Dysfunctional decision-making in pathological gambling: Pattern specificity and the role of impulsivity

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**ABSTRACT**

Dysfunctional decision-making in individuals with pathological gambling (PGs) may result from dominating reward-driven processes, indicated by higher impulsivity. In the current study we examined (1) if PGs show specific decision-making impairments related to dominating reward-driven processes rather than to strategic planning deficits and (2) whether these impairments are related to impulsivity. Nineteen PGs according to DSM-IV and 19 matched control subjects undertook the Cambridge Gambling Task (CGT) to assess decision-making. The delay discounting paradigm (DDP) as well as the UPSIS Impulsive Behavior Scale (measuring urgency, premeditation, perseverance and sensation seeking) were administered as multidimensional measures of impulsivity. Results revealed that (1) PGs exhibited higher risk seeking and an immediate reward focus in the CGT and, in contrast, comparable strategic planning to the control group. (2) Decision-making impairments were related to more severe delay discounting and, specifically, to increased urgency and less premeditation. Our findings suggest (1) the necessity to disentangle decision-making components in order to improve etiological models of PGs, and (2) that urgency and premeditation are specifically related to disadvantageous decision-making and should be tackled in intervention strategies focusing on emotion tolerance and control strategies.

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1. Introduction

While it is well known, that individuals diagnosed with pathological gambling (PGs) display impaired performance in neuropsychological decision-making tasks (e.g. Petry, 2001; Cavedini et al., 2002; Brand et al., 2005; Goudriaan et al., 2005; Linnet et al., 2006; Labudda et al., 2007; Forbush et al., 2008; Roca et al., 2008; Lawrence et al., 2009; Kertzman et al., 2011) and heightened impulsivity (Goudriaan et al., 2004; Verdejo-Garcia et al., 2008; van Holst et al., 2010), the relation of both constructs in PGs remains unclear. Findings from previous studies on this issue in non-gambling samples were inconsistent (e.g. Monterosso et al., 2001; Jollant et al., 2005; Zermatten et al., 2005; Suhr and Tsanadis, 2007; Dolan et al., 2008; Franken et al., 2008; Sweitzer et al., 2008; Janis and Nock, 2009; Perales et al., 2009; Xiao et al., 2009; Billieux et al., 2010) which may result from a neglected consideration of the lower-order sub-components, for either or both constructs. Thus, the present study aims to assess the relation of impaired decision-making and impulsivity in PGs taking a multidimensional perspective.

In line with recent models on pathways of addictions (Bechara, 2005; Bühringer et al., 2008; Redish et al., 2008b; Goldstein and Volkow, 2011) and specifically of pathological gambling (Bechara, 2003; Evans and Coventry, 2006; van Holst et al., 2010), we assume an important role of an – either antecedent or resultant – imbalance of (more automatic) motivational and valuation brain networks and (more reflective) cognitive control networks. According to these models, the motivational and valuation systems in PGs may overestimate the value of immediate short-term rewards. This would explain, on the one hand, the heightened impulsivity found in PGs, because the tendency towards immediate rewards while disregarding negative consequences is frequently considered a central aspect of impulsivity (Moeller et al., 2001; Bechara, 2005; Verdejo-Garcia et al., 2008). On the other hand, this imbalance may result in disadvantageous gambling-related decisions, as dominating reward-driven processes were found to be strongly related to impaired decision-making (Krawczyk, 2002; Fellows, 2004; Yechiam et al., 2005; Dunn et al., 2006; Rangel et al., 2008). Due to the lack of a consensus model of decision-making, a broad variety of tasks has been used to measure the construct (Fellows, 2004). However, a fractionating of lower-order decision-making components may be an advantageous approach to gain a deeper understanding of the
complexity of underlying processing mechanisms (see e.g. Busemeyer and Stout, 2002; Krawczyk, 2002; Clark et al., 2004; Brand et al., 2005; Fellows and Farah, 2005; Vehiam et al., 2005; Diekhof et al., 2008). Following this approach, it can be expected that PGs will show specific impairments in decision-making sub-components associated with reward and valuation. These decision-components have often been related to processes in the ventromedial regions of the prefrontal cortex (PFC) (e.g. Brand et al., 2006; Lawrence et al., 2008; Clark, 2010). Indeed, PGs display functional changes in these brain areas in tasks of reward processing and decision-making (Potenza et al., 2003; Reuter et al., 2005; Potenza, 2008; Clark, 2010). In contrast, decision-making components like reasoning or strategic planning – often related to processes in the dorsolateral PFC – may be unchanged in PGs (Lawrence et al., 2009; Clark, 2010).

