Dimensions and disorder specificity of impulsivity in pathological gambling

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HIGHLIGHTS

• We found four impulsivity-related dimensions with a comprehensive task battery.
• The corresponding impulsivity profile of pathological gambling (PG) was investigated.
• PG is related to an overall heightened impulsivity profile compared to healthy controls.
• The impulsivity profile of PG is similar to those of alcohol dependence.
• PG is related to higher ‘choice impulsivity’ compared to Gilles de la Tourette syndrome.

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ABSTRACT

Impulsivity is a core characteristic of pathological gambling (PG), even though the underlying structure and disorder specificity is unclear. This study aimed to explore different dimensions of impulsivity in a clinical sample including PG. Furthermore, we aimed to test which alterations of the impulsivity-related dimensions are disorder specific for PG. Participants were individuals diagnosed with PG (n = 51) and two groups also characterized by various impulsive behaviors: an alcohol dependence (AD; n = 45) and a Gilles de la Tourette syndrome (GTS; n = 49) group. A healthy control (HC; n = 53) group was recruited as comparison group. A comprehensive assessment was used including impulsivity-related and antipodal parameters of the Stop Signal Task, Stroop Task, Tower of London Task, Card Playing Task, Iowa Gambling Task and the Barratt Impulsiveness Scale-11. Principal axis factor analysis revealed four impulsivity-related dimensions that were labeled ‘self-reported impulsivity’, ‘prepotent response impulsivity’, ‘choice impulsivity’ and ‘motor impulsivity’. The PG group scored significantly higher on all four dimensions compared to the HC group. In contrast, the PG group did not differ on any of the dimensions from the AD or the GTS group, except for ‘choice impulsivity’ where the PG group exhibited higher factor scores compared to the GTS group. Altogether, PG is associated with generally heightened impulsivity profiles compared to a HC group, which may be further used for intervention strategies. However, heightened scores in the impulsivity dimensions are not disorder specific for PG. Further research on shared or different underlying mechanisms of these overlapping impulsivity impairments is necessary.

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1. Introduction

Over the past years, a substantial body of research has highlighted that impulsivity is an important etiological factor for pathological gambling (PG; e.g., Shenassa, Paradis, Dolan, Wilhelm, & Buka, 2012; Verdejo-Garcia, Lawrence, & Clark, 2008). Our study aimed to explore the multidimensional nature of impulsivity in a sample including PG and to elucidate which patterns of impulsivity-related alterations are disorder specific for PG.

The clinical as well as the neuropsychological picture PG has been characterized by increased impulsivity (American Psychiatric Association (APA), 2000, 2013; van Holst, van den Brink, Veltman, & Goudriaan, 2010b; Verdejo-Garcia et al., 2008). The construct can be broadly defined as the tendency to act rapidly upon stimuli or inner impulses.
that may result from a lack of adequate forethought and/or a reduced ability to inhibit prepotent or habitual responses (Evenden, 1999; Moeller, Barratt, Dougherty, Schmitz, & Swann, 2001). However, there has been an inconsistent conceptualization of impulsivity, possibly resulting from a remarkable diversity of (1) underlying causes (Bickel, Jarmolowicz, Mueller, Gatchalian, & McClure, 2012), (2) dimensions of the construct (Dick et al., 2010) and (3) resulting behavioral expressions as well as an unsystematic interrelation of those three levels (Enticott & Ogloff, 2006). Research on the construct level of impulsivity has shown its multidimensional nature (e.g., Broos et al., 2012; Ginley, Whelan, Meyers, Releya, & Pearlson, 2013; Moeller et al., 2001; Whiteside & Lyam, 2001) and confirmed that comparable impulsivity dimensions exist in healthy people and clinical groups (Meda et al., 2009). To apply this multidimensional approach of impulsivity in PG research would importantly increase knowledge on PG-specific patterns of impulsivity alterations (e.g., increased choice impulsivity) and help to clarify underlying processes (e.g., devaluation of future rewards; Bechara, 2003; Bühringer, Wittchen, Gottlebe, Kufeld, & Göschke, 2008; Redish, Jensen, & Johnson, 2008). Up to now, only one study showed differences of non-gamblers, low-risk gamblers and symptomatic gamblers (one or more PG criteria) in three impulsivity dimensions (Ginley et al., 2013). Unfortunately, PG was not diagnosed in this study, and the impulsivity dimensions that were used merely relied on self-reports which may not cover the full impulsivity spectrum (Broos et al., 2012; Enticott & Ogloff, 2006).

