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Cognitive processes underlying impaired decision-making under uncertainty in gambling disorder

Damien Brevers[*,a,b], **Gilly Koritzky**[a], **Antoine Bechara**[a], and **Xavier Noël**[b]

Damien Brevers: brevers@usc.edu; Gilly Koritzky: koritzky@usc.edu; Antoine Bechara: bechara@usc.edu; Xavier Noël: xnoel@ulb.ac.be

[a]Department of Psychology, and Brain and Creativity Institute, University of Southern California, 3620A McClintock Avenue, 90089-2921, Los Angeles, CA, USA

[b]Psychological Medicine laboratory, Faculty of Medicine, Brugmann-campus, Université Libre de Bruxelles (ULB), 4, Place van Gehuchten, 1002, Brussels, Belgium

Abstract

Objective—Pathological gamblers display at the Iowa Gambling Task (IGT) a strong preference for choices featuring high immediate rewards, but higher unpredictable and more delayed losses. The present study aimed, by applying the Expectancy-Valence (EV) model to the IGT, at identifying impaired components of decision-making under uncertainty in pathological gamblers.

Methods—Twenty pathological gamblers and 20 non-gamblers performed the IGT. The EV model breaks down IGT performance into three cognitive processes: (i) the subjective weight that the individual assigns to gains versus losses (gain/loss parameter), (ii) the degree of prominence given to recently-obtained information, compared to past experience (recency parameter), and (iii) the consistency between learning and responding (consistency parameter).

Results—Pathological gamblers obtained higher scores on the gain/loss parameter as compared to controls, indicating higher sensitivity to monetary gains. This measure was also correlated with the degree of gambling dependence severity. No between-group difference was observed in the recency and the consistency parameters.

Conclusion—These findings suggest that pathological gamblers' strong preference for choices featuring high rewards but higher losses during the IGT is due to a hypersensitivity for large monetary gains, which might reflect a hypersensitivity in their reward systems. In contrast, we

[*]Corresponding author: Damien, Brevers, PhD, Department of Psychology, and Brain and Creativity Institute, University of Southern California, 3620A McClintock Avenue, 90089-2921, Los Angeles, CA, USA, Phone: (213) 740-8528, dbrevers@ulb.ac.be, brevers@usc.edu.

Contributors

Damien Brevers Antoine Bechara and Xavier Noël designed the study and wrote the protocol. Brevers Damien conducted literature searches and provided summaries of previous research studies. Damien Brevers recruited the participants and collected the data. Damien Brevers and Gilly Koritzky conducted the statistical analysis. Damien Brevers wrote the first draft of the manuscript and all authors contributed to and have approved the final manuscript.

Conflict of interest

None.

found in pathological gamblers no evidence of inability to integrate information across time, a function that has been shown previously to be linked to damage in the prefrontal cortex.

Keywords

decision-making; gambling disorder; cognitive modeling; sensitivity to reward

1. Introduction

Gambling disorder is characterized by an exaggerated preference for high-uncertain rewards (e.g., Brevers et al., 2013a; van Holst et al., 2010). This abnormal pattern of decision-making has been repeatedly detected through the use of the Iowa Gambling Task (IGT; for reviews, see Brevers et al., 2013b; Goudriaan et al, 2004; van Holst et al., 2010). On this complex task, 4 card decks feature payoffs that vary over time and involve different cognitive processes (Bechara et al., 1994; Dunn et al., 2006). More specifically, during this task, pathological gamblers (PG) display a strong preference for choices featuring high rewards but higher losses (i.e., disadvantageous deck selection), rather than choosing from options featuring low rewards but lower losses (i.e., advantageous deck selection) (Brevers et al., 2013b). Even though such extensive behavioral testing is insightful, there is currently little information on the specific cognitive processes that underlie impaired IGT performances in PG (Brevers et al., 2013b; Goudriaan et al., 2006).

According to the Expectancy-Valence (EV) model (Busemeyer and Stout, 2002), choice in complex environments is based on subjective expectancies, which are formed based on the experienced outcomes (gains and losses), but are also affected by individual differences in three components of the learning and decision process. The first is a motivational factor, which indicates the subjective weight the individual assigns to gains versus losses. The second is a learning-rate factor, indicating the degree of prominence given to recently obtained information, compared to past experience. The third is a response factor, indicating how consistent the decision-maker is between learning and responding.

Decision-making deficits observed in complex decision-making tasks – such as the IGT – can be broken down into these three basic components (Busemeyer and Stout, 2002). The EV model has been successfully used to discriminate among specific component processes of IGT performance in individuals with different addictive disorders, including alcohol, cannabis and cocaine addictions (Stout et al., 2004; Yechiam et al., 2005). In the present study, we aim to use the EV model in order to distill PGs' IGT performances into more basic cognitive components.