A neuropsychological task which differentiates between different components of decision-making behavior is the Cambridge Gambling Task (CGT) (Rogers et al., 1999). The CGT assesses parameters related to risk seeking (e.g. ‘risk taking’), an immediate reward focus (e.g. ‘delay aversion’) or strategic planning (e.g. ‘percentage of rational choices’). First studies using the CGT in gamblers and PGs revealed disorder-specific deficits in risk seeking rather than in strategic planning (Lawrence et al., 2008; Grant et al., 2011). Crucially, both studies did not explicitly report on other parameters related to reward-driven processes like delay aversion or chasing behavior within a task (i.e. betting larger sums of money or taking greater risks with an intention to recover prior losses immediately) (O’Connor and Dickerson, 2003; Linnet et al., 2006).

According to our present hypothesis, the impaired reward- and valuation-related components of decision-making are positively related to impulsivity, in contrast to the strategic components of decision-making (Lawrence et al., 2008). To our best knowledge, to date, there are no studies on the relation of impaired decision-making components and impulsivity in PGs. Studies on this relation in non-gambling samples have mainly been conducted without considering the aforementioned multidimensional nature of decision-making and of impulsivity itself (e.g. Reynolds et al., 2006; Verdejo-Garcia et al., 2008; Broos et al., 2012). Especially, the behaviorally assessed impulsivity dimension delay discounting (Bechara, 2003; Franken et al., 2008) as well as self-reported dimensions concerning the tendency to act rashly in an emotional context (urgency) and the lack of forethought (Whiteside and Lyam, 2001) may be relevant mechanisms underlying impaired decision-making (Enticott and Ogloff, 2006). Hitherto, studies with non-gambling samples assessing the relation of delay discounting and decision-making yielded inconsistent results (Monterosso et al., 2001; Janis and Nock, 2009), whereas studies on urgency and premeditation underpin our hypothesis (Zermatten et al., 2005; Billieux et al., 2010).

In summary, we expected a specific pattern of impaired decision-making components in PGs which is related to an imbalance of reward- and valuation-related and reflection-related brain networks, as indicated by increased risk seeking and an immediate reward focus. Further, we hypothesized that impulsivity is an important indicator of this imbalance. Thus, we expect that the impaired decision-making components are specifically related to the impulsivity dimensions delay discounting, urgency and premeditation. As impaired decision-making is important in the development (e.g. starting to gamble regularly), maintenance (e.g. chasing behavior) and cessation (as well as relapse) of pathological gambling, it is of central importance to understand its components and underlying mechanisms. If a dominating reward- and valuation-system, indicated by an elevated impulsivity, turns out to be the core mechanism rather than problems in reasoning or strategic planning, this would be an important result for the adaptation of etiological models as well as therapeutic strategies.

2. Methods

2.1. Design

We used a cross-sectional design with matched-pairs to compare a pathological gambling group (PGG) and a paired control group (CG). In detail, we matched for each member of PGG a corresponding member of the control group. The matching was realized according to age (>± 2 years), gender and smoking status (daily smoking or not), because these variables were found to be associated with different decision-making and impulsivity measures (Mitchell, 2004; Reynolds et al., 2007; Fields et al., 2009). All individuals in the CG were related to a unique corresponding individual in the PGG and, thus, the samples were dependent. The matched-pairs design has the advantage to obtain improved estimates of group differences by keeping possible confounders constant and, consequently, to achieve greater statistical power and economy (e.g. Mitchell and Jolley, 2012).

A power analysis was performed previously with Stata 11.2 (StataCorp, 2011) based on an analysis of variance design with paired measures and two-sided dependent t-test comparisons. A sample size of 19 in each group was needed for detecting medium-to-large effects of the CGT performance differences (d=0.7) found in earlier studies (Lawrence et al., 2009), with α=0.05 and β=0.80. The study was approved by the local Ethics Committee at the TU Dresden, Germany.

2.2. Screening

Participants of the PGG and the CG were recruited in 2009 in Dresden (Germany) by newspaper, internet advertisements and postings on community boards. Included in the PGG were subjects who fulfilled diagnostic criteria for pathological gambling according to DSM-IV-TR (American Psychiatric Association, 2000) in the last 12 months. Excluded were subjects who fulfilled any of the following criteria assessed in a telephone interview: (1) age under 18, (2) psycho-tropic medication in the last 3 months, (3) current treatment for mental disorders, (4) disorders which might influence cognition or motor performance (e.g. attention deficit hyperactivity disorder) and (5) mother tongue other than German. Additionally, all volunteers were personally screened for comorbidity with the Munich Composite International Diagnostic Interview (DIA-X/M-CIDI) (Wittchen and Pfister, 1997; Wittchen et al., 1998). Exclusion criteria regarding comorbidity were (1) current (last 3 months) other mental disorders (i.e. somatoform disorders, anxiety disorders, affective disorders, eating disorders, substance use disorders, obsessive compulsive disorders, psychotic disorders) with the exception of nicotine dependence, because we included smokers in both groups.

