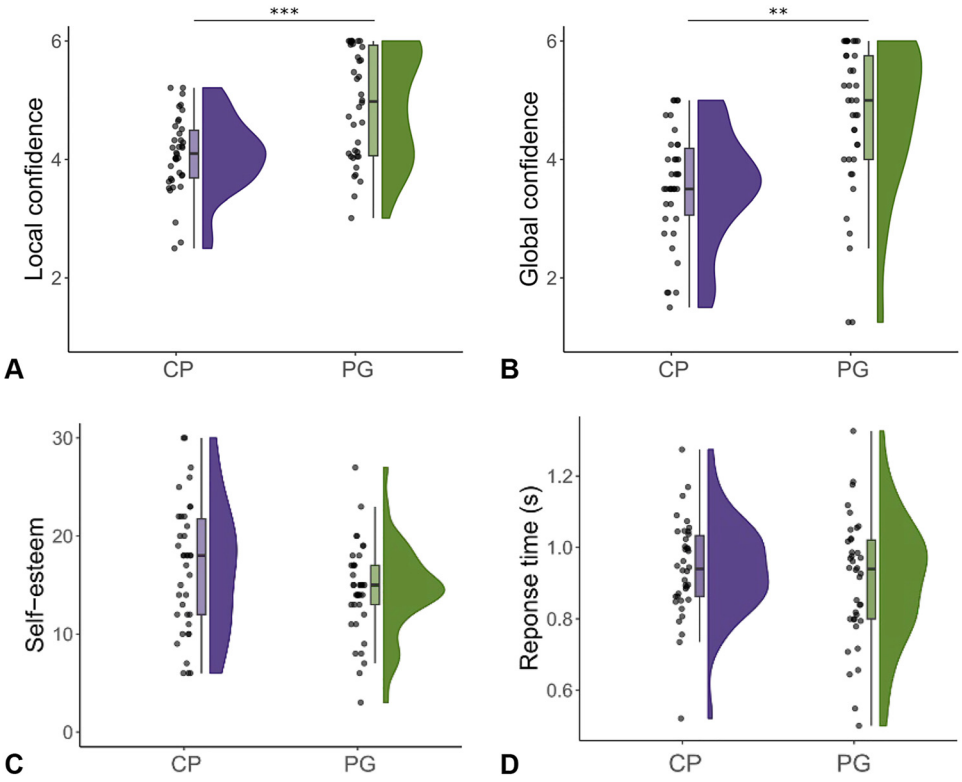

Fig. 4. **A.** Local trial confidence, **B.** global task confidence, and **C.** self-esteem for $N = 38$ control participants (CP) and $N = 38$ problem gamblers (PG). Dots show data from individual participants. Violin and box plots show the distributions of participant means. $^{*}p < 0.01$, $^{**}p < 0.001$, $^{***}p < 0.0001$ 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)