2. Material and methods

2.1. Participants

Participants were 20 pathological gamblers (PG) and 20 controls. All subjects were adults (> 18 years old). Participants received 15 euros for their participation and their travel cost was reimbursed. They all provided informed consent that was approved by the appropriate human subject committee at the Brugmann University Hospital. The demographic data for the two groups are described in Table 1.

2.2. Recruitment and Screening Methods

PG were recruited through advertisement in the casino complex *VIAGE*, in Brussels, Belgium. The ads asked for participants who "gambled frequently" to participate in a one-day study to explore factors associated with gambling. In order to exclude occasional or non-frequent gamblers, a telephone-screening interview was conducted by means of a locally developed screening tool which included an examination of frequency of gambling behavior and comorbid psychiatric disorders. Participants were judged to be medically healthy and without comorbid substance use disorder on the basis of the Addiction Severity Index Short Form.

Gambling dependence severity was assessed using the South Oaks Gambling Screen (SOGS; Lesieur and Blume, 1987). All PG (n = 20) scored ≥ 5 on the SOGS, indicative of probable pathological gambling. Controls were recruited from the clerical and clinical staff belonging to the psychiatric department of the Brugmann University Hospital. To avoid biases, resulting from knowledge of how these tasks operate, psychiatrists and psychologists were excluded from participation. On the SOGS, only four control participants reported betting on lotteries occasionally (i.e., less than once a week) over the past 12 months preceding testing. None of the other controls gambled.

2.3. Current Clinical Status

Current clinical status of depression and anxiety was rated with French versions of the Beck Depression Inventory (Beck et al., 1961) and the Spielberger State–Trait Anxiety Inventory (STAI; Spielberger, 1983), respectively.

2.4. The Iowa Gambling task (IGT)

During the IGT play, participants saw a display of four decks of cards that were identical in appearance, except for their labels A, B, C and D. They were told that the game involved a long series of card selections (N = 100) and that the goal was to earn as much money as possible. Participants were given written instructions in which they were told that some decks were worse than others, and that they should avoid these decks in order to succeed in the task. Details of this task are now common and can be found in initial publications (Bechara et al., 1994, 1997). Briefly, Decks A and B yield relatively higher immediate gains (in "play money") in comparison to Decks C and D. However, unpredictably all decks yield losses, but these losses are set to be much higher in decks A and B relative to C and D. As such, decks A and B are considered disadvantageous (they lead to net loss in the long term), whereas decks C and D are considered advantageous (they lead to net gain in the long term).

2.5. Cognitive Modeling of the IGT's Results

The Expectancy-Valence model predicts the next choice ahead in complex decision-making tasks. Based on a trial-to-trial analysis of behavior during the task, the model estimates three individual parameters corresponding to the following components, for each decision maker (for a more detailed explanation of the computation and estimation process, see Appendix A):

2.5.1. Attention-weight—This is motivational component indicating the subjective weight the individual assigns to gains versus losses. The sensitivity to reward parameter ranges between 0–1, and represents the relative weight assigned to gains (rewards) in the evaluation of alternatives.

2.5.2. Recency—This is a learning-rate component indicating the degree of prominence given to recent outcomes, at the expense of relying on the full range of past experience. The Recency parameter ranges between 0–1, and represents (inversely) the tendency to take long-term considerations into account.

2.5.3. Consistency—This is a probabilistic component indicating how consistent the decision-maker is between learning and responding. The Consistency parameter ranges between (−5)−5 and represents the tendency to choose from the alternatives with the higher subjective expectancies, as opposed to making random selections.

2.6. Statistical Analysis

Non-parametric statistical tests have been used due to (1) the small size of the present sample and (2) the non-normal distribution of the IGT data (proportion of advantageous selection and EV model parameters).

3. Results

3.1. Demographics and current clinical status

We observed no difference in terms of gender and level of education between the gambler and non-gambler groups (see Table 1). Mann-Whitney *U* tests revealed no significant difference between PG and controls on age, depression, state and trait anxiety (see Table 1). We observed no significant correlation (Spearman *r*, N = 40) between performance on the IGT (proportion of advantageous selection and EV model parameters) and current clinical status (depression or anxiety).

