Disadvantageous decision-making in borderline personality disorder: Partial support from a meta-analytic review

Christian Paret\textsuperscript{a*}, Christine Jennen-Steinmetz\textsuperscript{b}, Christian Schmahl\textsuperscript{a}

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\textsuperscript{a} Department of Psychosomatic Medicine and Psychotherapy, Central Institute of Mental Health Mannheim, Medical Faculty Mannheim / Heidelberg University, Germany

\textsuperscript{b} Department of Biostatistics, Central Institute of Mental Health Mannheim, Medical Faculty Mannheim / Heidelberg University, Germany

* corresponding author, mailing address: Central Institute of Mental Health, J5, D-68159 Mannheim, Germany, email: christian.paret@zi-mannheim.de
Abstract

To achieve long-term goals, organisms evaluate outcomes and expected consequences of their behaviors. Unfavorable decisions maintain many symptoms of borderline personality disorder (BPD); therefore, a better understanding of the mechanisms underlying decision-making in BPD is needed. In this review, the current literature comparing decision-making in patients with BPD versus healthy controls is analyzed.

Twenty-eight empirical studies were identified through a structured literature search. The effect sizes from studies applying comparable experimental tasks were analyzed.

It was found that 1) BPD patients discounted delayed rewards more strongly; 2) reversal learning was not significantly altered in BPD; and 3) BPD patients achieved lower net gains in the Iowa Gambling Task (IGT). Current psychotropic medication, sex and differences in age between the patient and control group moderated the IGT outcome. Altered decision-making in a variety of other tasks was supported by a qualitative review.

In summary, current evidence supports the altered valuation of outcomes in BPD. A multifaceted influence on decision-making and adaptive learning is reflected in this literature.

Keywords:
Decision-Making; Borderline Personality Disorder; Delay Discounting; Reversal Learning; Gambling Task; Psychopathology; Reinforcement Learning; Value; Reward; Punishment; Emotion Regulation; Cognitive Flexibility; Impulsivity; Ventromedial Prefrontal Cortex; Orbitofrontal; Meta-analysis
Abbreviations:

1 Introduction

For the clinician, it is clear that patients with Borderline Personality Disorder (BPD) are prone to disadvantageous decision-making. They tend to engage in impulsive behavior without regarding adverse long-term consequences. For example, patients injure themselves to alleviate stress, show suicidal tendencies, and engage in abusive relationships to avoid abandonment. Consequences are often devastating and contribute to frequent crises, and this entails further medical and psychosocial treatments. A detailed analysis of decision-making in BPD could improve understanding the causes for disregard of adverse consequences and help to improve psychiatric treatment.

Decisions are ubiquitous in daily life and “commit the organism to one out of several possible behaviors” (Pearson, Watson, & Platt, 2014, p. 950). Behavior is guided by the subjective value of outcomes and expectations about future reinforcement (i.e., reward and punishment). They let us flexibly choose between multiple options.

In a recent meta-analysis, Unoka & Richman (2016) report impaired decision-making in BPD. Though several measures of executive functioning were analyzed, only two studies were classified to assess decision-making. In this paper, we offer a more comprehensive and in-depth literature analysis based on the neuropsychological foundations of decision-making. Individuals take into account the motivational value and probability of expected gains and losses in their decisions (Kahneman & Tversky, 1979). In order to maximize outcomes, they weigh the options in hand according to the subjective value they attribute to each of these options. This conceptualization applies to situations that require subjects to select between options associated with different values and different probabilities of receiving rewards or punishments. Thus, processes such as delay discounting and reinforcement learning, as well as decisions under risk and ambiguity are fundamental for the study of decision-making (Pearson et al., 2014).
In contrast to other reviews on executive functions (e.g. (Ruocco, 2005; Unoka & Richman, 2016)), we focus on neuropsychological studies using tasks that are consistent with the aforementioned conceptualization of decision-making. Other processes relevant for daily life decision-making but not fitting to the framework (e.g. response inhibition or planning assessed with the Tower-of-London task) are not addressed here. For conciseness, social and moral decision-making are not addressed either.

