



AKADÉMIAI KIADÓ

Confidence and risky decision-making in gambling disorder

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BRIEF REPORT



ABSTRACT

Background and aims: People with Gambling Disorder (GD) often make risky decisions and experience cognitive distortions about gambling. Moreover, people with GD have been shown to be overly confident in their decisions, especially when money can be won. Here we investigated if and how the act of making a risky choice with varying monetary stakes impacts confidence differently in patients with GD ($n = 27$) relative to healthy controls (HCs) ($n = 30$). **Methods:** We used data from our previous mixed-gamble study, in which participants were given the choice of a certain option or a 50/50 gamble with potential gains or losses, after which they rated their confidence. **Results:** While HCs were more confident when making certain than risky choices, GD patients were specifically more confident when making risky choices than certain choices. Notably, relative to HCs, confidence of patients with GD decreased more strongly with higher gain values when making a certain choice, suggesting a stronger fear of missing out or “anticipated regret” of missing out on potential gains when rejecting the risky choice. **Discussion:** The current findings highlight the potential relevance of confidence and “regret” as cognitive mechanisms feeding into excessive risk-taking as seen in GD. Moreover, this study adds to the limited previous work investigating how confidence is affected in value-based risky contexts.

KEYWORDS

confidence, gambling disorder, risky decision-making, mixed-gamble, regret

INTRODUCTION

Gambling involves taking risks, typically with a high probability of loss against a smaller probability of gain. While for most people gambling is a leisure activity, for some people it develops into a gambling disorder (GD), described as the continuation or escalation of gambling despite the occurrence of negative consequences (American Psychiatric Association, 2013). It is often hard to grasp why people continue to show irrational gambling behavior when it is clear that, in the long term, “the house always wins”.

Research on risk taking and gambling-related cognition finds that people with GD make more risky decisions (Brand et al., 2005; Brevers et al., 2012; Ligneul, Sescousse, Barbalat, Domenech, & Dreher, 2013; Ochoa et al., 2013; Spurrier & Blaszczynski, 2014), are less loss averse (Gelskov, Madsen, Ramsøy, & Siebner, 2016; Giorgetta et al., 2014; Hoven, Hirmas, Engelmann, & van Holst, 2023) and exhibit higher levels of cognitive distortions about gambling than people without GD (Joukhador, Maccallum, & Blaszczynski, 2003; Ledgerwood et al., 2020). Cognitive distortions about gambling often involve cognitions that minimize the perceived risk of gambling and encourage gambling (Goodie & Fortune, 2013) (i.e., “the illusion of control” (Langer, 1975)). Moreover, people with GD have been

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shown to be overly confident in their decisions (Brevers et al., 2013, 2014; Goodie, 2005; Lakey, Goodie, & Campbell, 2007), especially when money can be won (Hoven et al., 2022). We recently replicated our findings using a mixed-gamble task showing that relative to controls, patients with GD gambled more, and that increasing amounts of potential gains increased confidence more strongly in patients than in controls (Hoven et al., 2023). Since accurate confidence is important for monitoring errors (Boldt & Yeung, 2015; Yeung & Summerfield, 2012), learning (Meyniel, Schlunegger, & Dehaene, 2015) and planning subsequent actions (Desender, Boldt, & Yeung, 2018), having too much confidence in one's choices could contribute to risky decision-making (Hoven et al., 2022). While it has become clear that contextual cues, such as monetary incentives, can bias confidence, little is known about how the presence of risk and the act of making a risky choice impacts confidence and whether this interacts with incentive value.

One prior study conducted in healthy subjects investigated the impact of risky choices on confidence judgments (da Silva Castanheira, Fleming, & Otto, 2021). Their results indicated that confidence was significantly higher when selecting a certain prospect compared with a risky one - an intuitive finding that reflects the decision-makers feeling of uncertainty that comes with making a risky choice. Since there are little to no other studies that have investigated this in GD, it remains unknown whether risky choices and monetary incentives affect confidence of people with GD in the same way as healthy controls (HCs).