A multidimensional conceptualization of impulsivity further allows a comparison of patterns of impulsivity impairments between PG and other mental disorders. This is highly important since heightened impulsivity is a core characteristic of various other mental disorders than PG, including substance use disorders (SUDs) or neurodevelopmental disorders like attention deficit/hyperactivity disorder (ADHD) or Gilles de la Tourette syndrome (GTS) (e.g., Eddy, Rizzo, & Cavanna, 2009; Moeller et al., 2001; Rogers, Moeller, Swann, & Clark, 2010; Swann, Björk, Moeller, & Dougherty, 2002). Previous studies comparing impulsivity in PG with other mental disorders (e.g., Goudriaan, Oosterlaan, de Beurs, & van den Brink, 2005, 2006a; Kalechstein et al., 2007; Lawrence, Luty, Bogdan, Sahakian, & Clark, 2009a, 2009b; Leeman & Potenza, 2012) focused on the behavioral level of impulsivity where the construct is operationalized with task scores (Dick et al., 2010; Moeller et al., 2001). However, it would be advantageous to use factor scores when comparing PG with other mental disorders since a reduction of task-specific and error variance can be achieved (Aichert et al., 2012; Miyake & Shah, 1999), and clearer conclusions regarding differences on the causal level can be drawn.

Against this background, our first research question concerns the multidimensional nature of impulsivity in a sample including individuals with PG. We assumed to explore at least two impulsivity-related dimensions, including response impulsivity and choice impulsivity (according to, e.g., Bickel et al., 2012; Dalley, Everitt, & Robbins, 2011; Kim & Lee, 2011). Furthermore, it is important to study which impulsivity dimensions are specifically altered in PG to have a better insight in altered brain processes. For this second research question, we compared PG with healthy controls as well as with individuals with alcohol dependence (AD) or GTS. AD and GTS are important comparison groups for PG because both disorders have been shown to be associated with impulsive behaviors (e.g., Eddy et al., 2009; Rogers et al., 2010). We hypothesized that individuals with PG would score higher on all impulsivity-related dimensions compared to the healthy control group. Regarding disorder specificity, we assumed that there would be differences in choice impulsivity between the PG group and the AD and GTS groups since PG may be related to stronger disorder-specific alterations in the valuation and motivation-related brain systems (e.g., Goudriaan et al., 2005; Kräplin et al., 2014). From a clinical point of view, those patterns of impulsivity impairments would provide evidence for effective therapy supplements.

2. Methods

2.1. Participants and procedure

Four groups aged 18 to 60 years were investigated in the study: 51 individuals diagnosed with PG, 45 individuals diagnosed with AD and 49 individuals diagnosed with GTS and 53 healthy control (HC) individuals. Results regarding neurocognitive deficits in this sample have been published elsewhere (Goudriaan et al., 2005, 2006a; Goudriaan, Oosterlaan, de Beurs, & van den Brink, 2006b), where a detailed description of recruitment and screening procedures can be found. The sample used in this study largely overlaps with the early reported studies, although the numbers of participants differ slightly for reasons related to missing data for the factor analyses (see Section 2.3).

PG and AD were diagnosed according to DSM-IV (American Psychiatric Association (APA), 2000), and GTS was diagnosed by a psychiatrist or neurologist. We performed a group-based matching of the PG group and the AD, GTS and HC in terms of age, gender, and intelligence. Demographic characteristics for the four groups are presented in Table 1. Current nicotine dependence was assessed with the Fagerström Test for Nicotine Dependence (FTND; Heatherton, Kozlowski, Frecker, & Fagerström, 1991). Despite the attempt to match the groups and partly due to the exclusion of some participants with missing data, the groups differed significantly in age, gender and nicotine dependence. In order to prevent bias, we used those variables as covariates in the analyses. Exclusion criteria for all groups were other lifetime comorbid mental disorders than studied (including other SUDs, except for nicotine dependence). The three disorder groups were mutually exclusive with regard to the mental disorder under study. The study protocol was approved by the Medical Ethics Committee of the Academic Medical Centre of the University of Amsterdam.