2.3. Final sample

Out of 93 screened subjects, the final sample resulted in 19 participants for each group. Reasons for exclusion in the PGG were: no pathological gambling diagnosis (n=19), history of ADHD or medication (n=2) and current mental disorders (n=5). In the CG we excluded those interested persons who did not match to one of the PGG in terms of age, gender or smoking status according to our paired sample design (n=24). Further exclusion criteria in the CG were: history of ADHD or medication (n=2) and current mental disorders (n=2). The final sample included only male participants due to small number of females fulfilling DSM-IV criteria for pathological gambling (n=1). Demographic and clinical data of the final sample are shown in Table 1. We found no significant differences in age and years of education between groups. The mean number of fulfilled DSM-IV criteria for pathological gambling in the PGG was 7.36. Thirteen of the 19 matched pairs showed the same income class. There was a non-significantly higher rate of alcohol consumption in the PGG (t(18)=1.74, p=0.10). Regarding mental disorders there were no significant differences in number of lifetime mental disorders. Current (last 3 months) nicotine dependence did also not significantly differ between the groups: 26% (n=5) of the PGG and 42% (n=8) of the CG were diagnosed having a current nicotine dependence.

2.4. Measurements

2.4.1. Cambridge Gambling Task (CGT)

We used the CGT provided by the Cambridge Neuropsychological Test Auto-mated Battery (CANTAB, Cambridge Cognition Ltd., Cambridge, United Kingdom) to assess decision-making. Ten blue and red boxes were presented in a varying ratio (9:1, 8:2, 7:3 and 6:4). Participants had to decide whether a yellow token is hidden under a red or a blue box, staking a proportion of points on this choice being correct. The available proportion of points to be staked were 5%, 25%, 50%, 75% or 95% of the current points given in ascending (5–95%) or descending (95–5%) order. Ascending and descending conditions were randomized and balanced within and matched between groups.

As dependent variable we used eight decision-making parameters according to the hypothesized sub-components. Risk seeking behavior was operationalized with the following three parameter: (1) ‘Overall proportion bet’ as the mean proportion
of points gambled across all conditions and box ratios. (2) ‘Risk taking’ which was calculated as the mean proportion of points staked if the more likely outcome was chosen (i.e. if the participant choose blue if the blue boxes are in the majority) across all conditions and box ratios. In the parameter (3) ‘bankruptcies’ we summed all blocks which were terminated because the total points dropped as low as 1 point. The immediate reward focus was operationalized with two parameters: (4) ‘Delay aversion’ which is the difference of risk taking in the descending minus ascending condition. The two conditions offer the possibility to separate risk taking (i.e. high stakes are preferred in general) from rash choices (i.e. early bets are preferred in general) (Murphy et al., 2001; Manes et al., 2002; Clark et al., 2003). Further, we examined (5) ‘chasing behavior’ as the percentage of staked points after losses to regain the lost money immediately (Vitaro et al., 1999).

The last three parameters were assessed to operationalize the strategic planning behavior. As parameter (6) ‘quality of decision-making’ was chosen, which indicates the proportion of rational decisions, i.e. the number of trials where the more likely outcome was chosen, divided by all trials. (7) ‘Risk adjustment’ which quantifies bet calibration across ratios. This was calculated according the CANTAB manual: [% bet 9:1]+(% bet 8:2)–(% bet 7:3)–(% bet 6:4)]/[Average % bet], so higher scores indicate a better calibration of bets (Deakin et al., 2004). The (8) ‘deliberation time’ was the mean latency from cue presentation to the decision over all trials.

### 2.4.2. Delay discounting paradigm (DDP)

Participants completed 192 trials presented on a computer screen using E-Prime (Pittsburgh, PA). They were instructed to decide on each trial between two hypothetic amounts of money: a smaller reward available sooner (sooner/smaller, e.g. “18.73€ now”) on the left side of the screen and a larger reward available later (later/larger, e.g. “21.75€ in 7 days”) on the right side of the screen. Participants had to react with a left button press for the sooner/smaller and with a right button press for the later/larger reward. All participants were instructed to respond to the hypothetical choices as if they were real choices. We used hypothetical choices, as previous studies showed that they are comparable to real choices (Lagorio and Madden, 2005). The sooner/smaller reward had a value between 17 and 23€ and was randomly taken from a pool of items with the mean value of 20€ and a standard deviation of 2€. The value of the later/larger reward was systematically varied by increasing the value of the sooner/smaller by 1%, 2%, 3%, 7%, 12%, 18%, 27%, 40%, or 80%. The time delay was systematically varied for the sooner/smaller reward being either “now” or in 7 days and the later/larger reward being additionally delayed by 2, 3, 5, 7, 9, 12 or 15 days. Varying the amount of money and the delay of time offers the possibility to identify the indifference points of each participant. These points represent the subjective equivalence between the immediate and delayed reward. As parameter (7) ‘quality of decision-making’ was dependent variable for the DDP (Dishmchadse et al., 2013). The higher the k-value, the more steeply the individual discounts rewards delayed in time which, in turn, is an indicator of increased impulsivity.