Based on previous findings (Brevers et al., 2013, 2014; Goodie, 2005; Lakey et al., 2007), we hypothesized that first, patients with GD relative to HCs are generally more confident in their choices made during an experiment where incentives can be won. Secondly, while HCs are relatively more confident in certain versus risky choices, patients with GD are relatively more confident in risky versus certain choices because of their experience with gambling. Finally, we hypothesized that confidence judgments of patients with GD compared to HCs are more sensitive to increases in potential gains, in line with the suggestion that gamblers might be more overconfident with greater potential gains (Hoven et al., 2022) such that increasing gain value increases (/decreases) confidence more strongly when making a risky (/certain) choice. We tested these hypotheses by utilizing data from our previous mixed-gamble study (Hoven et al., 2023).

METHODS

Participants

As the current study used data from our previous mixed-gamble study (Hoven et al., 2023), the description of the participants are the same as in our previous paper. 27 patients with GD and 30 HCs were included, matched on age, sex and education, recruited online and via patient clinics in the Netherlands. All patients with GD had been in treatment and gambled regularly within the previous year and were

diagnosed by a certified medical professional for gambling disorder using the DSM-5 criteria. All subjects did not currently or in the previous 6 months suffer from any psychiatric disorder (except for gambling disorder for the GD group), and did not use medication.

Experimental task and procedure

All subjects performed a mixed-gamble task including 160 trials (Fig. 1A). Gambles were presented with an equal (50/50) chance of either gaining or losing a specific value and subjects chose between two options: rejecting (certain option) or accepting (risky option) the gamble. The certain option entailed opting for the initial endowment of €25 without the possibility of bonuses. The risky option entailed potentially gaining or losing additional bonuses as presented by the gamble. After each choice, feedback indicated the chosen option (but no feedback about wins and losses was provided until the end of the experiment to prevent learning) and subjects were asked to rate their confidence on a 7-point scale. Each combination of gains and losses was shown twice for counterbalancing, and gains or losses never appeared on the same side for more than three times in a row. All subjects performed a training session. For more details see Fig. 1A and (Hoven et al., 2023). The same exclusion criteria as in our previous study (Hoven et al., 2023) were applied, leading to a final sample of 26 patients GD and 29 HCs.

Analyses

For all analyses we used R (version 1.4.1106) with the packages emmeans (Lenth Russel & Love Jonathon, 2017), lme4 (Bates, Mächler, Bolker, & Walker, 2015) and lmerTest (Kuznetsova, Brockhoff, & Christensen, 2017). Age, sex, education level, gambling severity and percentage gambling choices were compared between groups using two-sample *t*-tests or chi-square tests.

To test for group differences in the effects of choice type, value and their interaction on confidence, we fit two mixed-effects models on our trial-by-trial data. In the first model, the effects of choice, group and expected value ($0.5 \cdot \text{loss value} + 0.5 \cdot \text{gain value}$), and their three-way interaction on confidence were investigated. Moreover, a covariate of the log of the reaction time (logRT, due to skewness), random intercepts and random slopes of EV and choice were included. In the second model, instead of using expected value, we investigated the separate effects of gain and loss value and their interactions with choice and group (choice*gain*group and choice*loss*group) on confidence. In both models, LogRT, EV, gain and loss values were z-scored and an effects coding scheme was used for the categorical group and choice variables. Post-hoc tests were performed to quantify significant interactions.

Ethics

The experiment was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Board of the University of Amsterdam.