2.2. Measures

2.2.1. Stop signal task

The stop signal task was modified by Scheres, Oosterlaan and Sergeant (2001). A total of six blocks with 64 trials were administered of which the first block was only used for training purposes, and not included in the statistical analysis. Participants were instructed to respond as fast as possible. In 75% of the trials, a ‘go’ signal occurred and in 25% of the trials a stop signal occurred at a variable delay (stop signal delay), which was calculated using an algorithm that resulted in a 50% successful inhibition rate. The dependent measure was the Stop Signal Reaction Time (SSRT), which was computed as the difference between mean reaction time on go trials and the averaged stop signal delay. A slower SSRT was suggested as an indicator of impaired response inhibition.

2.2.2. Stroop Task

The Stroop Task consisted of three cards, each with 100 items. Card 1 contained color words printed in black, card 2 contained rectangles printed in different colors and card 3 contained words printed in incongruent colors. Participants had to name the words (card 1) or the colors (cards 2 and 3) as fast as possible. The dependent variable of this task was the interference score calculated as the difference in the reading time between card 2 and card 3. Impaired response inhibition was indicated by a higher interference score.

2.2.3. Tower of London Task

It has been suggested that different dimensions of impulsivity have an antipode in executive functioning like planning, i.e., that both concepts are widely separated on a shared continuum and can be assessed with overlapping measurements (Bickel et al., 2012). Indeed, various studies suggest that performance in planning tasks like the Tower of London Task can be (partly) attributed to inhibition abilities (Baughman & Cooper, 2007; Mitchell & Poston, 2001; Miyake et al., 2000; Zook, Davalos, DeLoosh, & Davis, 2004). In this task, participants...
had to move colored balls on pegs from a start configuration to a given end configuration. Three points were given for the successful solution of an item on the first trial, two points for solutions on the second trial, and so on. In the applied version, three trials of two, three, four and five move problems were presented. The dependent variable was the sum of points earned on a total of 12 problems. Lower scores on the Tower of London Task were used to reflect impaired response inhibition in terms of a lower ability to inhibit the more automatic perceptual strategy in favor of counterintuitive goal conflict moves (e.g., Miyake et al., 2000).

2.2.4. Card Playing Task
This task was an adapted version of the Card Playing Task described by Newman, Patterson and Kosson (1987). Subjects had the possibility to play 100 cards on a computer screen and win or lose money according to the type of card. After each card, subjects had two choices: to play the next card or to quit. A medium number of cards were the best strategy to win a maximum amount of money. In contrast, a conservative or perseverative card selection strategy resulted in a suboptimal amount of money (see also Goudriaan et al., 2005). Therefore, the dependent measure of the Card Playing Task was the amount of money earned. Less money was thought to reflect impulsive choice in terms of immediate reward seeking and a lack of forethought.

2.2.5. Iowa Gamble Task
A computerized version of the Iowa Gamble Task (IGT) was used as described elsewhere (Bechara, Damasio, Damasio, & Lee, 1999). Participants had to choose one card from four available decks. Unknown to the subject, two decks were advantageous in the long run, whereas the two other decks were disadvantageous. The dependent measure was the number of cards picked from the advantageous decks minus the number of cards from the disadvantageous decks. Choosing more disadvantageous cards was suggested to reflect impulsive choice in terms of an over-valuation of immediate rewards and a lack of forethought (Bechara, 2004; Bechara, Dolan, & Hindes, 2002).

2.2.6. Barratt Impulsiveness Scale-11
To assess self-reported impulsivity, the Dutch version of the Barratt Impulsiveness Scale-11 (BIS-11; Patton, Stanford, & Barratt, 1995) was used. The 30 items form three subscales: Motor Impulsiveness, Attentional Impulsiveness, and Non-planning Impulsiveness. In the current study, Cronbach’s alpha of the full-scale score was .83 and varied between .60 (non-planning impulsiveness) and .84 (attentional impulsiveness) for the three subscales. The dependent measures were the sum scores on each of the three subscales. A higher score was indicative for higher self-reported impulsivity.

