



# To play or not to play: A personal dilemma in pathological gambling



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## ARTICLE INFO

### Article history:

Received 11 December 2013

Received in revised form

10 June 2014

Accepted 22 June 2014

Available online 28 June 2014

### Keywords:

Loss aversion

Decision-making

Impulsivity

Course of pathology

## ABSTRACT

Research has shown that healthy people would rather avoid losses than gamble for even higher gains. On the other hand, research on pathological gamblers (PGs) demonstrates that PGs are more impaired than non-pathological gamblers in choice under risk and uncertainty. Here, we investigate loss aversion by using a rigorous and well-established paradigm from the field of economics, in conjunction with personality traits, by using self-report measures for PGs under clinical treatment. Twenty pathological gamblers, at the earlier and later stages of clinical treatment, were matched to 20 non-gamblers (NG). They played a “flip coin task” by deciding across 256 trials whether to accept or reject a 50–50 bet with a variable amount of gains and losses. They completed questionnaires aimed at assessing impulsivity. Compared to NG, pathological gamblers, specifically those in the later stages of therapy, were more loss averse and accepted a lower number of gambles with a positive expected value, whereas their impulsivity traits were significantly higher. This study shows for the first time that changes in loss aversion, but not in personality traits, are associated with the time course of pathology. These findings can be usefully employed in the fields of both gambling addiction and decision-making.

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## 1. Introduction

Gambling addiction is currently a real problem among the population. Although gambling represents a recreational activity for most people, it is an affliction for many others. About 1.6% of adult population (Reuter et al., 2005) is unable to stop their gambling behavior, and therefore an increasing number of individuals are asking for help. The Diagnostic and Statistical Manual (DSM; American Psychiatric Association, 1980) defined criteria for pathological gambling in 1980, classifying it as an “impulse control disorder not elsewhere categorized”. Pathological gambling (PG) is also defined as a “habit and impulse disorder” in the International Classification of Disorders (ICD 10). This impulse disorder has seriously detrimental consequences for the quality life in people that experience gambling addiction. PG is associated with increased substance abuse, as well as losses of money that may lead to bankruptcy, suicide, divorce and legal problems (Lesieur and Rosenthal, 1991). The latest version of the DSM (DSM-V;

American Psychiatric Association, 2013) defines gambling disorder as an addictive disorder, and more specifically as a “non-substance-related disorder”, under the classification of Substance-related and Addictive Disorders.

Several cognitive factors are related to PG, such as the gambler's fallacy, illusion of control, and superstitions (Ladouceur and Walker, 1996). These factors, along with others such as the failure to understand mutual independence of chance events, imply that, for example, after a sequence of losing bets, PGs bet even more as they interpret these independent outcomes as dependent, irrationally expecting gains to follow losses (Breen et al., 2001). Indeed, frequent gamblers produce more irrational statements than non-frequent gamblers when gambling (Gaboury and Ladouceur, 1989; Griffiths, 1994). The cognitive factors can have important implications in PG's ability to make decisions. Research in this field has shown impaired PG performance on decision-making (Monterosso et al., 2001; Suhr and Tsanadis, 2007; Franken et al., 2007; Sweitzer et al., 2008; Crone et al., 2003). Several studies demonstrated, for example, that pathological gamblers have a preference for options with higher risk and reward (Bechara, 2003, 2005), and for short rather than long temporal outcomes rewards (Petry, 2001). Several other studies have shown that PGs are more impaired than controls in decision-making