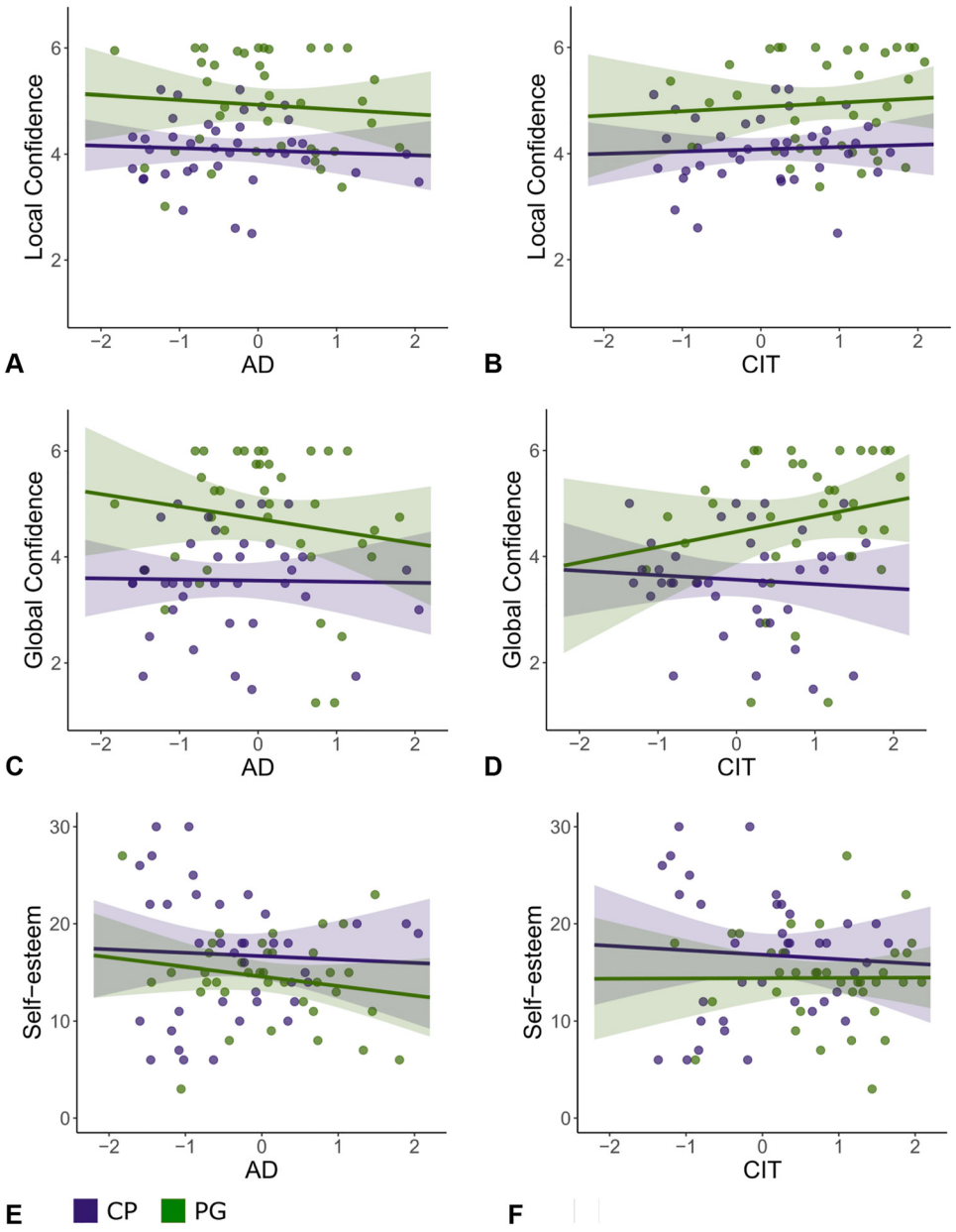

Fig. 5. Relationship between the transdiagnostic symptom dimensions (Anxiety-Depression (AD) and Compulsive Behaviour and Intrusive Thought (CIT) and confidence at all levels of the metacognitive hierarchy (local confidence, global confidence, and self-esteem) for $N = 38$ control participants (CP) and $N = 38$ problem gamblers (PG)

best at explaining the observed differences in confidence bias. Notably, the significant group effects on local confidence ($\beta = 0.91$, $SE = 0.23$, $p < 0.001$) and global confidence ($\beta = 1.02$, $SE = 0.32$, $p < 0.005$) 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 ($\beta = 0.05$, $SE = 0.11$, $p = 0.654$) and global ($\beta = 0.12$, $SE = 0.16$, $p = 0.441$) confidence. As before, the effects of Anxiety-Depression on local ($\beta = -0.08$, $SE = 0.10$, $p = 0.408$) and global ($\beta = -0.09$, $SE = 0.14$, $p = 0.534$) confidence were not significant in the regression models. In the case of self-esteem, there were no significant effects of any of group ($\beta = -2.4$, $SE = 1.58$, $p = 0.135$), Compulsive Behaviour and Intrusive Thought ($\beta = 0.21$, $SE = 0.78$, $p = 0.791$) or Anxiety-Depression ($\beta = -0.44$, $SE = 0.70$, $p = 0.533$). None of the covariates (gender, age, and task accuracy) were significant in any of the three regression models (all $p > 0.15$).