Neuroimaging work provides profound evidence for involvement of the ventromedial prefrontal cortex (vmPFC) and orbitofrontal cortex (OFC) in risky choices (Christakou, Brammer, Giampietro, & Rubia, 2009; Hartstra, Oldenburg, Van Leijenhorst, Rombouts, & Crone, 2010; N. S. Lawrence, Jollant, O’Daly, Zelaya, & Phillips, 2009; Li, Lu, D’Argembeau, Ng, & Bechara, 2010), reversal learning (Budhani, Marsh, Pine, & Blair, 2007; Gläscher, Hampton, & O’Doherty, 2009; Greening, Finger, & Mitchell, 2011; Hampshire, Chaudhry, Owen, & Roberts, 2012; Hampton, Bossaerts, & O’Doherty, 2006; O’Doherty, Critchley, Deichmann, & Dolan, 2003; Remijnse, Nielen, Uylings, & Veltman, 2005) and temporal delay discounting (Scheres, de Water, & Mies, 2013). Neurological patients with vmPFC/OFC lesions show marked deficits in these tasks (Bechara, Damasio, Damasio, & Anderson, 1994; Rolls, Hornak, Wade, & McGrath, 1994; Sellitto, Ciaramelli, & di Pellegrino, 2010; Tsuchida, Doll, & Fellows, 2010; for a review see Zald & Andreotti, 2010). To summarize, vmPFC and OFC activations represent the learning history of rewards and punishments, task rules and the immediacy of expected reward delivery. Further, they are involved in the computation of the subjective value of outcomes; comprising both actually received and expected rewards and punishments (Bartra, McGuire, & Kable, 2013).
Patients with vmPFC/OFC lesions are impaired in emotion regulation and frequently show social disturbances (Damasio, Grabowski, Frank, Galaburda, & Damasio, 1994) or display increased emotional reactivity and deficits in several real-life competencies, such as social appropriateness (Anderson, Barrash, Bechara, & Tranel, 2006). Hence, we hypothesize that vmPFC/OFC malfunction is implicated in BPD. This is supported by several studies applying brain volumetry analyses and reported differences in grey matter volume in BPD patients versus healthy controls (Bertsch et al., 2013; Brunner et al., 2010; Chanen et al., 2008; de Araujo Filho et al., 2014; Rossi et al., 2013; Sato et al., 2012; Tebartz van Elst et al., 2003) and in BPD patients versus other clinical populations (Bertsch et al., 2013; Richter et al., 2014). In a recent meta-analysis, Schulze, Schmahl & Niedtfeld (2016) found reduced grey matter volume in the vmPFC and OFC (Brodman areas 10 and 11) of patients with BPD. Therefore, studies using tasks that are sensible for vmPFC/OFC impairment could contribute to the understanding of some of the psychopathological mechanisms involved in BPD.

Here, we aim to provide a meta-analysis of studies that compared patients with BPD to non-patient control participants (further referred to as ‘controls’) in decision-making tasks. Patients with BPD were expected to have worse outcomes (e.g. less reward, more punishment or less net gains) than controls. The literature search was guided by an a priori scheme of relevant neuropsychological functions involving subjective value processing, i.e. delay discounting (reflecting a form of impulsive decision-making, see e.g. Krause-Utz et al., 2016), reinforcement reversal learning/model-based learning and risky-choice behavior. The latter is usually assessed with experimental gambling tasks.

After the literature search, eligible studies were assigned to four categories useful for further analyses: (A) temporal delay discounting (TDD), (B) reversal learning tasks (REV), (C) Iowa Gambling Task (IGT) and (D) other decision-making tasks
(ODT). These are briefly described in Table 1. Categorization reduces complexity and makes the results tangible for statistical meta-analysis. However, cognitive processes associated with the task categories partly overlap. Most importantly with regard to this review, all tasks involve the subjective valuation of (expected) outcomes to maximize gains and minimize losses. Moreover, basic processes like working memory and sustained attention are involved that may contribute to differences in performance for patients with BPD (Hagenhoff et al., 2013; Ruocco, 2005; Unoka & Richman, 2016). Furthermore it should be emphasized, that the IGT is a complex cognitive task involving reversal learning of stimulus-outcome relations (Fellows & Farah, 2005).

In addition to summarizing findings on general group differences, we performed a moderator analysis to explore the impact of study characteristics on group effects. Moderators of interest were the matching of samples for sociodemographic data, psychotropic medication at time of testing, sex and psychiatric comorbidity.
<table>
<thead>
<tr>
<th>Task</th>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temporal delay discounting tasks</td>
<td>TDD</td>
<td>Organisms have a tendency to de-value delayed rewards compared to immediate rewards. Thus, they may favor a lower but immediate reward over a higher though temporally delayed reward.</td>
</tr>
<tr>
<td>Reversal learning tasks</td>
<td>REV</td>
<td>In REV, subjects are repeatedly presented with two stimuli. Selection of one stimulus is more often rewarded with an incentive than selection of the other stimulus. Sometimes associations reverse and the other stimulus has a higher reward probability. REV is sensitive for how well subjects track changes in response-reward and response-punishment relationships.</td>
</tr>
<tr>
<td>The Iowa Gambling Task</td>
<td>IGT</td>
<td>In the IGT, subjects are presented with four card decks. By drawing cards from each of the decks, they can win and lose money. Two decks are advantageous: when preferentially drawing from these, subject’s gains will out-level losses over the course of the experiment. In contrast, the other decks are disadvantageous and repeated selection will lead to overall losses. Subjects need to consider the history of winning and losing in the IGT to perform well.</td>
</tr>
<tr>
<td>Other decision making tasks</td>
<td>ODT</td>
<td>Tasks that fit the inclusion criteria but are not suitable for one of the above categories are summarized here.</td>
</tr>
</tbody>
</table>