2.3. Data analysis
Missing data occurred not at random and were thus excluded from further analyses (n = 26 cases). All statistical analyses were conducted using Stata 12.1 (StataCorp., 2012). To improve interpretability, scores were reversed in that higher parameter values represent higher impulsivity. In the tables, unreversed scores are presented. To explore the underlying dimensions of different impulsivity-related measures, we used principal axis factor analysis (PFA; see, e.g., Fabrigar, Wegener, MacCallum, & Strahan, 1999). Promax rotation was used to allow the resulting dimensions to be correlated (kappa = 3, according Tatsaryn, Wood, & Gorsuch, 1999). This approach accounts for the assumption that impulsivity is one construct with different, but related, dimensions. Factor selection was conducted using the scree plot and parallel analysis (Horn, 1965). Parallel analysis is a Monte Carlo-based simulation method that compares the observed eigenvalues with those obtained from a random data set. A factor is retained if the eigenvalue increases the 95th percentile of eigenvalues derived from the random sample after 1000 replications.

After extracting the factors, individual factor scores were estimated using the regression method. For further analysis, we used the factor score of each participant since these values represent the common variance of the impulsivity-related parameters with less influence of task-specific and error variance. To test for disorder specificity of the dimensions, we used the factor scores in a regression analysis with dummy coding for groups. The PG group was the reference group in the regression analysis. Accordingly, negative beta values indicate a higher factor score in the PG group. We used age, gender as well as FTND scores as covariates in the regression model since there were significant differences in these variables (see Table 1). Standardized group differences were presented to emphasize disorder-specific impulsivity patterns of PGs and their effect sizes.

3. Results
3.1. Multidimensionality of impulsivity
Descriptive data of means and standard deviations for all impulsivity measures are presented separately for the PG, AD, GTS and HC groups in Table 2. Concerning the adequateness of the sample for principal axis factor analysis, a Kaiser–Meyer–Olkin (K-M-O) coefficient of 0.64 (moderate according Kaiser & Rice, 1974) and a significant Bartlett Test indicated appropriate inter-correlation of data. The scree plot of the PFA and the parallel analysis yielded a four-factor solution (Fig. 1).

We named the first factor ‘self-reported impulsivity’, where loadings were highest for the three BIS-11 scales (see Table 3). The second factor, which involves the Stroop Task and the Tower of London Task, was labeled ‘prepotent response impulsivity’ since both tasks assess the ability to deliberately suppress a prepotent response (word reading or using a perceptual strategy, respectively) in favor of an instructed response (color reading or using goal-conflicting moves, respectively) (Friedman & Miyake, 2004; Miyake et al., 2000). High factor scores indicate a lower ability to inhibit prepotent responses. The Iowa Gambling Task and the Card Playing Task loaded on the third factor. As both tasks assess the tendency to select cards according to immediate rewards rather than according to forethought or planning strategies, we labeled the factor ‘choice impulsivity’ (Kim & Lee, 2011). The Stop Signal Task loaded specifically on the fourth factor. We named this factor ‘motor impulsivity’ since the SSRT is indicative for the ability to inhibit
impulsivity is a multidimensional construct and (2) that PG is associated with an overall heightened impulsivity profile which has no PG-specific characteristics compared to other mental disorders.

In the current study, a comprehensive assessment of impulsivity-related as well as antipodal (executive function) parameters was used to account for the various aspects of the broad impulsivity construct (e.g., Bickel et al., 2012; Dalley et al., 2011) and to assess possible patterns of impulsivity impairments in PG. Our factor analytic approach revealed the following impulsivity-related dimensions: ‘self-reported impulsivity’, ‘prepotent response impulsivity’, ‘choice impulsivity’ and ‘motor impulsivity’. This confirms the multidimensional conceptualization of the impulsivity construct highlighted in previous studies (Broos et al., 2012; Moeller et al., 2001; Reynolds, Ortengren, Richards, & Wit, 2006; Verdejo-Garcia et al., 2008). However, it is important to recognize that our separate factor for self-reported impulsivity may be supposed as artificial method factor (Reynolds, Penfold, & Patak, 2008), which is not indicative for specific causes of impulsivity like dysfunctional inhibition processes. From the self-report dimension, it can rather be concluded that healthy controls and PG may differ in (1) specific aspects of impulsivity which are not incorporated in behavioral tasks like social desirability or self-reflection (Broos et al., 2012; Enticott & Ogloff, 2006; Moeller et al., 2001) or (2) trait impulsivity capturing broader situational and behavioral aspects of the construct (Dick et al., 2010; Mitchell, 2004). Future studies may use additional self-report instruments to assess a broader range of this dimension including, e.g., reward and punishment sensitivity (Ginley et al., 2013; Meda et al., 2009) or a motor response during its already initiated execution (Aichert et al., 2012). A high factor value suggested a low ability to inhibit motor action.