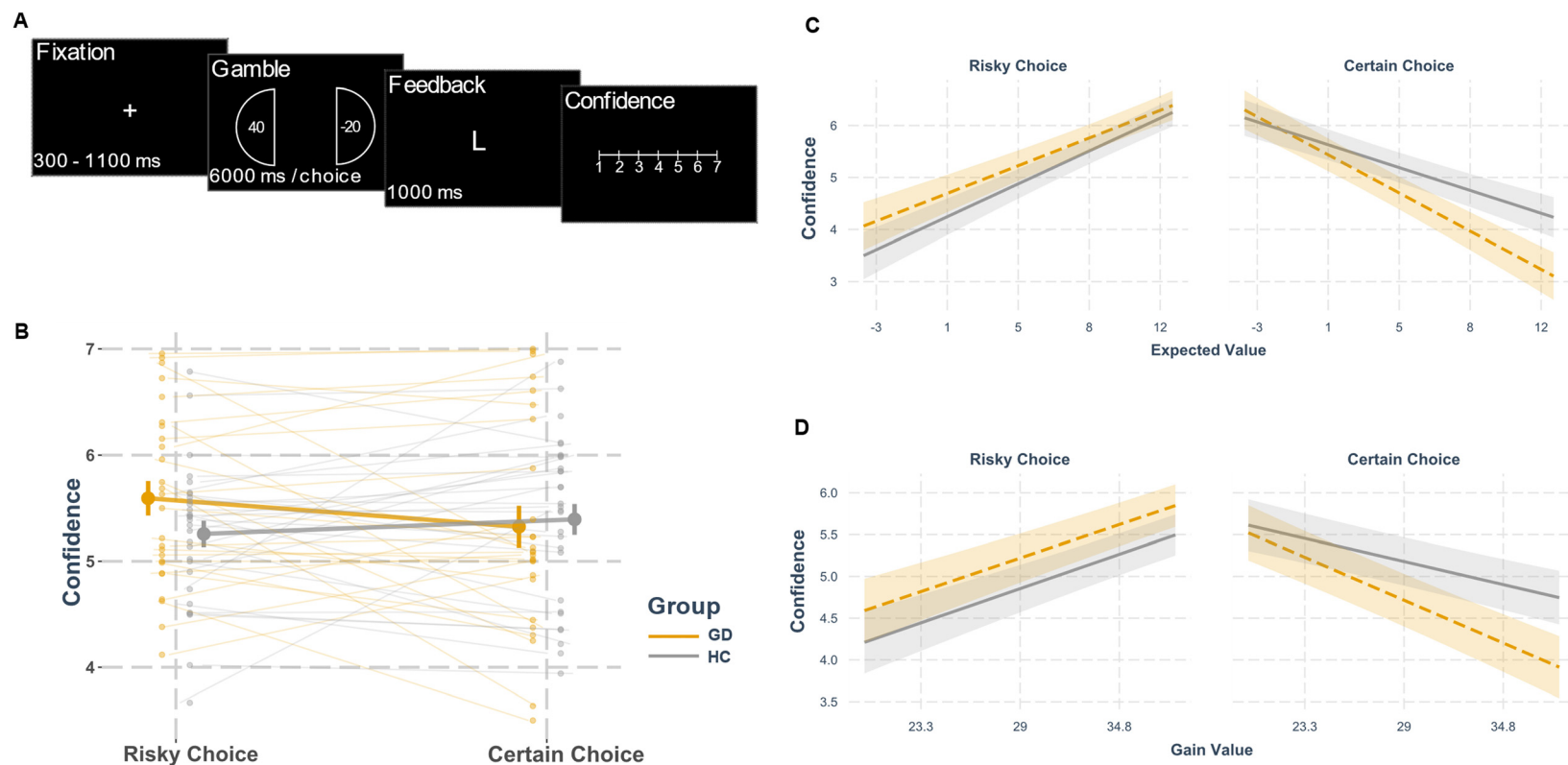


Fig. 1. Mixed gambles task and results. (A) At the beginning of each trial a fixation cross was shown, jittered between 300 and 1,100 ms. Then the gamble was shown (i.e., gain and loss value stimuli; left stimulus centered on 480×540 , right stimulus centered on $1,440 \times 540$) for the duration of the decision with a maximum of 6,000 ms. Subjects were asked to accept or reject the gamble using the up or down key, respectively, after which a brief feedback message was shown indicating and confirming their choice (1,000 ms. L = lottery (risky) option, X = certain option, 'Respond Faster' = if failed to respond within 6,000 ms). After each choice participants rated their confidence on a scale from 1 (not sure) to 7 (very sure) (unlimited time). Subjects did not receive any feedback about the outcome of their choices (win or loss outcomes) until after completion of the experiment to avoid history and learning effects. (B) The significant interaction effect between choice type and group shows that the GD group were more confident when making risky choices, while the HC group were more confident when making certain choices. Large dots and error bars signify means and standard errors, smaller dots represent individual subject data points (Table 1A). (C) A significant three-way interaction between expected value, choice type and group shows that increasing expected value of the gamble has a stronger negative effect on confidence in the GD group when making certain choices (Table 1A). (D) A significant three-way interaction between gain value, choice type and group shows that increasing gain value has a stronger negative effect on confidence in the GD group when making certain choices (see Table 1B). Yellow color indicates GD, grey color indicates HC