Table 1. Categorization of decision-making tasks for this review.

## 2 Methods

### 2.1 Study selection procedure

Titles were searched in PubMed, Web of Science, PsycINFO and PSYINDEX databases to include the search term “Borderline Personality Disorder” and at least one of the terms “Decision Making”, “Reversal*”, “Gambling Task”, “Temporal
Discounting”, “Delay Discounting”, “Deferred Gratification”, “Delayed Gratification”, “Intertemporal Preference” or “Model Based**”. An initial search was performed in December 2015 and a final one on 24 June 2016 to retrieve papers published in the interim. Titles and abstracts were screened using the covidence website tool by two reviewers (C.P. and S.M.). Additionally, references of the articles finally included in the review were screened for other relevant publications. Records were complemented by other relevant studies from the authors’ library when they were not found in the literature search. To identify unpublished studies, online conference abstracts (from the ESSPD, ISSPD, SOBP, ACNP, DGPPN, and APA conferences) from the last five years were screened and experts from the field were contacted about ongoing or unpublished studies. No additional studies were found to be eligible with this approach.

For inclusion, studies needed to report results from a decision-making task and include a patient group diagnosed with BPD according to ICD or DSM criteria. They include a control group without a current psychiatric diagnosis. The selection procedure of studies is outlined in Figure 1.

2.2 Coding

The sample sizes, group means and standard deviations were coded to compute between-group effect sizes for each eligible study. If not available, the effect sizes were calculated based on the reported test statistics or effects. Negative effects were coded, when BPD patients made more disadvantageous decisions (in TDD: showed increased discounting of delayed rewards) versus controls. Matching of experimental groups was coded for age, sex, socioeconomic status (SES; years of education or highest educational qualification achieved) and intelligence (IQ; result from intelligence test).
Most studies either reported SES or IQ, and variables were combined in one parameter (SES/IQ; see supplementary material S1 for additional information on coding). Matching was assumed if a statistical test of the group mean difference did not show a statistical trend (p>0.1). If one or more patients received psychotropic medication at the time of testing, then medication was coded true (‘1’), otherwise false (‘0’). Age was coded as the mean age of both groups. The mean female-to-male ratio of both groups was coded (variable: sex; sex>0.5 indexes more female than male participants). Current substance use, current depression, lifetime psychosis and current eating disorder (current or lifetime) was coded.

2.3 Statistical analysis

For meta-analysis, we used Cohen’s $d$ as the effect size measure and computed Hedges’ $g$ adjusted for bias. According to Cohen’s classification, $d=0.2$ is a small effect, $d=0.5$ is a medium effect and $d=0.8$ is a large effect. Effect sizes were weighted by inverse squared standard errors and congregated in fixed-effects analyses (Lipsey & Wilson, 2000; Wilson, 2005) for each task category. This resulted in three separate analyses. Heterogeneity of effect sizes was estimated with the Q-statistic. In case of significance, the null-hypothesis of homogeneity was rejected and the influence of moderators was assessed with ANOVA and regression models (Wilson, 2005). Moderator analyses were conducted separately with each parameter introduced in the coding section, as far as there were sufficient cases for statistical comparison.

Statistical analyses were conducted with SPSS version 23 (IBM Corp. Armonk, NY). Statistical significance was defined at the 0.05 level.
3 Results

3.1 Sample description

For descriptive data of eligible studies see Table 2.