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 (Fig. 6). Both the problem gamblers and control participants exhibited a strong association between local trial confidence and global task confidence (problem gamblers: $r = 0.71$, $p < 0.0001$; control participants: $r = 0.75$, $p < 0.0001$). Applying Fisher's Z-test to examine whether the

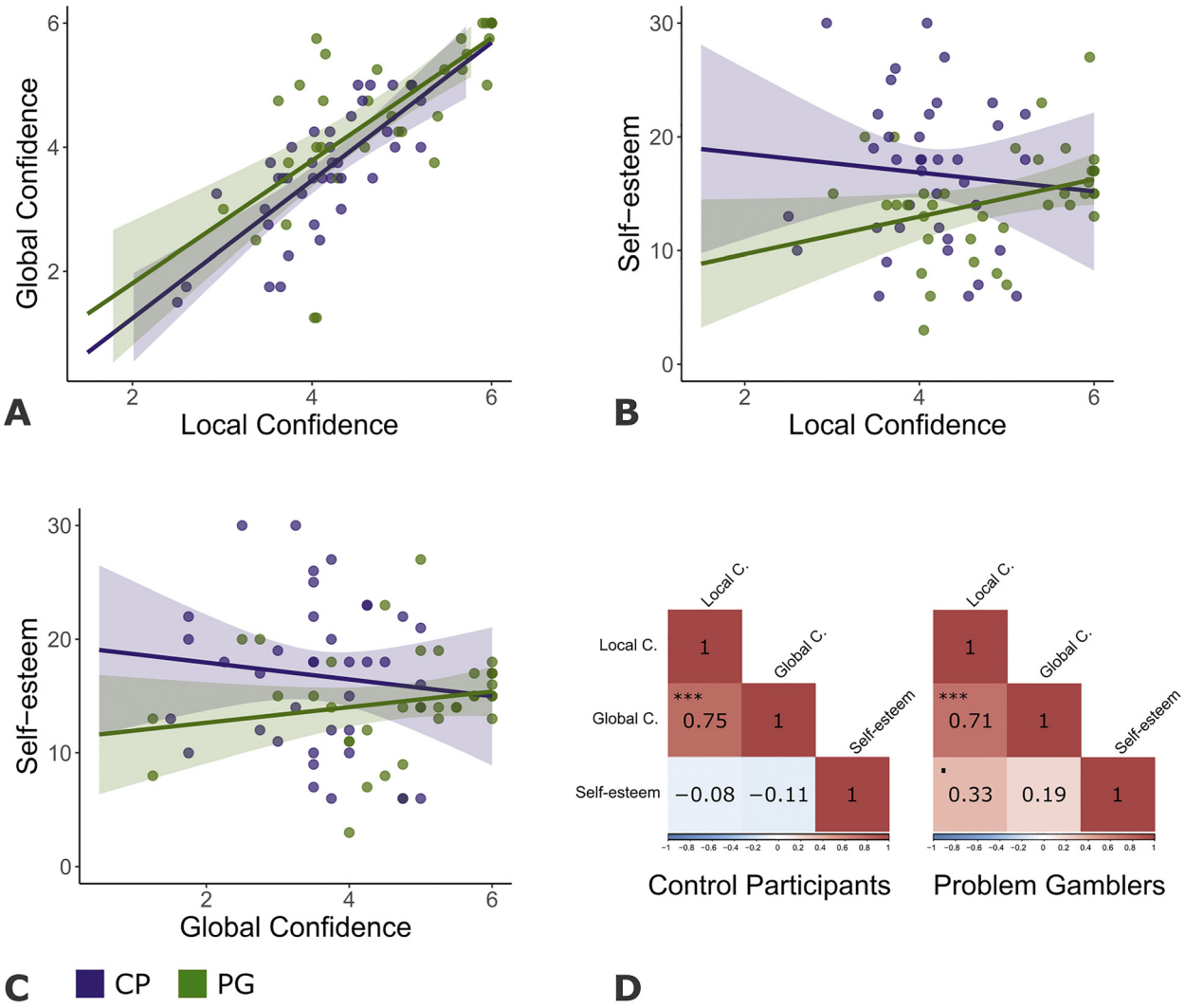

Fig. 6. **A.–C.** Relationship between local trial confidence, global task confidence, and self-esteem for $N = 38$ control participants (CP) and $N = 38$ problem gamblers (PG). **D.** Correlation matrix for local trial confidence, global task confidence, and self-esteem for control participants and problem gamblers. · $p < 0.05$, $^{*}p < 0.01$, $^{**}p < 0.001$, $^{***}p < 0.0001$