RESULTS

No group differences were found in age (GD: 37.4 ± 12.1 ; HC: 34.8 ± 8.61 ; $t^{53} = 0.92$, $p = 0.36$), sex (GD: 21 males, 5 females; HC: 23 males, 6 females; $X^2 = 2.8 \cdot 10^{-31}$, $p = 1$) or education level (GD: 3.08 ± 0.89 ; HC: 3.31 ± 1.17 ; $t^{53} = 0.83$, $p = 0.41$). Problem Gambling severity index (PGSI (Ferris, Wynne, & Wynne, 2001)) scores were significantly higher in patients with GD (15.3 ± 3.94) than in HCs (0) (Welch's $t^{25} = -19.87$, $p < 0.001$). Patients with GD scored 59.3 ± 23.2 on the Gamblers Beliefs Questionnaire (GBQ; Steenbergh, Meyers, May, & Whelan, 2002), a self-report measure of gamblers' cognitive distortions, where a higher score indicates more cognitive distortions. In general, patients with GD made more risky choices ($60.7\% \pm 4.22\%$) than HCs ($42.7\% \pm 3.81\%$) ($t_{53} = 3.175$, $p = 0.002$), and previous work using this dataset indicated less loss aversion in patients with GD compared to HCs (Hoven et al., 2023).

The first mixed-effects model showed a significant main effect of reaction time on confidence, indicating increased confidence for choices with faster reaction times (Table 1A). A significant interaction between choice and group showed that GD patients were more confident in risky than certain choices (post-hoc: $Z = 2.781$, $p = 0.005$), and a trend effect for the opposite pattern for HCs (post-hoc: Z -ratio = -1.772 , $p = 0.076$) (Fig. 1B). The significant

interaction between choice and EV indicated that confidence increased with increasing EV for risky choices (slope = 0.583), but decreased for certain choices (slope = -0.587). The significant three-way interaction between choice, EV and group indicated that GD patients, compared to HC, showed even lower confidence rates when rejecting high EV gambles (Fig. 1C). Post-hoc analyses confirmed that the negative effect of EV on confidence when making a certain choice was stronger in GD (slope: -0.734) than in HC (slope -0.439 ; $Z = -3.573$, $p < 0.001$).

Model 2 (Table 1B) separated the effects of gain and loss value, which were orthogonalized, allowing us to inspect whether the interaction effects observed in model 1 are driven by either gain or loss values. We find a similar three-way interaction effect between choice, gain value and group (Fig. 1D), but not with loss value. Indeed, confidence of the GD group declined more strongly with increasing gain value when choosing the certain option, relative to HCs (GD slope: -0.513 , HC slope: -0.276 , post-hoc $Z = -3.628$ $p < 0.001$). Moreover, a significant interaction between loss value and choice indicated that with increasing loss value, all subjects became more confident when they chose the certain option (slope: 0.448), but became less confident when they chose the risky option (slope: -0.438). A significant interaction between loss value and group showed that the GD group was less sensitive to loss value (slope: 0.08) than the HC group

Table 1. Results of mixed-effects models on confidence. Shown are the estimates, their standard errors (SE), t -values and p -values. Loss values were entered as absolute values for easier interpretation. The value of the choice options were modeled as expected value in model 1 and, separately as (experimentally orthogonalized) gain and loss value in model 2