<table>
<thead>
<tr>
<th>number of studies (k)</th>
<th>TDD</th>
<th>REV</th>
<th>IGT</th>
<th>ODT</th>
</tr>
</thead>
<tbody>
<tr>
<td>age</td>
<td>30.7±4.9</td>
<td>31.4±4.7</td>
<td>30.5±4.3</td>
<td>30.3±2.6</td>
</tr>
<tr>
<td>sex¹</td>
<td>0.85±0.12</td>
<td>0.86±0.13</td>
<td>0.85±0.17</td>
<td>0.84±0.16</td>
</tr>
<tr>
<td>n BPD</td>
<td>233</td>
<td>69</td>
<td>350</td>
<td>150</td>
</tr>
<tr>
<td>n controls</td>
<td>252</td>
<td>84</td>
<td>325</td>
<td>164</td>
</tr>
<tr>
<td>age matched²</td>
<td>5/6</td>
<td>3/4</td>
<td>6/8</td>
<td>7/7</td>
</tr>
<tr>
<td>sex matched²</td>
<td>5/6</td>
<td>2/3</td>
<td>8/8</td>
<td>7/7</td>
</tr>
<tr>
<td>SES/IQ matched²</td>
<td>5/6</td>
<td>2/3</td>
<td>3/8</td>
<td>6/6</td>
</tr>
<tr>
<td>medication³</td>
<td>2/4</td>
<td>3/4</td>
<td>4/7</td>
<td>6/7</td>
</tr>
<tr>
<td>cSUD⁴</td>
<td>1/6</td>
<td>0/4</td>
<td>0/9</td>
<td>2/6</td>
</tr>
<tr>
<td>cDep⁴</td>
<td>2/3</td>
<td>1/4</td>
<td>0/6</td>
<td>2/5</td>
</tr>
<tr>
<td>lPsych⁴</td>
<td>0/4</td>
<td>1/3</td>
<td>0/8</td>
<td>0/6</td>
</tr>
<tr>
<td>ED⁴</td>
<td>2/2</td>
<td>3/3</td>
<td>4/5</td>
<td>5/5</td>
</tr>
</tbody>
</table>

Table 2. Sociodemographic and clinical sample characteristics of eligible studies (mean±SD). The ¹ female-to-male ratio (values >0.5 indicate more females than males). Number of studies with group differences (p<0.1) / number of studies providing sufficient information for statistical group comparison of age. ² Number of studies with n>0 patients on psychotropic medication at time of testing / number of studies reporting on medication status of BPD group. ³ Number of studies with n>0 patients on psychotropic medication at time of testing / number of studies providing information on medication status of BPD group. ⁴ Number of studies with n>0 patients with comorbid diagnosis / number of studies providing information on comorbid diagnoses in BPD group. SES=socioeconomic status, cSUD=current substance use disorder diagnosis, cDEP=current depression diagnosis, lPsych=lifetime psychosis, and ED=eating disorder diagnosis.
The ODT category comprised seven studies and each study applied another task. Combining outcomes from different tasks can obscure important differences in study characteristics. Therefore, we refrained from combining results in a statistical analysis and rather present the findings in a qualitative review.

3.2 Meta-analysis

All three meta-analytic comparisons found negative effects suggesting disadvantageous decision-making in patients with BPD versus controls. A medium effect was found in TDD indicating steeper discount functions of delayed rewards in BPD patients versus controls (Figure 2; $d=-0.55$, [-0.73, -0.37] (95%-confidence interval), $p<0.001$, $k=6$, where ‘k’ denotes the number of cases). That is, patients were increasingly willing to accept immediate but smaller fictitious money offers rather than wait longer to receive a larger amount. Patients were not significantly impaired in reversal learning (Figure 3; $d=-0.28$, [-0.60, 0.04], $p=0.086$, $k=4$). The patients made more disadvantageous decisions in the
IGT compared to controls as seen in a small-to-medium effect (d=\-0.32, [-0.47, -0.16], p=0.001, k=9).

Significant heterogeneity of effects between studies was found in the IGT (Q=18.15, df=8, p<0.05) suggesting potential moderator effects. Heterogeneity was not supported by the statistic in TDD and REV.

A moderator analysis of effect sizes was conducted for sex composition, age matching, SES/IQ matching, current medication intake and comorbidity with ED in the IGT. In regression analysis, we assessed the influence of sex composition on IGT performance. The model was significant (Q=5.25, df=1, p<0.05, R²=0.40, k=8) and demonstrated more disadvantageous decisions in samples with a higher proportion of female participants (beta=-0.63, [-1.64, -0.13]). In addition, we found age-matching to significantly moderate group differences in the IGT (Q_{between}=7.55, df=1, p<0.01). Studies with age-matched groups showed more disadvantageous decisions in patients versus controls (d=-0.57, [-0.79, -0.35], p<0.001, k=6); studies investigating patients older than controls did not yield significant differences (d=-0.12, [-0.35, 0.10], p=0.28, k=2). Heterogeneity within the subgroups was not significant (Q_{within}=5.56, df=6,
The SES/IQ was not a significant moderator of group effects ($Q_{between}=0.04$, df=1, $p=0.85$). Further, medication was related to effect size differences in the IGT ($Q_{between}=13.37$, df=1, $p<0.001$). Studies including patients who were medicated at the time of testing showed a medium-to-large effect ($d=-0.68$, [-0.96, -0.41], $p<0.001$, $k=4$), while studies with exclusion of medicated patients did not show group differences on average ($d=-0.03$, [-0.25, 0.19], $p=0.82$, $k=3$). Heterogeneity within subgroups was not significant ($Q_{within}=3.67$, df=5, $p=0.60$). Finally, comorbidity with ED did not moderate group differences ($Q_{between}=0.71$, df=1, $p=0.40$).