strength of these correlations differed between the two groups showed that the correlation coefficients did not significantly differ ($Z = -0.33$, $p = 0.74$). In contrast, self-esteem appeared to be largely independent of local confidence in the control participants ($r = -0.08$, $p = 0.629$), but was positively associated with local confidence in the problem gamblers ($r = 0.33$, $p < 0.05$; $z = 1.78$, $p = 0.075$). Self-esteem was not significantly correlated with global confidence in either group (problem gamblers: $r = 0.19$, $p = 0.251$; control participants: $r = -0.11$, $p = 0.522$; $Z = 1.26$, $p = 0.208$).

DISCUSSION

An internal sense of confidence plays a crucial role in guiding one's 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 (Rouault et al., 2018). 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 numerically 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 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. Further research is needed to elucidate the specific mechanisms underlying these group differences in confidence that are not accounted for by the assessed transdiagnostic symptoms.

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 raises intriguing questions about the underlying mechanisms contributing to heightened decision confidence in this group. Research conducted by Hoven, de Boer, et al. (2022) 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; Cowley, Briley, & Farrell, 2015; Goodie, 2005; Goodie & Fortune, 2013; Ledgerwood et al., 2020; Mallorquí-Bagué et al., 2019; Orgaz, Estévez, & Matute, 2013). 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 heightened confidence (Perandrés-Gómez, Navas, van Timmeren, & Perales, 2021; Van Timmeren, Daams, Van Holst, & Goudriaan, 2018). Possibly supporting the notion of a lack of sensitivity to belief-contradicting evidence, a study by Wyckmans et al. (2019) found that individuals with problem gambling disorder demonstrated impaired model-based learning, especially after non-rewarded outcomes. These individuals also exhibited faster reaction times compared to control participants following non-rewarded decisions. This lack of reduced speed in response after a loss in problem gamblers was also observed by Goudriaan, Oosterlaan, de Beurs, and van den Brink (2005). Such behaviour has also been associated with increased impulsive responding often observed in problem gamblers (Verdejo-García, Lawrence, & Clark, 2008). However, results in the current study did not reveal any differences in mean reaction times between the problem gamblers and control participants. This lack of a reaction time difference suggests that impulsivity, as measured by response times, may not have been a direct contributor to the observed heightened confidence in problem gamblers in the current study.

Although group effects persisted even after accounting for Anxiety-Depression and Compulsive Behaviour and Intrusive Thought, these effects were smaller than those found when not accounting for the transdiagnostic dimensions. This finding indicates that, although the differences in confidence levels between problem gamblers and control participants are not exhaustively captured by the Anxiety-Depression and Compulsive Behaviour and Intrusive Thought symptom dimensions, these factors do explain some of the observed variance. Moreover, a regression model not including group as a predictor showed significant effects of Compulsive Behaviour and Intrusive Thought on elevated local and global confidence. Heightened confidence linked to Compulsive Behaviour and Intrusive Thought has been suggested to reflect difficulties in developing an accurate cognitive map or model of the task environment (Gillan et al., 2016). Evidence for this comes from Seow and Gillan (2020), who demonstrated that individuals with higher Compulsive Behaviour and Intrusive Thought were less likely to use evidence to inform their confidence evaluations, 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. This hypothesis aligns with theoretical frameworks suggesting that confidence judgements are influenced not only by immediate task performance but also by preconceived beliefs and expectations about one's abilities (Boldt, Schiffer, Waszak, & Yeung, 2019). While direct empirical evidence specifically linking distorted prior expectations to confidence judgments in those with Compulsive Behaviour and Intrusive Thought symptoms is currently lacking, this opens a promising avenue for future research.