### 2.4.3. UPPS Impulsive Behavior Scale

The UPPS Impulsive Behavior Scale (Whiteside and Lyamin, 2001; Whiteside et al., 2005) distinguishes between four dimensions of impulsivity: (1) urgency, the tendency to act rashly under conditions of negative effect, (2) premeditation, the tendency to reflect on the consequences of an act before engaging in that act, (3) perseverance, an individual’s ability to remain focused on a task and (4) sensation seeking, the tendency to enjoy and pursue activities that are exciting and openness towards novel experiences that may be dangerous. Using exploratory factor analysis, the authors extracted the scales out of 20 scales measuring impulsivity-like traits. The final questionnaire consists of 45 items and the factor structure was validated with confirmatory factor analysis. The German version of the UPPS scale shows also reliable (Cronbach’s α between 0.83 and 0.85) and valid acquisition of the hypothesized impulsivity facets (Kampfe and Mitte, 2009).

### 2.5. Statistical analyses

Data were analyzed with Stata 11.2 (StataCorp, 2011). With the matched-pair design used in our study, the CG was not independently assigned, but dependent according the PGC. Since this matching procedure leads to a matching of variances between the two groups and dependencies between the obtained measures, these data has to be treated as dependent. As recommended for dependent data within a matched-pairs design, all statistical analyses were conducted using tests for dependent measures (e.g. Howell, 2009; Mitchell and Jolley, 2012).

For the first aim regarding the specificity of decision-making alterations, we analyzed the eight parameters of the CGT. For analysis of variance (ANOVA), we used box ratio, condition (ascending, descending) as well as the matched groups as within subject factors. If sphericity assumptions were violated, Greenhouse-Geisser corrections are reported. The first exploratory data analyses showed that the CGT parameters quality of decision making and bankruptcies were not normally distributed. Thus, we used the Friedman test (to test the group and condition effect) and the Wilcoxon signed-rank test for related samples (to test the box-ratio effect) as equivalent non-parametrical tests. Regarding the k-parameter to assess behavioral impulsivity, two participants were excluded from the analysis because they did not execute a sufficient number of sooner/smaller (one participant showed 0%) or later/larger (one participant showed 0.1%) choices to estimate the discounting function. An additional analysis including all participants did not change the pattern of results. We used a two-tailed t-test for matched pairs to assess the difference between groups. For the self-report, we first investigated the differences between groups in the UPPS Impulsive Behavior Scales using ANOVA for repeated measures with the four scales as well as the matched groups as within-subject factor. Since this matching procedure leads to a matching of variances between the two groups, we computed additional bootstrapped regression analyses. In those analyses, we used the appropriate CGT decision-making parameters as dependent variable. The independent variables were the appropriate impulsivity dimensions and the dummy coded group. A significant interaction of both independent variables would point to a group-specific correlation, which would have been further analyzed. The number of participants included in the analyses is either 34 or 38. Thirty-four cases can be found in all analyses with the DDP data since, as described above, two subjects and

### Table 1

Demographical and clinical data with means (standard deviation), total numbers (percentages), ranges and test statistic of group differences between the pathological gambling group (PGG) and the control group (CG).