A)	Parameter	Estimate (SE)	Model 1: expected value	
			t -value	p value
	Intercept	5.00 (0.09)	58.49	<0.001
	Choice (Certain Option)	-0.05 (0.06)	-0.81	0.419
	Group (GD)	-0.03 (0.09)	-0.40	0.687
	Expected Value	-0.001 (0.04)	-0.05	0.960
	Reaction Time	-0.37 (0.01)	-25.86	<0.001
	Choice (Certain Option) \times Group (GD)	-0.21 (0.06)	-3.24	0.002
	Choice (Certain Option) \times Expected Value	-0.58 (0.02)	-32.62	<0.001
	Group (GD) \times Expected Value	-0.10 (0.04)	-2.70	0.009
	Choice (Certain Option) \times Group (GD) \times Expected Value	-0.05 (0.02)	-2.80	0.005
AIC: 24001.46 R^2 : 0.506 # observations: 8,295 trials (of 55 subjects)				
B)	Parameter	Estimate (SE)	Model 2: gain and loss value	
			t -value	p value
	Intercept	4.99 (0.08)	58.81	<0.001
	Choice (Certain Option)	-0.04 (0.06)	-0.69	0.491
	Group (GD)	-0.02 (0.08)	-0.29	0.774
	Gain Value	0.01 (0.03)	0.19	0.849
	Loss Value	0.01 (0.03)	0.17	0.862
	Reaction Time	-0.36 (0.01)	-25.65	<0.001
	Choice (Certain Option) \times Group (GD)	-0.21 (0.06)	-3.20	0.002
	Choice (Certain Option) \times Gain Value	-0.40 (0.02)	-25.62	<0.001
	Group (GD) \times Gain Value	-0.06 (0.03)	-2.19	0.033
	Choice (Certain Option) \times Loss Value	0.44 (0.01)	29.65	<0.001
	Group (GD) \times Loss Value	0.08 (0.03)	2.57	0.013
	Choice (Certain Option) \times Group (GD) \times Gain Value	-0.06 (0.02)	-3.72	<0.001
	Choice (Certain Option) \times Group (GD) \times Loss Value	-0.001 (0.01)	-0.04	0.972
AIC: 23912.11 R^2 : 0.514 # observations: 8,295 trials (of 55 subjects)				



(slope: -0.07) in terms of decreasing their confidence. Finally, neither PGSI nor GBQ score within the GD group correlated significantly with mean confidence (both $p > 0.25$) or confidence for risky choices (both $p > 0.5$).

As a sensitivity analyses to verify whether fatigue or time on task affected our results, we included trial number as a covariate and also tested for the trial*group interactions in the two described models. The results indicated no significant effect of trial number nor trail*group interactions on any of the results. Moreover, including this variable did not change any of our previously reported results.

DISCUSSION

Why do patients with GD continue to gamble regardless of all the negative consequences? One answer may lie in overconfidence in their actions, specifically when risk and monetary incentives are involved. This study investigated how making a risky choice with varying monetary stakes impacts confidence and whether patients with GD are affected differently than HCs.

There was some evidence for our first hypothesis of general increased confidence in GD compared with HCs. There was convincing support for our second hypothesis: relative to HCs (who have higher confidence when making a certain versus risky choice), patients with GD are more confident when making risky choices than certain choices. Notably, relative to HCs, confidence of patients with GD decreased more strongly with higher gain values when making a certain choice. Hence, these findings also partly support our third hypothesis of increased sensitivity to gain values in GD patients and point to our measure of confidence capturing a stronger fear of missing out or “anticipated regret” of missing out on potential gains when rejecting gambles.

This fear of missing out on potential gains is recognized in the clinical presentation of GD (Ladouceur, 2004) and may be reflected in the higher willingness to gamble. Patients often describe that their only solution to solving their financial problems is taking excessive risks in the hope of obtaining high gains. Indeed, research has shown that scarcity creates “bandwidth taxes” that reduce mental resources, impairing cognitive ability and causing counterproductive behavior, such as risk-taking (Liang, Ye, & Liu, 2021), which perpetuates poverty (Haushofer & Fehr, 2014; Ong, Theseira, & Ng, 2019). In the current study, as expected, more patients with GD ($n = 18$) experienced debts than HCs ($n = 5$). In that light, this stronger fear of missing out on potential gains may not only speak to patients with GD but also to people who experience financial debts. The lower confidence when selecting the certain option found in the GD group aligns well with recent findings by Wu, Kennedy, Goshko, and Clark (2021). They computationally assessed an anticipatory regret parameter that captured the difference between the worst outcome in one gamble versus the best outcome in the other gamble and found that people with GD experience increased anticipatory regret relative to

controls. While our findings and those of Wu et al. (2021) should be considered preliminary, they highlight the relevance of regret and confidence as cognitive mechanisms in disordered gambling. Future studies on this topic are needed and can draw on extensive mathematical and experimental methods developed by behavioral economics.