Visual inspection of funnel plots did not indicate gross deviations from symmetry of effect sizes (Figure S2, Supplementary Material). This would be an indication of publication bias. Conclusions on asymmetry are limited due to the small sample sizes in each of the analyses.

### 3.3 Other decision-making tasks: summary of findings

In the ODT category, we summarized studies that applied tasks differing in dimensions of outcome valence (i.e., prospective rewards and punishments) and instructions of reinforcement probability (i.e., explicit vs. implicit). Because they tap into different aspects of decision-making, they were not combined in statistical analysis. We found five studies investigating the influence of knowledge on probabilities of winning and losing on the patient’s choices. In these tasks, subjects select between options. Some are more advantageous (‘safe’ options) than others (‘risky’ options). Risky options are associated with a larger probability of losing or not winning money; on the other hand, they promise large gains, though with lower probability compared to safe options. To maximize outcomes, subjects need to consider both the amount of
money they could win and the probability of winning. In contrast to the IGT, where subjects need to learn probabilities by trial and error, subjects are explicitly informed about the probability of winning (or losing) on each trial.

Patients with BPD were less sensitive to potential losses (Sánchez-Navarro, Weller, López-Navarro, Martínez-Selva, & Bechara, 2014; Saunders, Goodwin, & Rogers, 2015) and made more risky decisions (Bazanis et al., 2002; Sánchez-Navarro et al., 2014; Svaldi, Philipsen, & Matthies, 2012). In probability discounting, Barker et al. (2015) observed BPD patients to prefer smaller, though guaranteed, rewards in comparison to controls. Although patients achieved lower net gains versus controls, the latter finding supports rather increased risk aversion than risk seeking in this type of task.

In two other tasks, subjects needed to repeatedly choose between a large (25) and a small (5) number of points (Andreou et al., 2015; Vega et al., 2013). After selection, they received feedback whether they had won or lost points. Both outcomes had equal probabilities implicit to participants. The results were ambiguous; one study found that patients preferred selection of the higher number (Andreou et al., 2015) the other did not (Vega et al., 2013). However, the latter study found controls but not patients adjusted choices based on feedback.

In general, sample matching was high quality, but influences from medication and comorbid diagnosis are difficult to assess (see Table 2 for sample information).

4 Discussion

The subjective value we assign to expected outcomes is crucial for our daily life decisions. Thus, altered valuation and decision-making is of large significance for
health and well-being and may have detrimental consequences for the lives of patients diagnosed with BPD. This meta-analysis of the current literature offers significant evidence for altered subjective valuation of expected outcomes in BPD. This became particularly evident in the increased preference of immediate over delayed rewards. In contrast, current evidence does not clearly link impaired adaptive learning to BPD. While reversal learning was not found significantly altered, patients tended to make more disadvantageous choices in the IGT. Moderator analyses of the IGT suggested that other factors than a BPD diagnosis might matter. Indeed, recent evidence has already demonstrated intact IGT learning in BPD: patients made more advantageous deck choices in later blocks (LeGris, Toplak, & Links, 2014) and improved performance in repeated task assessment (Krause-Utz, 2016, personal communication). On this background, poor IGT performance could rather be attributable to other processes than learning per se. A qualitative review further emphasized a tendency to neglect the risk of losing. In contrast, playing for high stakes was not unanimously reported. Our findings complement self-assessment data showing a reduced sensitivity to rewards and punishments (Soler et al., 2014) and may relate to a lack of neural discrimination between advantageous and disadvantageous outcomes in BPD (Andreou et al., 2015; Enzi et al., 2013; Schuermann, Kathmann, Stiglmayr, Renneberg, & Endrass, 2011; Vega et al., 2013; Völlm et al., 2007).