<table>
<thead>
<tr>
<th></th>
<th>PGC</th>
<th>CG</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>S.D.</td>
</tr>
<tr>
<td>Age</td>
<td>31.37</td>
<td>15.71</td>
</tr>
<tr>
<td>Years of education</td>
<td>14.75</td>
<td>1.84</td>
</tr>
<tr>
<td>Number of DSM-IV criteria for PG</td>
<td>7.16</td>
<td>1.39</td>
</tr>
<tr>
<td>Alcohol consumption *</td>
<td>25.00</td>
<td>18.80</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>S.D.</td>
</tr>
<tr>
<td>Affective disorder</td>
<td>7</td>
<td>36.84</td>
</tr>
<tr>
<td>Anxiety disorder</td>
<td>3</td>
<td>15.79</td>
</tr>
<tr>
<td>Substance use disorder</td>
<td>14</td>
<td>73.68</td>
</tr>
<tr>
<td>Any disorder</td>
<td>11</td>
<td>57.89</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>%</th>
<th>Range per subject</th>
<th>%</th>
<th>Range per subject</th>
</tr>
</thead>
<tbody>
<tr>
<td>Affective disorder</td>
<td>5</td>
<td>26.32</td>
<td>0–1</td>
<td></td>
</tr>
<tr>
<td>Anxiety disorder</td>
<td>6</td>
<td>31.58</td>
<td>0–1</td>
<td></td>
</tr>
<tr>
<td>Substance use disorder</td>
<td>11</td>
<td>57.89</td>
<td>0–2</td>
<td></td>
</tr>
<tr>
<td>Any disorder</td>
<td>11</td>
<td>57.89</td>
<td>0–4</td>
<td></td>
</tr>
</tbody>
</table>

### DSM-IV: Diagnostic and Statistical Manual of Mental Disorders, 4th Edition.

* Alcohol consumption as quantity-frequency-index. ***Significant at p < 0.001 (two-tailed).
than the yielded a non-reliable tendency that the PGG placed higher wagers decision-making parameters indicative for strategic planning:

The missing effects of box ratio in delay aversion ($F(1,16) = 5.74, p = 0.03$) indicate, on the one hand, a tendency of the PGs to stake more points on the descending conditions than in the ascending condition compared to the CG which is illustrated in Fig. 1a. The missing effects of box ratio in delay aversion ($F(3,48) = 1.69, p = 0.18$) showed that the effect is independent of the chance to win. On the other hand, we found also significant group differences in chasing behavior ($t(18) = -2.36, p = 0.02$) reflecting the fact that the PGG showed a higher percentage of staked points after losses (Fig. 1b). Contrary to our expectations, we did not find significant differences in overall proportion bet and bankruptcies. However, the ANOVA for overall proportion bet yielded a non-reliable tendency that the PGG placed higher wagers than the CG ($F(1,18) = 3.21, p = 0.09$).

As predicted, we did not find group differences in the decision-making parameters indicative for strategic planning: quality of decision-making, risk adjustment and deliberation times (all $p \geq 0.05$).

3.1.2. Impulsivity

3.1.2.1. Behaviorally assessed impulsivity. The k-value of the DDP was significantly higher in the PGG (Table 2), indicating a steeper decrease in the discounting curve as a function of temporal delay compared to the CG ($t(16) = 2.66, p = 0.01$) (Fig. 2) which demonstrated a lower ability to delay rewards.

3.1.2.2. Self-reported impulsivity. Results of an ANOVA for dependent measures in Table 2 revealed significant differences between the two groups in self-reported impulsivity ($F(1,18) = 4.43, p = 0.002$). Additional post hoc comparisons revealed a significant group difference in urgency ($t(18) = 4.58, adjusted p < 0.00025$), but no significant group differences for the other impulsivity facets (all $p \geq 0.05$).

### Table 2

<table>
<thead>
<tr>
<th>Parameter</th>
<th>PGG n=19 (S.D.)</th>
<th>CG n=19 (S.D.)</th>
<th>Test statistic Group differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>CGT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall proportion bet</td>
<td>0.43 (0.20)</td>
<td>0.33 (0.16)</td>
<td>$F(1,18) = 3.21, p = 0.09$</td>
</tr>
<tr>
<td>Risk taking</td>
<td>0.47 (0.22)</td>
<td>0.36 (0.18)</td>
<td>$F(1,16) = 5.71, p = 0.03$</td>
</tr>
<tr>
<td>Bankruptcies in N (%)</td>
<td>4 (21.15)</td>
<td>3 (15.85)</td>
<td></td>
</tr>
<tr>
<td>Delay aversion</td>
<td>0.25 (0.21)</td>
<td>0.11 (0.15)</td>
<td>$F(1,16) = 0.57, p = 0.03$</td>
</tr>
<tr>
<td>Chasing (percentage of points staked after losses)</td>
<td>51.18 (23.11)</td>
<td>36.14 (15.83)</td>
<td>$t(18) = 2.36, p = 0.02$</td>
</tr>
<tr>
<td>Quality of decision making</td>
<td>0.89 (0.09)</td>
<td>0.91 (0.16)</td>
<td>$Z = -1.19, p = 0.23$</td>
</tr>
<tr>
<td>Risk adjustment</td>
<td>1.84 (1.57)</td>
<td>1.51 (1.59)</td>
<td></td>
</tr>
<tr>
<td>Deliberation time</td>
<td>2322.99 (1099.02)</td>
<td>2087.84 (387.15)</td>
<td>$F(1,18) = 0.01, p = 0.94$</td>
</tr>
<tr>
<td>DDP k-value</td>
<td>0.06 (0.04)</td>
<td>0.03 (0.02)</td>
<td>$t(16) = 2.66, p = 0.01$</td>
</tr>
<tr>
<td>UPPSa</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urgency</td>
<td>36.11 (5.80)</td>
<td>28.11 (5.41)</td>
<td>$t(18) = 4.58, p &lt; 0.00025$**</td>
</tr>
<tr>
<td>Premeditation</td>
<td>36.84 (7.65)</td>
<td>38.00 (6.22)</td>
<td>$t(18) = 0.49, p = 0.62$</td>
</tr>
<tr>
<td>Perseverance</td>
<td>34.05 (4.85)</td>
<td>36.84 (5.84)</td>
<td>$t(18) = 1.56, p = 0.07$</td>
</tr>
<tr>
<td>Sensation seeking</td>
<td>39.05 (8.25)</td>
<td>40.11 (7.69)</td>
<td>$t(18) = 0.51, p = 0.31$</td>
</tr>
</tbody>
</table>