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. Further research would be needed to directly examine the mechanisms by which local confidence judgements are integrated into global assessments in the context of problem gambling. Interestingly, self-esteem was not correlated with either local or global confidence in the control participants. In contrast to the control participants, there was a significant correlation between self-esteem and local confidence within the problem gamblers. This discrepancy 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 lack of association between self-esteem and local/global confidence in control participants contrasts with recent research that revealed a positive association between individual confidence and self-esteem (Moses-Payne, Rollwage, Fleming, & Roiser, 2019). Rouault, Will, Fleming, and Dolan (2022) 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. (2023) found that higher-order self-beliefs were positively correlated with confidence at both local and global levels, independent of objective performance. The apparent divergence of these findings from our results may be explained by our small sample size or the inclusion of controls scoring exceedingly low on the gambling scale (PGSI = 0).

LIMITATIONS

One limitation of the current study is the size of the sample, which may not have been sufficient to detect subtle effects. Specifically, although there was no clear effect of Anxiety-Depression on confidence, this finding should be considered within the context of the effect sizes reported for the associations of Anxiety-Depression with reduced confidence, and Compulsive Behaviour and Intrusive Thought with elevated confidence in previous studies (Rouault et al., 2018; Seow & Gillan, 2020), and even in the same task as used in the present study (Fox et al., 2024). 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. Additionally, there was a trend towards lower self-esteem in the problem gambler compared to the control group, which, however, was not significant, possibly also owing to the limited sample size. It is also important to consider that findings from the general population may not always be generalisable to patient populations. Hence, drawing inferences from general population studies, such as Rouault et al. (2018), 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. A recent study comparing non-clinical highly compulsive individuals to OCD patients found that whereas highly compulsive individuals did indeed display heightened levels of local and global confidence, OCD patients exhibited lower confidence across all three levels of the metacognitive hierarchy (Hoven, Rouault, van Holst, & Luigjes, 2022). This implies that confidence manifestations can significantly vary, even among populations sharing compulsive tendencies. Another limitation to consider is the technological requirement for participation in our study. Only individuals who owned a smartphone and possessed the knowledge to use it were eligible to participate, as the study necessitated downloading an app and completing the task and questionnaires through this medium. This method excludes a segment of the gambler population who either cannot afford a smartphone or lack the proficiency to use such technology. Thus, the results of our study may not be generalizable to all gamblers, particularly those on the lower end of the socioeconomic spectrum or those with limited technological literacy. Lastly, it is a limitation that this study was cross-sectional in design. This precludes an examination of how local decision confidence may aggregate over time to shape global task performance confidence and eventually broader self-beliefs. A longitudinal approach would be valuable to better elucidate the dynamic interplay between these different hierarchical levels of metacognitive processing.

CONCLUSION

Given that heightened confidence 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 heightened confidence 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 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 heightened confidence and persistent gambling behaviours in this group. To develop our understanding of how local confidence is aggregated to form global estimates and eventually self-beliefs, future research should employ longitudinal designs that can map this process of aggregation of confidence over time to other levels of the hierarchy. Relatedly, future work would benefit from using multiple and more distinct fist-order tasks upon which participants can base their local confidence judgements, allowing us to distinguish global assessments from local ones more fully. A final suggestion for future work is to consider the confidence biases observed in gambling, anxious—depression and compulsivity from a normative modelling perspective. This would allow researchers to understand how the observed alterations reflect deviations from a normative standard. Likewise, including other potential predictors of confidence such as optimism might help researchers to develop a more holistic understanding of how confidence is disrupted in problem gamblers.

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Appendix

Table A1. Regression table predicting **local confidence** by group, age, gender, and mean accuracy for $N = 38$ control participants and $N = 38$ problem gamblers.

Predictor	Estimate	Std error	*t*	*p*
Group (gambler)	0.91	0.20	4.66	<0.001 ***
Age	0.00	0.10	0.09	0.93
Gender (male)	−0.18	0.25	−0.74	0.46
Mean accuracy	0.09	0.10	0.97	0.34

Table A2. Regression table predicting **global confidence** by group, age, gender, and mean accuracy for $N = 38$ control participants and $N = 38$ problem gamblers.