Moderator analysis found that studies that included patients receiving psychotropic medication at the time of testing yielded significant group differences in the IGT. Otherwise, excluding patients taking medication was associated with a lack of differences. There are two explanations for this finding. First, patients not taking medication or willing to withdraw medication before study participation may be less severely impaired than others. Second, metabolic changes due to medication may affect
the cognitive functions crucial for IGT performance. Evidence against the latter comes from previous studies (LeGris et al., 2014). Furthermore, Unoka & Richman (2016) proposed that BPD patients with a lower percentage of co-morbid psychiatric diagnoses outperform those with a higher percentage of diagnoses in measures of cognitive functions, such as attention and executive functioning. Thus, a more general cognitive functioning impairment could contribute to findings of IGT impairment in BPD (but see (Toplak, Sorge, Benoit, West, & Stanovich, 2010) for evidence against this). Our analysis is not suited to distinguish between possible causes. Furthermore, the sex-composition of the samples was a significant moderator of IGT scores. While between-group sex differences were adequately controlled (Table 2), the results demonstrate that effect sizes increased with higher proportions of female participants. That is, studies with dominantly or exclusively female participants reported the most pronounced differences between patients and controls. This is in line with evidence that healthy female subjects achieve lower IGT net scores than male subjects (Evans & Hampson, 2015). In addition, a significant moderation effect of age-matching was found.

Taken together, results demonstrate several sources of possible influence on the current evidence base that were not yet addressed sufficiently. Due to the small number of studies, moderators were not compared in a statistical model. It should be noted that non-significant results from moderator analyses do not prove that SES, IQ and psychiatric comorbidity have no effect on the IGT; though independency of IGT performance from IQ is suggested (Toplak et al., 2010).

Other factors not considered in our statistical analysis may influence decision-making in BPD. For instance, higher BPD symptom severity was found to correlate with delay discounting (Völker et al., 2009), reversal learning errors (Paret, Hoesterey, Kleindienst, & Schmahl, 2016) and disadvantageous decision-making in gambling tasks
The effects of impulsivity on REV, the IGT and other neuropsychological decision-making tasks have also been demonstrated in healthy subjects (Franken, van Strien, Nijs, & Muris, 2008). Likewise, BPD research has shown correlations of impulsivity with delay discounting (Coffey, Schumacher, Baschnagel, Hawk, & Holloman, 2011; Krause-Utz et al., 2016; K. A. Lawrence, Allen, & Chanen, 2010; Völker et al., 2009), reversal learning errors (Berlin, Rolls, & Iversen, 2005; Paret et al., 2016) and disadvantageous decisions in gambling tasks (Bazanis et al., 2002; Legris, Links, van Reekum, Tannock, & Toplak, 2012; Schuermann et al., 2011; Svaldi et al., 2012). In addition, depression was found to predict disadvantageous decision-making in BPD (Svaldi et al., 2012). Furthermore, impaired IGT performance and alterations in neural responses to rewards were connected to non-suicidal self-injury (NSSI) (Rigler, David, & David, 2016; Sauder, Derbidge, & Beauchaine, 2016) and suicidality (Richard-Devantoy, Berlim, & Jollant, 2014; but see Gorlyn, Keilp, Oquendo, Burke, & John Mann, 2013 for non-significant findings). LeGris & van Reekum (2006) suggested that altered decision-making influences the expression of NSSI and suicidal behavior, which are present in the majority of patients diagnosed with BPD. Finally, influences from motives and states on TDD are manifold (reviewed by Story, Moutoussis, & Dolan, 2015) including low income, perceived deficit states and environmental hazards. These can lead subjects to discount delayed rewards more strongly. Social exclusion (K. A. Lawrence et al., 2010) and experimentally induced stress (Krause-Utz et al., 2016) were not observed to alter TDD in BPD, but more research targeted to identify other possible influences is needed.

Importantly, it may not be useful to try to disentangle all of these influences from the ‘pure’ BPD-diagnosis-effect. In addition to comparing diagnostic groups, it would be useful to further examine how different facets of psychopathology such as
impulsivity, symptom severity and NSSI influence decision-making. Such an approach would likely decrease the cost of ecological validity.