CGT: Cambridge Gambling Task; DDP: Delay Discounting Paradigm; UPPS: UPPS Impulsive Behavior Scale.

*Significant at $p \leq 0.01$ (two-tailed).

* Adjusted $a$-error for post hoc comparisons.

** Significant at $p \leq 0.05$ (two-tailed).

*** Significant at $p \leq 0.00025$ (two-tailed).
3.2. Associations of decision-making parameters and impulsivity

3.2.1. Behaviorally assessed impulsivity

As reported in Table 3, the k-value of the DDP shows significant medium (p = −0.31) to large (p = 0.47) correlations with all parameters of the CGT, except for the deliberation time. This indicates that individuals showing steeper delay discounting show a higher average betting behavior, risk taking, delay aversion and chasing. Additionally, steeper delay discounting was associated with a lower proportion of rational choices and a poorer calibration of bets. The interaction of k-value and group in the regression analyses was significant for overall proportion bet and risk taking. Further analysis showed that the correlation was driven by the PGG (r = 0.51, p = 0.002; r = 0.53, p = 0.002) rather than the CG (r = −0.23, p = 0.26; r = 0.27, p = 0.18). This showed that there is a specific relation between delay discounting and the risk seeking component of decision-making in PGs whereas the other reported relations were group-unspecific.

3.2.2. Self-reported impulsivity

Urgency showed a significantly positive correlation with delay aversion and chasing of the CGT (Table 3). CGT overall proportion bet and risk-taking were significantly correlated with premeditation; the relationship was negative, indicating an increase in overall proportion bet and risk-taking with decreasing premeditation. Additionally deliberation time was significantly and positively correlated with perseverance. No other correlations did reach significance. There was no significant interaction of the UPPS dimensions and group with respect to the decision-making parameters. This result points to a group-unspecific relation between the two measures. Finally, the DDP showed significant positive correlations with urgency and significant negative correlations with premeditation (Table 3).

4. Discussion

In the current study, we investigated the specificity of impaired decision-making sub-components in PGs and the relation of these impairments to multidimensionally assessed impulsivity. Our results showed that PGs displayed specific impairments of decision-components which are presumably related to dominating reward- and valuation-systems tuned to immediate short-term rewards. This was further supported by the finding that heightened impulsivity was specifically related to these decision-making impairments.

4.1. Specificity of decision-making impairments in pathological gambling

According to recent models of neural systems and pathways involved in addiction and pathological gambling (Bechara, 2003, 2005; Evans and Coventry, 2006; Bühringer et al., 2008; Redish et al., 2008b; van Holst et al., 2010; Goldstein and Volkow, 2011), we had predicted specific impairments in the reward- and valuation-related components of decision-making, rather than in components related to strategic planning or reasoning. Supporting this assumption, we found evidence for increased risk seeking in PGs compared to the control group, as indicated by higher risk taking behavior. Unexpectedly, we did not find differences in the risk seeking parameters ‘overall proportion bet’ or ‘bankruptcies’ between PGs and the control group, even though there was a tendency that PGs placed higher bets in general. Further support for our hypothesis stems from the finding of a stronger focus on immediate rewards in PGs. In contrast, the performance of PGs did not differ with respect to parameters indicative for strategic planning behavior. Regarding etiological models the identification of decision-making impairments in pathological gambling

![Fig. 2. Subjective values of rewards delayed in time from 1 to 15 days. The median values are presented for the pathological gambling group (PGG, dark gray circles) and for the control group (CG, light gray circles). The lines represent the hyperbolic function when fit to the group median indifference points.](image)