3.2. Specificity of impulsivity-related alterations in pathological gambling

According to the global F-test and using age, gender and nicotine dependence as covariates, all four factors differed significantly between the groups (Table 4). Results of the pairwise group comparisons with age, gender and nicotine dependence as covariates indicated that all factors differed significantly between the PG and the HC group. The highest effect size was observed for self-reported impulsivity (standardized beta = −0.84). Furthermore, the regression analyses showed no significant disorder-specific group differences in the impulsivity-related dimensions between the PG and AD groups. The PG and GTS groups differed significantly on ‘choice impulsivity’, where the PG group scored higher than subjects with GTS (standardized beta = −0.25). Other group differences were not significant.

4. Discussion

4.1. General discussion

Previous research on the role of impulsivity and its disorder specificity in PG has hardly studied the multidimensional construct level. Our findings yield (1) that further support from a clinical sample that

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Table 2

Means and standard deviations (SD) of the dependent impulsivity variables for the pathological gambling (PG), the alcohol dependent (AD), the Gilles de la Tourette syndrome (GTS) and the healthy control (HC) groups.

<table>
<thead>
<tr>
<th></th>
<th>PG group Mean</th>
<th>SD</th>
<th>AD group Mean</th>
<th>SD</th>
<th>GTS group Mean</th>
<th>SD</th>
<th>HC group Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stop Signal Task</td>
<td>140.03</td>
<td>58.34</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stop signal reaction time</td>
<td>31.41</td>
<td>15.53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tower of London</td>
<td>33.24</td>
<td>2.54</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sum of earned points</td>
<td>0.02</td>
<td>31.57</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iowa Gambling Task</td>
<td>9.63</td>
<td>5.10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Card Playing Task</td>
<td>17.73</td>
<td>4.24</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Money earned</td>
<td>23.35</td>
<td>3.72</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motor sum score</td>
<td>26.04</td>
<td>3.93</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 1. Scree plot of eigenvalues of the principal axis factor analysis compared to the 95th percentile of eigenvalues from the parallel analysis with a random data matrix of the same sample size as in the original sample (N = 149) and 1000 replications.

Table 3

Principal axis factor analysis yielded four rotated components (N = 149). The eigenvalues, the explained variance and the factor loadings of the impulsivity measures after Promax rotation (Kappa = 3) were presented. Bold indicates the highest factor loading of each task.

<table>
<thead>
<tr>
<th>Rotated Components</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eigenvalue</td>
<td>2.18</td>
<td>1.22</td>
<td>1.16</td>
<td>1.04</td>
</tr>
<tr>
<td>Variance</td>
<td>27.26%</td>
<td>15.21%</td>
<td>14.44%</td>
<td>12.95%</td>
</tr>
<tr>
<td>Stop Signal Task</td>
<td>−0.03</td>
<td>−0.04</td>
<td>0.04</td>
<td>0.39</td>
</tr>
<tr>
<td>Stroop Task</td>
<td>0.01</td>
<td>0.40</td>
<td>−0.03</td>
<td>0.08</td>
</tr>
<tr>
<td>Tower of London task</td>
<td>0.00</td>
<td>0.43</td>
<td>0.05</td>
<td>−0.10</td>
</tr>
<tr>
<td>Iowa Gambling Task</td>
<td>−0.01</td>
<td>0.05</td>
<td>0.41</td>
<td>0.10</td>
</tr>
<tr>
<td>Card Playing Task</td>
<td>0.06</td>
<td>−0.05</td>
<td>0.35</td>
<td>−0.12</td>
</tr>
<tr>
<td>BIS-11 attention impulsivity</td>
<td>0.50</td>
<td>0.03</td>
<td>0.01</td>
<td>0.14</td>
</tr>
<tr>
<td>BIS-11 motor impulsivity</td>
<td>0.75</td>
<td>−0.03</td>
<td>−0.09</td>
<td>−0.04</td>
</tr>
<tr>
<td>BIS-11 non-planning impulsivity</td>
<td>0.72</td>
<td>0.01</td>
<td>0.10</td>
<td>−0.03</td>
</tr>
</tbody>
</table>

The highest factor loadings are marked in bold.
Table 4

Results of the regression analysis with the global test (F-Test and p-value) for differences in the four impulsivity factors over the four groups with age, gender and nicotine dependence (score in the Fagerström Test for Nicotine Dependence) as control variables and the single comparisons (standardized beta coefficient and p-value) for the pathological gambling (PG) group as reference compared with the alcohol dependent (AD), the Gilles de la Tourette syndrome (GTS) and the healthy control (HC) groups. Bold indicates significant values at the 0.05 level.