We propose three possible and non-exclusive explanations for a conditional decision-making deficit: First, motivational processes could differ between TDD and other decision-making tasks. More speculatively, processes could also differ between tasks requiring subjects to learn stimulus-reward associations and tasks making them explicit via instructions. Second, BPD patients may be able to compensate for deficient value processing. Typically, reversal learning tasks present repeated stimulus-outcome reversal and participants are instructed beforehand that stimulus-outcome relations will reverse during the task. Without instructions, patients might monitor reinforcers with less vigilance. Thus, task knowledge may prepare them to overcome this deficit. Consequently, we would expect increased recruitment of the dorsolateral PFC, which was discussed to contribute to response shifting more generally (Hampton & O’doherty, 2007; Remijnse et al., 2005; Xue et al., 2013). This may even become more pronounced with increasing task demands (Mitchell, Rhodes, Pine, & Blair, 2008). Third, psychopathological traits may affect decision-making differentially. In support of this, preliminary data on different facets of impulsivity in BPD showed, that impulsive urgency predicted an increased reversal learning error rate but not delay discounting (Krause-Utz et al., 2016; Paret et al., 2016). In contrast, a lack of premeditation significantly predicted increased delay discounting but did not affect reversal learning (Krause-Utz et al., 2016; Paret et al., 2016). In this sense, behavioral and anatomical correlates of subjective value and decision-making could identify differences in neuroplasticity related to impulsivity and other traits that affect decision-making in BPD.
More research on the predictors of decision-making deficits in BPD and their treatment is needed. Importantly, studies should report whether patients were on medication at the time of testing, and sex differences need to be addressed. Additionally, questionnaire or interview data on symptom severity, affectivity, impulsivity and social functioning as well as correlations with behavioral data should be reported.

4.1 Limitations

Our conclusions are limited by the small number of studies. This is particularly important in terms of moderator analyses. Potential publication bias is a general problem of meta-analysis and refers to significant findings getting published more likely (and quickly) than non-significant findings. Though indicators of publication bias were not observed, potential publication bias cannot be reliably excluded particularly in the face of a limited evidence base. Nonetheless, the importance of this study lies in the aggregation of the currently available data in the field. This is the only window into the phenomenon of decision-making in BPD available for research.

In addition to these limitations, we emphasize that this review focusses on decision processes based on the subjective value of outcomes. Of course, decision-making is a multifaceted concept, and other processes are implicated in real-life decisions. We do not want to underestimate the importance of other processes and tasks in the realm of decision-making such as social and moral decision-making, set-shifting as assessed with the Wisconsin Card Sorting Test as well as response inhibition, planning, etc. There is evidence that neural correlates differ between some of the latter processes and the tasks included in this review (e.g. Seres, Unoka, & Kéri, 2009; Zald
& Andreotti, 2010). Therefore and because of conceptual reasons, it seems reasonable not to mix results in a single paper to achieve a concise and targeted analysis.

Finally, impairments in the IGT could be attributed to Cluster B personality disorders more generally rather than BPD specifically (Ruocco, McCloskey, Lee, & Coccaro, 2009). Additionally, findings in the decision-making studies could be influenced by variable effort on cognitive testing for patients with BPD (Ruocco, 2016).

4.2 Conclusion

Neuropsychological studies find that certain aspects of decision-making, particularly delay discounting, are altered in BPD. Though patients with BPD tend to neglect the risk of losing when offered risky choices, impaired adaptive learning is not clearly linked to BPD in this meta-analysis. More research on subjective value processing and decision-making is needed, and we include directions for future work.

5 Acknowledgements

We thank Sylvia Cackowski, Annegret Krause-Utz and Michael McCloskey who kindly provided additional data and statistics. Furthermore, we thank Stephanie Mall for help with screening and coding of studies and Anja Voigt for helpful support in production of graphics.
6 References


Bazanis, E., Rogers, R. D., Dowson, J. H., Taylor, P., Meux, C., Staley, C., ... Sahakian, B. J. (2002). Neurocognitive deficits in decision-making and planning of


Rossi, R., Pievani, M., Lorenzi, M., Boccardi, M., Beneduce, R., Bignotti, S., … Frisoni, G. B. (2013). Structural brain features of borderline personality and bipolar


Figures

Records identified through systematic literature search
\[ n = 316 \]

Records identified through other sources
\[ n = 6 \]

Records after duplicates removed
\[ n = 306 \]

Application of exclusion criteria

Excluded: \[ n = 278 \]

- No decision making task
  \[ n = 249 \]

- Both BPD patient (according to ICD / DSM) and healthy control data need to be reported for eligibility;
  \[ n = 16 \]

- Task data or statistics not available
  \[ n = 10 \]

- Results from same sample reported in another record
  \[ n = 3 \]

Studies included
\[ n = 29 \]

- Temporal delay discounting: \[ n = 9 \]
- Reversal learning: \[ n = 4 \]
- Iowa Gambling Task: \[ n = 9 \]
- Other decision making task: \[ n = 7 \]
Figure 1. Selection of eligible studies for review. a One study reported results from a TDD and ODT task. b N=3 studies were not included in meta-analysis (see Supplementary Material S1 for more information on eligibility).