3.2. Proportion of advantageous deck selection

In controls, a Friedman test revealed that the proportion of advantageous choice was higher in the last block of 20 trials (*Median* = 0.80, *IQR* = 0.49) than in the first block of 20 trials (*Median* = 0.44, *IQR* = 0.14; $X^2(1,20) = 4.77$, $p = 0.029$), indicating that controls had learned to perform better during the task. In the PG group, we observed no difference between the proportion of advantageous choice in the last block of 20 trials (*Median* = 0.48, *IQR* = 0.34) and in the first block of 20 trials (*Median* = 0.40, *IQR* = 0.20; $X^2(1,20) = 0.80$, $p = 0.37$), indicating that no such learning had occurred. Mann-Whitney *U* test was then performed to examine between-groups differences on the total proportion of advantageous deck selection (across the 100 trials). There was a significant difference between PG and controls (Mann–Whitney *U* statistic = 109.50, $Z = -2.45$, $p = .013$), indicating that the total proportion of advantageous deck selection was lower in PG (*Median* = 0.50, *IQR* = 0.15) than in controls (*Median* = 0.70, *IQR* = 0.24).

3.2. Modeling Results

Model fit was positive (M = 24.35; SD = 31.47). Mann-Whitney U tests showed that PG obtained lower scores on the attention-weight parameter than controls (Mann–Whitney U statistic = 103.50, $Z = -2.63$, p = .008), which indicates higher gain sensitivity in PG. We observed no significant between-group difference on the recency (Mann–Whitney U statistic = 140.00, $Z = -1.72$, p = .11) and on the consistency parameters Mann–Whitney U statistic = 195.00, $Z = -0.14$, p = .90). These findings are depicted in Table 2.

3.3. Relationship between EV model's parameters, total task performance and gambling dependence severity

There was a significant correlation between the total proportion of advantageous deck selection (summed across the 100 trials) and the attention-weight parameter (Spearman's *rho* (40) = −.51, $p < 0.001$). Furthermore, in the PG group, scores on the attention-weight parameter were correlated with scores on the SOGS (Spearman's *rho* (20) = 0.52, p = 0.018). This indicates that even within this group of pathological gamblers, gain sensitivity accounts for much of the variance in the severity of the gambling disorder/behavior. No other significant result was observed.

4. Discussion

In this study, we investigated the potential contribution of three psychological processes (attention-weight; recency; consistency) involved in PGs' impaired IGT performance.

Findings of the present study could be summarized as follows: we first observed that PG choose disadvantageous decks more often than control participants. This is consistent with several prior studies (for reviews, see Brevers et al., 2013b; Goudriaan et al, 2004; van Holst et al., 2010). The novel findings of this study are the cognitive modeling results, which revealed that PG obtained higher scores on the attention-weight parameter as compared to their controls, indicating higher sensitivity to monetary gains. This measure was negatively associated with advantageous deck selection. Moreover, in the PG group, scores on the attention-weight parameter were correlated with scores on gambling dependence severity. Hence, the more elevated the sensitivity to monetary gains, the more severe the gambling problem is.

Importantly, we observed no between-group difference on the recency parameter. This result suggests that PGs' tendency to choose disadvantageously may not be specifically due to rapid discounting of past outcomes or to an inability to anticipate consequences of choosing cards from each deck (Yechiam et al., 2005). This result also implies (at least indirectly) that poor decision-making in PG may not be linked to impairments in the prefrontal cortex, since prior studies have linked prefrontal cortex damage to increased scores in the recency parameter (e.g., Koritzky et al., 2013). There was also no significant difference between PG and their controls on the choice consistency parameter. This result indicates that PG did not make erratic or random choices, that is, they were able to make choices according to the subjective expectancy associated with the forthcoming choice option. Noteworthy, due to small sample size, non-significant results (e.g., non-significant between-group difference on the EV model's recency parameter) must be interpreted with caution. Moreover, another limitation of this study is that gamblers participants were only screened using the SOGS (which determines “probable pathological gambling”), rather than using both the SOGS and a DSM-V based diagnostic interview for gambling disorder (APA, 2013). Hence, additional studies are needed in order to replicate present preliminary findings.

As a whole, the present findings suggest that PG persist in choosing from disadvantageous decks because of their hypersensitivity for large monetary gains. Put differently, in PG, prior to choosing a deck option, high monetary rewards may carry more weight than signals triggered by monetary losses. In this context, options featuring high-reward but higher losses may be flagged as salient, as compared with options featuring low rewards and losses. This assumption is in line with brain-imaging studies showing that, as compared with non-gamblers, disadvantageous deck selection during the IGT is associated with enhanced activation within PGs’ brain-reward systems, such as the striatum and the mesolimbic dopamine system (Linnet et al., 2010, 2011a; 2011b; Power et al., 2012). One direction for future studies would be to examine brain-correlates of monetary gain sensitivity, estimated with the EV model (for an example of integrating EV model’s parameters with fMRI data analyses, see Koritzky et al., 2013).