Table 3

<table>
<thead>
<tr>
<th></th>
<th>DDP</th>
<th>UPPS</th>
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<tbody>
<tr>
<td></td>
<td>k-value*</td>
<td>r</td>
</tr>
<tr>
<td>Overall proportion bet</td>
<td>0.38* (0.10 to 0.65)</td>
<td>0.44* (0.13 to 0.74)</td>
</tr>
<tr>
<td>Risk taking</td>
<td>0.35 (0.09 to 0.65)</td>
<td>0.44 (−0.19 to −0.25)</td>
</tr>
<tr>
<td>Deliberation time</td>
<td>0.14 (−0.21 to 0.50)</td>
<td>0.03 (−0.31 to 0.31)</td>
</tr>
<tr>
<td>Freedom adjustment</td>
<td>0.37 (0.05 to 0.64)</td>
<td>0.28 (0.03 to 0.53)</td>
</tr>
<tr>
<td>Quality of decision-making</td>
<td>0.47 (0.22 to 0.72)</td>
<td>0.22 (0.17 to 0.69)</td>
</tr>
<tr>
<td>Urgency</td>
<td>0.13 (0.03 to 0.62)</td>
<td>0.03 (−0.31 to 0.31)</td>
</tr>
<tr>
<td>Premeditation</td>
<td>0.34 (−0.61 to −0.07)</td>
<td>0.16 (−0.53 to 0.15)</td>
</tr>
<tr>
<td>Perseverance</td>
<td>0.33 (−0.61 to −0.04)</td>
<td>0.14 (−0.53 to 0.25)</td>
</tr>
<tr>
<td>Sensation seeking</td>
<td>0.32 (−0.61 to −0.06)</td>
<td>0.17 (−0.53 to 0.19)</td>
</tr>
</tbody>
</table>

CGT: Cambridge Gambling Task; DDP: Delay Discounting Paradigm, UPPS: Impulsive Behavior Scale, r = Pearson product-moment correlation coefficient; CI: Confidence intervals.

* Correlation with those participants who showed discounting (n = 34).

* Significant at p ≤ 0.05 (two-tailed).

** Significant at p ≤ 0.01 (two-tailed).
of such specific dysfunctional components of decision-making contributes to a better understanding of possible underlying processes such as alterations in specific brain networks (Bechara, 2005; Bühringer et al., 2008, 2012; Redish et al., 2008a; van Holst et al., 2010; Goldstein and Volkow, 2011). Our results add further support to the assumption that dysfunctional decision-making in PGs is primarily related to an overactive motivational and valuation network as they showed increased risk seeking and an immediate reward focus. In contrast, the fact that we did not find differences in strategic planning suggests that reasoning or strategic planning were relatively intact. Interestingly, impairments in CGT-parameters of strategic planning were found in individuals with substance use disorders (Rogers et al., 1999; Lawrence et al., 2009). One explanation for this discrepancy may be that changes in dorsolateral PFC processes leading to impairments of executive and planning functions are a specific consequence of chronic substance use (Lawrence et al., 2009) or become visible only in very severe PGs (Clark, 2010). One might speculate that we recruited moderate PGs and thus observed only impairments in valuation and decision-making processes, whereas impairments of executive and planning functions may only be present in severe treatment-seeking PGs. Hence, it will be an important aim for future research to further elucidate specific patterns of decision-making impairments with regards to different mental disorders and to the disorder severity.

4.2. Associations of decision-making parameters and impulsivity in pathological gambling

As in previous studies, we found that PGs discount the subjective value of delayed rewards to a greater degree than control individuals (Petry and Casarella, 1999; Petry, 2001a; Alessi and Petry, 2003; Dixon et al., 2003; Holt et al., 2003; Mackillop et al., 2006; Billieux et al., 2012). Importantly, the impulsivity dimension delay discounting was positively associated with the impaired decision-making components risk seeking and the increased focus on immediate rewards. Our results further showed that the relation between delay discounting and risk seeking was entirely driven by the PGG and did not show up in control individuals. One possible explanation is that delay discounting is not related to risky decision-making per se, and that this relation is moderated or mediated by other factors such as control illusion, which are specifically present in PGs (Clark, 2010). Unexpectedly, delay discounting was also associated with strategic planning behavior, except for deliberation time. For example, individuals with high delay discounting show also less rational choices. One explanation may be that the DDP is not a pure measure of impulsivity in terms of devaluing of future events, but acquires also elements of strategic planning and reflection as indicated by the positive relation of delay discounting and working memory (Bickel et al., 2012).