<table>
<thead>
<tr>
<th>Factors</th>
<th>Global Test</th>
<th>Single comparison</th>
<th>Single comparison</th>
<th>Single comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F-value</td>
<td>p-value</td>
<td>Beta</td>
<td>p-value</td>
</tr>
<tr>
<td>Self-reported impulsivity</td>
<td>8.31</td>
<td>&lt;0.001</td>
<td>-0.16</td>
<td>0.415</td>
</tr>
<tr>
<td>Prepotent response impulsivity</td>
<td>5.15</td>
<td>0.002</td>
<td>0.05</td>
<td>0.740</td>
</tr>
<tr>
<td>Choice impulsivity</td>
<td>3.78</td>
<td>0.012</td>
<td>-0.19</td>
<td>0.186</td>
</tr>
<tr>
<td>Motor impulsivity</td>
<td>10.42</td>
<td>&lt;0.001</td>
<td>0.11</td>
<td>0.342</td>
</tr>
</tbody>
</table>

4.2. Limitations

Several limitations regarding this study should be noted. First, our results may suffer from a reduced generalizability due to the fact that the PG group consisted of treatment seeking participants. Second, we used different tasks, which are not typically considered to measure impulsivity like the Tower of London Task. However, it has been suggested that impulsivity and executive functions are conceptual antipodes with overlapping measures (Bickel et al., 2012). Furthermore, previous research has shown that inhibition is an important underlying process of the Stroop Task and the Tower of London Task (Baugham & Cooper, 2007; Mitchell & Poston, 2001; Miyake et al., 2000; Nigg, 2000; Zook et al., 2004). Third, the K-M-O coefficient indicated that data were moderately adequate for factor analysis, what could also be seen in the moderate factor loadings. Last, the factors were detected using four different groups. Due to the sample size, it could not be tested whether the factor structure would be invariant across all four groups.

4.3. Conclusion

Our results indicate that all four impulsivity-related dimensions differentiate PG from healthy controls, but they also show that impulsivity represents a general underlying characteristic of different mental disorders, including AD and GTS. Additional research is needed to clarify the specific and shared role of cognitive deficits in prepotent response impulsivity, motor impulsivity and choice impulsivity in different psychiatric disorders, e.g., prefrontal brain damages resulting from the neurotoxic effects of substances like alcohol (Sullivan, 2003) or shared pre-existing cognitive control deficits in addictive behaviors, including PG (Goschke, 2014). Furthermore, intervention strategies could be matched according to specific causes. For example, if impulsive behaviors result from a maladaptive valuation of immediate and future rewards, PG could profit from therapy supplements that enhance the maladaptive valuation of immediate and future rewards (e.g., Advisor-Teller Money Manager; Black & Rosen, 2011) or from interventions that provide more immediate and frequent reinforcement, such as contingency management (Petry, 2000). If impulsivity is attributable to inhibitory control deficits, other strategies like training of automatic behavior (Wiers, Gladwin, Hofmann, Salemink, & Ridderinkhof, 2013) or pharmacotherapy that improves inhibitory control may be more useful (Bechara et al., 1999).

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Contributors

Author Anja Kräplin conceptualized the study, conducted literature search, analyzed the data and wrote the first draft of the manuscript. Author Gerhard Bühringer supervised the draft writing. Author Anna E. Goudriaan provided the data set and supervised the data analysis and the draft writing. Authors Gerhard Bühringer, Jaap Oosterlaan, Wim van den Brink, Thomas Goschke and Anna E. Goudriaan contributed to and have approved the final manuscript.

Conflict of interest

Authors Anja Kräplin, Jaap Oosterlaan, Wim van den Brink and Thomas Goschke declare to have no conflict of interest. Gerhard Bühringer has received unrestricted research grants from the Bavarian State Ministry of Finance (regulatory authority for and operator of the state gaming monopoly) via the Bavarian State Ministry of the Environment and Public Health, the German Federal Ministry of Economics and Technology (regulatory authority for the commercial gaming industry) and from the commercial gaming industry. Anna E. Goudriaan is supported by a VIDI research innovation grant (NWO-ZONMw grant ID: 91713354).

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