To conclude, by decomposing the IGT into three different psychological components, we found that the motivational process of weighting gains versus losses underlie poor IGT performance in gambling disorder.

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Appendix A

The Expectancy Valence model (EV; Busemeyer & Stout, 2002) is a learning model predicting the next choice ahead in repeated decision-making. The model assumes that making repeated choices from a set of alternatives generates a process of learning the expectancies of these alternatives. The individual’s choice is based on subjective expectancies, namely, an incorporation of the actual experienced outcomes into a learning and decision process with three components. Each component is represented by a parameter:

1) Relative weight to gains and losses, measured by the attention-weight parameter. The subjective evaluation of the gains and/or losses obtained upon making a choice is called a valence, and denoted $v(t)$. It is calculated as a weighted average of the gains and losses resulting from the chosen option in each trial t.

$$v_j(t){=}w \cdot win(t) - (1 - w) \cdot loss(t),$$

where *win*(t) and *loss*(t) are the amounts of money won or lost on trial t; and w is the attention weight parameter ($0 \leq w \leq 1$).

2) The rate at which recent outcomes are updated, or the relative effect of recent outcomes on the subjective expectancies formed by the decision maker. This is measured by the recency parameter. The outcomes produced by each alternative j are summarized by an expectancy score, denoted $E_j(t)$, and updated as follows:

$$E_j(t)=E_j(t-1)+\phi \cdot [v(t) - E_j(t-1)],$$

where j is the selected alternative. The recency parameter, φ, describes the degree to which subjective expectancies reflect the influence of the most recent experience relative to more distant past experiences ($0 \leq \varphi \leq 1$). Higher values of φ indicate a greater effect of recent information (at the expense of relying on the full past experience) on the next decision made. Low values of φ are generally more optimal.

3) The effect of expectancies on further choice, measured by the choice consistency parameter. The probability of choosing an alternative is a strength ratio of the subjective expectancy of that alternative, relative to all choice options (using Luce's rule):

$$\Pr[G_j(t+1)]=\frac{e^{\theta(t)\cdot E_j(t)}}{\sum_j e^{\theta(t)\cdot E_j(t)}}$$

where $\Pr[G_j(t)]$ is the probability that alternative j will be selected on trial t. The term $\theta(t)$ controls the consistency of the choice probabilities and the expectancies, where: $\theta(t) = (t/10)^c$, and c is the choice consistency parameter ($-5 \leq c \leq 5$).

Parameters are estimated based on a trial-to-trial analysis of the decision maker's behavior in the task. The accuracy of the model is assessed by comparing its ability to predict the individual's next decision, to a prediction based on the respondent's mean choices (a baseline model). The estimation procedure is described in detail in Busmeyer and Stout (2002). The statistical test used for comparing the fit of the models is the Bayesian Information Criterion (BIC) for log likelihood differences. Positive values of the BIC statistic indicate that the cognitive model performs better than the baseline model.

References

American Psychiatric Association. Diagnostic and statistical manual of mental disorders. 5. Washington, DC: American Psychiatric Press; 2013.

Bechara A, Damasio AR, Damasio H, Anderson SW. Insensitivity to future consequences following damage to human prefrontal cortex. Cognition. 1994; 50:7–15. [PubMed: 8039375]

Bechara A, Damasio H, Tranel D, Damasio AR. Deciding advantageously before knowing the advantageous strategy. Science. 1997; 275:1293–1294. [PubMed: 9036851]

Beck AT, Ward CH, Mendelson M, Mock J, Erbaugh J. An inventory for measuring depression. Archives of General Psychiatry. 1961; 4:561–571. [PubMed: 13688369]

Brevers D, Noël X. Pathological gambling the loss of willpower: A neurocognitve perspective. Socioaffective and Neuroscience Psychology. 2013a; 3:21592.

Brevers D, Bechara A, Cleeremans A, Noël X. Iowa Gambling Task (IGT): twenty years after – gambling disorder and IGT. Frontiers in Psychology. 2013b; 4:665. [PubMed: 24137138]

Busemeyer JR, Stout JC. A contribution of cognitive decision models to clinical assessment: decomposing performance on the Bechara gambling task. Psychological Assessment. 2002; 14:253–262. [PubMed: 12214432]

Dunn BD, Dalgleish T, Lawrence AD. The somatic marker hypothesis: A critical evaluation. Neuroscience and Biobehavioral Reviews. 2006; 30:239–271. [PubMed: 16197997]

Goudriaan AE, Oosterlaan J, de Beurs E, van den Brink W. Psychophysiological determinants and concomitants of deficient decision-making in pathological gamblers. Drug and Alcohol Dependence. 2006; 84:231–239. [PubMed: 16574343]

Goudriaan AE, Oosterlaan J, de Beurs E, van den Brink W. Pathological gambling: a comprehensive review of biobehavioral findings. Neuroscience Biobehavioral Review. 2004; 28:123–141.