As hypothesized, associations between the impaired decision-making components and higher urgency as well as less premeditation could be confirmed. The relations did not differ between the groups, which indicates that there is a general link between those sub-components. The findings accord with studies on the Iowa Gamble Task, which likewise showed that higher urgency and less premeditation are related to disadvantageous decision-making (Zermatten et al., 2005; Dolan et al., 2008; Xiao et al., 2009; Billieux et al., 2010). In contrast, there were no relations between urgency or premeditation and the strategic planning component of decision-making.

Our study is – to our best knowledge – the first to examine different sub-components of decision-making and impulsivity in order to analyze more specifically their interrelations in PGs and controls individuals. Our findings highlight the need for a multi-dimensional and multi-methodological approach regarding both constructs. For example, whereas laboratory measures may be effective in providing information of unconscious and highly automatic processes, self-report measures are useful to assess behaviors across various settings, like emotionally arousing situations, which cannot or only to a limited degree be investigated under laboratory conditions. Using this approach, our results illustrate that delay discounting, urgency and premeditation are specifically related to decision-making components in which PGs differ significantly from control individuals, namely risk-seeking and an immediate reward focus. This supports our hypotheses that higher impulsivity as well as impaired decision-making may result from the same alterations in reward- and valuation-related processes. However, the direction of causality remains unclear. One explanation may be, that changed reward processes result in disorder-specific alterations in trait urgency and premeditation which cause impaired decision-making (Rahman et al., 2001; Diekhof et al., 2008). A further possibility is that a common cause underlies both constructs, for instance a dysfunction of inhibitory control (Enticott and Ogloff, 2006; Gay et al., 2008). Finally, another model has been proposed that assumes a reverse causal relation: Poor inhibitory control may cause a tendency to make disadvantageous choices which, in turn, predicts high urgency resulting in problematic behaviors (Billieux et al., 2010). Prospective-longitudinal studies will be essential to delineate the causal relations. Moreover, the processes underlying and the pathways leading to pathological gambling may exhibit a high variability between individuals (Blaszczynski and Nower, 2002) and, consequently, vary according to the different impulsivity profiles of PGs (Billieux et al., 2012).

4.3. Limitations

A number of limitations that constrain the interpretation of our results should be mentioned. First, possible comorbid attention deficit hyperactivity disorder (ADHD) was assessed by verbal report only and Axis II disorders were not assessed at all. This may have had an influence on the behavioral findings, because both disorder groups are associated with impulse control and decision impairments (American Psychiatric Association, 2000). Second, there may be relevant effects of a life-time mental disorder in PGs, even though we did not detect significant differences in the amount of comorbid disorders. Especially the number of lifetime substance use disorder differed between the groups and might thus confound our results, e.g. due to neurological changes caused by excessive substance use. Third, subjects were sampled by convenience and the recruitment strategy was limited to newspaper, flyer and internet advertisement as well as postings on community boards. Therefore, confounding variables may have influenced our results and effect sizes may be smaller than in treatment-seeking PGs. However, this may considered an advantage regarding generalizability of our results, because only 2–7% of PGs are seeking treatment in a given year in Germany (Ludwig et al., 2013). Finally, we assumed in our power analysis a medium-to-large effect size on the basis of previous studies. However, some effects might have been smaller and may not have been detected with our sample size.

4.4. Implications and future research

Dysfunctional decision-making is a core characteristic of PGs (Cavedini et al., 2002; Bechara, 2003; Brand et al., 2005; Goudriaan et al., 2005). Nevertheless, possible underlying mechanisms and their interactions are not fully understood. Future research on etiological models may further focus the assessment of dissociable decision-making components, combining specific behavioral tasks
with neuroimaging methods to disentangle the complex decision process and the possible underlying mechanisms and neural systems in PCs. Particularly, tasks without a gambling-related context may be important to minimize confounding effects of cue-reactivity (Goudriaan et al., 2004).

To improve interventions, it is important to consider that separate underlying mechanisms of decision-making may be controlled by different brain mechanisms and benefit from distinct interventions (Robbins, 2000; Clark and Manes, 2004; Fellows and Farah, 2005). If urgency is an important core aspect involved in impaired decision-making of PCs, it would be indicated to put special emphasis on this component in treatment, for example, by helping the client to learn accepting and tolerating emotional distress without attempts to escape negative emotions by engaging in gambling. There are several treatment strategies that likewise emphasize acceptance of negative emotions in the context of behavior change (e.g. Acceptance and commitment therapy; Hayes et al., 1999). Regarding premeditation, psychotherapy interventions aimed at the enhancing behavior control strategies could be promising interventional strategies. Moreover, apart from consciously available aspects of impulsivity, training of more unconscious processes leading to impulsivity may be realized with the help of computer-aided neurocognitive trainings programs (Wiers et al., 2006; Houben et al., 2011; Wiers, 2011).

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References