The current study adds to the limited previous work investigating how confidence is affected in value-based risky contexts. da Silva Castanheira et al. (2021) found that healthy people are more confident when selecting certain options. Moreover, consistent with previous findings (De Martino, Fleming, Garrett, & Dolan, 2012; Folke, Jacobsen, Fleming, & De Martino, 2017), in the absence of risk, higher subjective values and faster RTs were associated with higher confidence ratings (da Silva Castanheira et al., 2021). We replicated these findings in our HCs and observed the weakening of these well-documented relations with risky decisions relative to certain decisions (see [Supplementary Materials](#)). These findings fit the notion that risky choices are accompanied by an inherent uncertainty about the option’s value and that RTs are slower under greater uncertainty (Lee & Daunizeau, 2019; Lee & Hare, 2023).

Our results should be interpreted with some limitations in mind. First, all included patients received treatment, and the task’s relative unattractiveness and artificial nature may have attenuated natural risk-taking behavior in our patient sample. Future studies should assess whether the current findings generalize to more realistic gambling situations and to untreated patients. Additionally, longitudinal studies are needed to dissect whether alterations in confidence under risk are a cause or consequence of GD. Furthermore, the influence of financial debts on confidence and anticipated regret needs to be established. Finally, the current results were secondary to our previous work (Hoven et al., 2023) and can be considered exploratory. Nonetheless, these results provide an important initial demonstration of how subjective confidence during risky decision-making is differently affected in patients with GD relative to HCs.

In sum, the current study points out that compared to HCs, patients with GD are generally more confident when taking risks versus playing it safe. Importantly, they become less confident about playing it safe when the potential winnings increase. This behavioral pattern matches anticipatory regret of missing out on potential gains, which may contribute to excessive risk-taking in GD patients.

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Authors’ contribution: JE designed the study task and RJvH the study protocol. MH collected all data. MH conducted the statistical analysis, with assistance of AH. RJvH and



MH wrote the first draft of the manuscript and all authors contributed to and have approved the final manuscript.

Conflict of interest: RJvH is an associate editor of the Journal of Behavioral Addictions. All other authors declare that they have no conflicts of interest.

SUPPLEMENTARY DATA

Supplementary data to this article can be found online at <https://doi.org/10.1556/2006.2023.00041>.