Koritzky G, He Q, Xue G, Wong S, Xiao L, Bechara A. Processing of time within the prefrontal cortex: recent time engages posterior areas whereas distant time engages anterior areas. Neuroimage. 2013; 72:280–286. [PubMed: 23380168]

Lesieur HR, Blume SB. The South Oaks Gambling Screen (SOGS): a new instrument for the identification of pathological gamblers. American Journal of Psychiatry. 1987; 144:1184–8. [PubMed: 3631315]

Linnet J, Møller A, Peterson E, Gjedde A, Doudet D. Dopamine release in ventral striatum during Iowa Gambling Task performance is associated with increased excitement levels in gambling disorder. Addiction. 2011a; 106:383–390. [PubMed: 20883460]

Linnet J, Mouridsen K, Peterson E, Møller A, Doudet DJ, Gjedde A. Striatal dopamine release codes uncertainty in gambling disorder. Psychiatry Research. 2011b; 204:55–60. [PubMed: 22889563]

Linnet J, Peterson E, Doudet DJ, Gjedde A, Møller A. Dopamine release in ventral striatum of pathological gamblers losing money. Acta Psychiatrica Scandinavia. 2010; 122:326–333.

Power Y, Goodyear B, Crockford D. Neural correlates of pathological gamblers preference for immediate rewards during the iowa gambling task: an FMRI study. Journal of Gambling Studies. 2012; 28:623–636. [PubMed: 22037936]

Spielberger, C. Manual for the State-Trait Anxiety Inventory: STAI (Eorm I). Consulting Psychologists Press; Palo Alto, CA: 1983.

Stout JC, Busemeyer JR, Lin A, Grant SR, Bonson KR. Cognitive modeling analysis of the decision-making processes used by cocaine abusers. Psychonomic Bulletin & Review. 2004; 11:742–747. [PubMed: 15581127]

van Holst RJ, van den Brink W, Veltman DJ, Goudriaan AE. Why gamblers fail to win: a review of cognitive and neuroimaging findings in pathological gambling. Neuroscience Biobehavioral Review. 2010; 34:87–107.

Yechiam E, Busemeyer JR, Stout JC, Bechara A. Using cognitive models to map relations between neuropsychological disorders and human decision making deficits. Psychological Science. 2005; 16:973–978. [PubMed: 16313662]

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Highlights

- The expectancy-valence model was used to examine problem gamblers' IGT performance
- Compared to controls, gamblers' exhibited an hypersensitivity to monetary rewards
- Gamblers were similar to controls at integrating information across time
- Gamblers were similar to controls in their choice consistency

Table 1

Demographic and current clinical status data for PG and control participants.

	PG	***Controls***
n	20	20
Age (years)	35.95 (10.53)	37.10 (10.52)
Gender (M/F)	16/4	15/5
Education (level 1/2/3)	4/11/5	2/12/6
SOGS	8.05 (2.56)	0.00
Gambling frequency (day per month)	13.41 (7.71)	
BDI	4.80 (5.97)	2.10 (1.61)
STAI S	41.05 (9.66)	37.85 (7.70)
STAI T	29.60 (10.80)	33.94 (8.19)

Note. All Mann-Whitney *U* tests *p*-value > 0.05, except for SOGS scores: $p < 0.0001$. Values shown are the mean and standard deviation on each measure. Level of education was coded as follows: level 1 = completion of the first 3 years of secondary school or equivalent; level 2 = completion of secondary school or equivalent; and level 3 = post-secondary school training. SOGS = South Oaks Gambling Screen, BDI = Beck Depression Inventory, STAI S = State subscale of the State-Trait Anxiety Inventory, STAI T = Trait subscale of the State-Trait Anxiety Inventory.

Table 2

Statistics of the EV model's parameters in the current sample.

	PG			*Controls*		
Parameter	***Mean***	***SD***	***Median***	***Mean***	***SD***	***Median***
Sensitivity to gains vs. losses* (*w*)	0.60	0.28	0.71	0.32	0.32	0.29
Recency (*φ*)	0.56	0.47	0.86	0.83	0.33	1.00
Consistency (*c*)	0.95	1.95	0.33	0.57	0.94	0.32

Note.

*Mann–Whitney $U = p < 0.05$.