Predictor	Estimate	Std error	*t*	*p*
Group (gambler)	1.08	0.28	3.90	<0.001 ***
Age	0.15	0.14	1.09	0.28
Gender (male)	−0.07	0.35	−0.21	0.83
Mean accuracy	−0.07	0.14	−0.52	0.60

Table A3. Regression table predicting **self-esteem** by group, age, gender, and mean accuracy for $N = 38$ control participants and $N = 38$ problem gamblers.

Predictor	Estimate	Std error	*t*	*p*
Group (gambler)	−2.43	1.33	−1.82	0.07
Age	1.05	0.67	1.56	0.12
Gender (male)	−0.84	1.75	−0.48	0.63

Table A4. Regression table predicting **local confidence** by Anxiety-Depression (AD) scores, Compulsive Behaviour and Intrusive Thought (CIT) scores, age, gender, and mean accuracy for $N = 38$ control participants and $N = 38$ problem gamblers.

Predictor	Estimate	Std error	*t*	*p*
AD	0.01	0.11	0.09	0.93
CIT	0.24	0.11	2.16	<0.05 *
Age	0.10	0.11	0.92	0.36
Gender (male)	−0.04	0.28	−0.14	0.89
Mean accuracy	0.05	0.11	0.46	0.65

Table A5. Regression table predicting **global confidence** by Anxiety-Depression (AD) scores, Compulsive Behaviour and Intrusive Thought (CIT) scores, age, gender, and mean accuracy for $N = 38$ control participants and $N = 38$ problem gamblers.

Predictor	Estimate	Std error	*t*	*p*
AD	0.02	0.15	0.10	0.92
CIT	0.34	0.15	2.21	<0.05 *
Age	0.27	0.15	1.78	0.08
Gender (male)	0.09	0.37	0.23	0.82
Mean accuracy	−0.11	0.15	−0.76	0.45

Table A6. Regression table predicting **self-esteem** by Anxiety-Depression (AD) scores, Compulsive Behaviour and Intrusive Thought (CIT) scores, age, gender, and mean accuracy for $N = 38$ control participants and $N = 38$ problem gamblers.

Predictor	Estimate	Std error	*t*	*p*
AD	−0.66	0.69	−0.96	0.34
CIT	−0.34	0.70	−0.49	0.63
Age	0.77	0.71	1.09	0.28
Gender (male)	−1.24	1.77	−0.70	0.49

Table A7. Regression table predicting **local confidence** by group, Anxiety-Depression (AD) scores, Compulsive Behaviour and Intrusive Thought (CIT) scores, age, gender, and mean accuracy for $N = 38$ control participants and $N = 38$ problem gamblers.

Predictor	Estimate	Std error	*t*	*p*
Group (gambler)	0.91	0.23	4.02	<0.001 ***
AD	−0.08	0.10	−0.83	0.41
CIT	0.05	0.11	0.45	0.65
Age	0.01	0.10	0.08	0.94
Gender (male)	−0.18	0.25	−0.72	0.47
Mean accuracy	0.11	0.10	1.13	0.26

Table A8. Regression table predicting **global confidence** by group, Anxiety-Depression (AD) scores, Compulsive Behaviour and Intrusive Thought (CIT) scores, age, gender, and mean accuracy for $N = 38$ control participants and $N = 38$ problem gamblers.

Predictor	Estimate	Std error	*t*	*p*
Group (gambler)	1.02	0.32	3.17	<0.01 **
AD	−0.09	0.14	−0.63	0.53
CIT	0.12	0.16	0.78	0.44
Age	0.17	0.14	1.15	0.26
Gender (male)	−0.07	0.36	−0.20	0.84
Mean accuracy	−0.04	0.14	−0.30	0.77

Table A9. Regression table predicting **self-esteem** by group, Anxiety-Depression (AD) scores, Compulsive Behaviour and Intrusive Thought (CIT) scores, age, gender, and mean accuracy for $N = 38$ control participants and $N = 38$ problem gamblers.

Predictor	Estimate	Std error	*t*	*p*
Group (gambler)	−2.39	1.58	−1.51	0.14
AD	−0.44	0.70	−0.63	0.53
CIT	0.21	0.78	0.27	0.79
Age	1.03	0.72	1.43	0.16
Gender (male)	−0.84	1.77	−0.47	0.64