REFERENCES

- American Psychiatric Association, A. (2013). *Diagnostic Statistical manual of mental disorders* (5th ed.).
- Bates, D., Mächler, M., Bolker, B. M., & Walker, S. C. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*, 67(1), 1–48. <https://doi.org/10.18637/JSS.V067.I01>.
- Boldt, A., & Yeung, N. (2015). Shared neural markers of decision confidence and error detection. *Journal of Neuroscience*, 35(8), 3478–3484. <https://doi.org/10.1523/JNEUROSCI.0797-14.2015>.
- Brand, M., Kalbe, E., Labudda, K., Fujiwara, E., Kessler, J., & Markowitsch, H. J. (2005). Decision-making impairments in patients with pathological gambling. *Psychiatry Research*, 133, 91–99. <https://doi.org/10.1016/j.psychres.2004.10.003>.
- Brevers, D., Cleeremans, A., Bechara, A., Greisen, M., Kornreich, C., Verbanck, P., & Noël, X. (2013). Impaired self-awareness in pathological gamblers. *Journal of Gambling Studies*, 29(1), 119–129. <https://doi.org/10.1007/s10899-012-9292-2>.
- Brevers, D., Cleeremans, A., Bechara, A., Greisen, M., Kornreich, C., Verbanck, P., & Noël, X. (2014). Impaired metacognitive capacities in individuals with problem gambling. *Journal of Gambling Studies*, 30(1). <https://doi.org/10.1007/s10899-012-9348-3>.
- Brevers, D., Cleeremans, A., Goudriaan, A. E., Bechara, A., Kornreich, C., Verbanck, P., & Noël, X. (2012). Decision making under ambiguity but not under risk is related to problem gambling severity. *Psychiatry Research*, 200, 568–574. <https://doi.org/10.1016/j.psychres.2012.03.053>.
- De Martino, B., Fleming, S. M., Garrett, N., & Dolan, R. J. (2012). Confidence in value-based choice. *Nature Neuroscience*, 16(1), 105–110. <https://doi.org/10.1038/nn.3279>.
- Desender, K., Boldt, A., & Yeung, N. (2018). Subjective confidence predicts information seeking in decision making. *Psychological Science*, 29(5), 761–778. <https://doi.org/10.1177/0956797617744771>.
- Ferris, J., Wynne, H., & Wynne, W. (2001). The Canadian problem gambling index: Final report. In *Canadian centre on substance abuse*. Canadian Centre on Substance Abuse. <https://doi.org/10.1007/s10899-010-9224-y>.
- Folke, T., Jacobsen, C., Fleming, S. M., & De Martino, B. (2017). Explicit representation of confidence informs future value-based decisions. *Nature Human Behaviour*, 1(1), 0002. <https://doi.org/10.1038/s41562-016-0002>.
- Gelskov, S. V., Madsen, K. H., Ramsøy, T. Z., & Siebner, H. R. (2016). Aberrant neural signatures of decision-making: Pathological gamblers display cortico-striatal hypersensitivity to extreme gambles. *NeuroImage*, 128, 342–352. <https://doi.org/10.1016/J.NEUROIMAGE.2016.01.002>.
- Giorgetta, C., Grecucci, A., Rattin, A., Guerreschi, C., Sanfey, A. G., & Bonini, N. (2014). To play or not to play: A personal dilemma in pathological gambling. *Psychiatry Research*, 219(3), 562–569. <https://doi.org/10.1016/J.PSYCHRES.2014.06.042>.
- Goodie, A. S. (2005). The role of perceived control and overconfidence in pathological gambling. *Journal of Gambling Studies/Co-Sponsored by the National Council on Problem Gambling and Institute for the Study of Gambling and Commercial Gaming*, 21(4), 481–502. <https://doi.org/10.1007/s10899-005-5559-1>.
- Goodie, A. S., & Fortune, E. E. (2013). Measuring cognitive distortions in pathological gambling: Review and meta-analyses. *Psychology of Addictive Behaviors*, 27(3), 730–743. <https://doi.org/10.1037/a0031892>.
- Haushofer, J., & Fehr, E. (2014). On the psychology of poverty. *Science*, 344(6186), 862–867. <https://doi.org/10.1126/science.1232491>.
- Hoven, M., de Boer, N. S., Goudriaan, A. E., Denys, D., Lebreton, M., van Holst, R. J., & Luigjes, J. (2022). Metacognition and the effect of incentive motivation in two compulsive disorders: Gambling disorder and obsessive-compulsive disorder. *Psychiatry and Clinical Neurosciences*, 76(9), 437–449. <https://doi.org/10.1111/pcn.13434>.
- Hoven, M., Hirmas, A., Engelmann, J., & van Holst, R. J. (2023). The role of attention in decision-making under risk in gambling disorder: An eye-tracking study. *Addictive Behaviors*, 138, 107550. <https://doi.org/10.1016/j.addbeh.2022.107550>.
- Joukhador, J., Maccallum, F., & Blaszczynski, A. (2003). Differences in cognitive distortions between problem and social gamblers. *Psychological Reports*, 92(3 Pt 2), 1203–1214. <https://doi.org/10.2466/pr0.2003.92.3c.1203>.
- Kuznetsova, A., Brockhoff, P. B., & Christensen, R. H. B. (2017). lmerTest package: Tests in linear mixed effects models. *Journal of Statistical Software*, 82(13), 1–26. <https://doi.org/10.18637/JSS.V082.I13>.
- Ladouceur, R. (2004). Gambling: The hidden addiction. *The Canadian Journal of Psychiatry*, 49(8), 501–503. <https://doi.org/10.1177/070674370404900801>.
- Lakey, C. E., Goodie, A. S., & Campbell, W. K. (2007). Frequent card playing and pathological gambling: The utility of the Georgia Gambling Task and Iowa Gambling Task for predicting pathology. *Journal of Gambling Studies*, 23, 285–297. <https://doi.org/10.1007/s10899-006-9034-4>.
- Langer, E. J. (1975). The illusion of control. *Journal of Personality and Social Psychology*, 32(2), 311–328.
- Ledgerwood, D. M., Dyshniku, F., McCarthy, J. E., Ostojic-Aitkens, D., Forfitt, J., & Rumble, S. C. (2020). Gambling-related cognitive distortions in residential treatment for gambling disorder. *Journal of Gambling Studies*, 36(2), 669–683. <https://doi.org/10.1007/S10899-019-09895-4>.
- Lee, D., & Daunizeau, J. (2019). Trading mental effort for confidence: The metacognitive control of value-based decision-making. *ELife*, 1–45. <https://doi.org/10.1101/837054>.