Column: 'study' identifies record (first author, year of publication). The middle column shows a forest plot with effect sizes and 95% confidence intervals (CI). The diamond size refers to the statistical weight, with which the effect size entered the meta-analytic comparison. On the horizontal axis, negative values mean that patients with BPD discounted delayed rewards more strongly than controls. The exact values of effect sizes with the lower and upper bound of the CI and the relative statistical weight are reported in the following two columns.
Figure 3. Statistics and results from the REV meta-analysis. Each row represents one record and the last row (bold letters) reports the results from meta-analysis. Columns: ‘study’ identifies record (first author, year of publication). The middle column shows a forest plot with effect sizes and 95% confidence intervals (CI). The diamond size refers to the statistical weight, with which the effect size entered the meta-analytic comparison. On the horizontal axis, negative values mean that patients with BPD performed worse than controls. The exact values of effect sizes with the lower and upper bound of the CI and the relative statistical weight are reported in the following two columns.

### Figure 3: Statistics and results from the REV meta-analysis

#### Reversal (REV)

<table>
<thead>
<tr>
<th>Study</th>
<th>Effect size [CI]</th>
<th>Weight (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barker et al. 2014</td>
<td>-0.17 [-0.77, 0.43]</td>
<td>28.61</td>
</tr>
<tr>
<td>Berlin et al. 2005</td>
<td>-0.56 [-1.13, -0.03]</td>
<td>34.08</td>
</tr>
<tr>
<td>Dinn et al. 2004</td>
<td>-0.61 [-1.51, 0.29]</td>
<td>12.73</td>
</tr>
<tr>
<td>Paret et al. 2016</td>
<td>0.17 [-0.48, 0.82]</td>
<td>24.59</td>
</tr>
<tr>
<td>Congregated effect</td>
<td>-0.28 [-0.60, 0.04]</td>
<td></td>
</tr>
</tbody>
</table>

#### Iowa Gambling Task (IGT)

<table>
<thead>
<tr>
<th>Study</th>
<th>Effect size [CI]</th>
<th>Weight (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black et al. 2009&lt;sup&gt;Age&lt;/sup&gt;</td>
<td>-0.61 [-1.20, -0.02]</td>
<td>6.89</td>
</tr>
<tr>
<td>Cackowski et al. 2014&lt;sup&gt;Med, Age&lt;/sup&gt;</td>
<td>-0.19 [-0.68, 0.29]</td>
<td>10.33</td>
</tr>
<tr>
<td>Gorlyn et al. 2013&lt;sup&gt;Med&lt;/sup&gt;</td>
<td>0.53 [-0.23, 1.28]</td>
<td>4.27</td>
</tr>
<tr>
<td>Haaland et al. 2007&lt;sup&gt;Med, Age&lt;/sup&gt;</td>
<td>-0.96 [-1.72, -0.19]</td>
<td>4.13</td>
</tr>
<tr>
<td>LeGris et al. 2012&lt;sup&gt;Med, Age&lt;/sup&gt;</td>
<td>-0.71 [-1.16, -0.27]</td>
<td>12.30</td>
</tr>
<tr>
<td>Maurex et al. 2006&lt;sup&gt;Age&lt;/sup&gt;</td>
<td>-0.37 [-0.82, 0.09]</td>
<td>11.62</td>
</tr>
<tr>
<td>McCloskey et al. 2003&lt;sup&gt;Med, Age&lt;/sup&gt;</td>
<td>-0.04 [-0.31, 0.22]</td>
<td>34.86</td>
</tr>
<tr>
<td>Minzenberg et al. 2008&lt;sup&gt;Med, Age&lt;/sup&gt;</td>
<td>-0.50 [-0.98, -0.01]</td>
<td>10.10</td>
</tr>
<tr>
<td>Schuermann et al. 2011&lt;sup&gt;Med, Age&lt;/sup&gt;</td>
<td>-0.75 [-1.42, -0.09]</td>
<td>5.49</td>
</tr>
<tr>
<td>Congregated effect</td>
<td>-0.32 [-0.47, -0.16]</td>
<td></td>
</tr>
</tbody>
</table>
Figure 4. Statistics and results from the IGT meta-analysis. Each row represents one record and the last row (bold letters) reports the results from meta-analysis. Columns: ‘study’ identifies record (first author, year of publication); ‘Age’/’Age’=groups were matched/not matched for age; ‘Med’/’Med’=patients taking psychotropic medication at time of testing were included/excluded. If ‘Age’ or ‘Med’ are not indexed, we were lacking sufficient data for coding. The middle column shows a forest plot with effect sizes and 95% confidence interval (CI). The diamond size refers to the statistical weight, with which the effect size entered the meta-analytic comparison. On the horizontal axis, negative values mean that patients with BPD made more disadvantageous decisions than controls. The exact values of effect sizes with the lower and upper bound of the CI and the relative statistical weight are reported in the following two columns.