- Lee, D. G., & Hare, T. A. (2023). Value certainty and choice confidence are multidimensional constructs that guide decision-making. *Cognitive, Affective, & Behavioral Neuroscience*, 23, 503–521. <https://doi.org/10.3758/s13415-022-01054-4>.
- Liang, S., Ye, D., & Liu, Y. (2021). The effect of perceived scarcity: Experiencing scarcity increases risk taking. *The Journal of Psychology*, 155(1), 59–89. <https://doi.org/10.1080/00223980.2020.1822770>.
- Ligneul, R., Sescousse, G., Barbalat, G., Domenech, P., & Dreher, J.-C. J.-C. (2013). Shifted risk preferences in pathological gambling. *Psychological Medicine*, 43(5), 1059–1068. <https://doi.org/10.1017/S0033291712001900>.
- Meyniel, F., Schlunegger, D., & Dehaene, S. (2015). The sense of confidence during probabilistic learning: A normative account. *Plos Computational Biology*, 11(6), e1004305. <https://doi.org/10.1371/journal.pcbi.1004305>.
- Ochoa, C., Alvarez-Moya, E. M., Penelo, E., Aymami, M. N., Gómez-Peña, M., Fernández-Aranda, F., ... Jiménez-Murcia, S. (2013). Decision-making deficits in pathological gambling: The role of executive functions, explicit knowledge and impulsivity in relation to decisions made under ambiguity and risk. *The American Journal on Addictions/American Academy of Psychiatrists in Alcoholism and Addictions*, 22(5), 492–499. <https://doi.org/10.1111/j.1521-0391.2013.12061.x>.
- Ong, Q., Theseira, W., & Ng, I. Y. H. (2019). Reducing debt improves psychological functioning and changes decision-making in the poor. *Proceedings of the National Academy of Sciences*, 116(15), 7244–7249. <https://doi.org/10.1073/pnas.1810901116>.
- Lenth Russel, & Love Jonathon. (2017). Package “lsmeans” title least-squares means. <https://doi.org/10.1080/00031305.1980.10483031>.
- da Silva Castanheira, K., Fleming, S. M., & Otto, A. R. (2021). Confidence in risky value-based choice. *Psychonomic Bulletin & Review*, 28(3), 1021–1028. <https://doi.org/10.3758/s13423-020-01848-y>.
- Spurrier, M., & Blaszczynski, A. (2014). Risk perception in gambling: A systematic review. *Journal of Gambling Studies*, 30(2), 253–276. <https://doi.org/10.1007/S10899-013-9371-Z>.
- Steenbergh, T. A., Meyers, A. W., May, R. K., & Whelan, J. P. (2002). Development and validation of the gamblers’ Beliefs Questionnaire. *Psychology of Addictive Behaviors: Journal of the Society of Psychologists in Addictive Behaviors*, 16(2), 143–149.
- Wu, Y., Kennedy, D., Goshko, C.-B., & Clark, L. (2021). “Should’ve known better”: Counterfactual processing in disordered gambling. *Addictive Behaviors*, 112, 106622. <https://doi.org/10.1016/j.addbeh.2020.106622>.
- Yeung, N., & Summerfield, C. (2012). Metacognition in human decision-making: Confidence and error monitoring. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 367(1594), 1310–1321. <https://doi.org/10.1098/rstb.2011.0416>.