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under risk as well as in decision-making under ambiguity and uncertainty (Brand et al., 2002, 2005; Labudda et al., 2007; Roca et al., 2008; Lawrence et al., 2009; Ligneul et al., 2013; Brevers et al., 2012). The difference between these two types of decisions is that the decisions under risk are those where outcome probabilities are known, whereas decisions under ambiguity and uncertainty are those in which such probabilities are unknown (Kahneman and Tversky, 1979). Studies on decisions under ambiguity and uncertainty have shown that PGs perform more poorly than healthy participants in the Iowa Gambling Task (Cavedini et al., 2002; Brand et al., 2005; Goudriaan et al., 2005; Linnet et al., 2006; Kertzman et al., 2006; Brevers et al., 2012). Also, PGs have impaired decisions under risk at both the executive (Brand et al., 2005) and feedback (Labudda et al., 2007) levels, as well as impaired decisions under ambiguity at pre- and post-choice emotional activation levels (Goudriaan et al., 2006). Recently, Ligneul et al. (2013) argued that PGs are risk seeking because they are characterized by increased risk attractiveness and greater optimism for risky events. In these studies, authors have also found that gamblers score higher than control participants on personality inventories assessing impulsivity.

To date, research has primarily focused on understanding the cognitive and personality differences between pathological gamblers and healthy individuals. Thus, researchers used self-report questionnaires, decision-making and other cognitive tasks and utilized as participants habitual or pathological gamblers, but not PGs during clinical treatment. As a consequence, it is still unknown whether and how these cognitive and personality factors change across the course of pathology. Interestingly, Goudriaan et al. (2008) recently investigated the predictive ability of both self-report measures (viewed as indicators of the phenotype of the disorder, that is “as the disorder appears”) and cognitive tasks (viewed as indicators of the endophenotype of the disorder, that is “functions that underlie a disorder”), on relapse in a group of out-patients PG.

They showed that endophenotypical characteristics (that is, cognitive measures on disinhibition and decision-making), but not phenotypical characteristics (that is, self-report measures on impulsivity and reward sensitivity), are predictive of relapse in PG. A more recent study (De Wilde et al., 2013) showed that some, but not all, cognitive and personality measures on impulsivity could detect changes between PGs (relapsed and non-relapsed) and healthy controls, whereas they did not show any difference between relapsed and non-relapsed PGs.

Taken together these studies help better understand differences in pathological gambling in a variety of cognitive and personality factors. However, it is still unclear whether, and how, endophenotypical cognitive characteristics, as detected by a paradigm investigating aversion to losses in a risky choice context, and phenotypical characteristics (on impulsivity, obsessive-compulsiveness related to pathological gambling and reward sensitivity), differ between pathological populations and non-pathological populations, and across the stages of pathology itself. This is the aim of the present study.

To the best of our knowledge, this is the first study that combines PGs under current clinical treatment along with a rigorous and well-established paradigm in economic field, with the aim of investigating variations in both the perceptions of losses and of impulsivity in pathological gamblers.

### 1.1. The current study

With this aim, we employed a well-known risky choice task, similar to the one used by De Martino et al. (2010). This task consists in a “flip coin task” where participants have to decide whether to accept or reject a 50–50 bet with a variable amount of

gains and losses. If they decide to accept the bet then the coin is flipped and they can lose or gain the amount of money associated with that gamble, whereas if they reject the gamble then nothing happens. Research has shown that healthy people's decisions are affected by the fact that they would rather avoid losses rather than gamble for even higher gains. Indeed, people usually only accept a 50–50 bet when the amount they could win is at least twice the amount they could lose (Kahneman, 2003; Rabin and Thaler, 2001). This behavior is driven by the fact that people's choices are based on how different outcomes will make them feel (Mellers et al., 1999; Loewenstein et al., 2003; Wilson and Gilbert, 2003). Players typically overestimate the intensity and duration of their negative feelings (Kahneman and Snell, 1992; Mellers and McGraw, 2001; Gilbert et al., 2002; Loewenstein et al., 2003; Wilson and Gilbert, 2003) and therefore they strongly try to avoid negative outcomes by refraining from gambling when the bet does not offer a higher gain than loss. This phenomenon, according to which losses loom larger – about 1.5–2 times – than gains, is called “loss aversion” and is well-described in Prospect theory (Kahneman and Tversky, 1979). Prospect theory describes risky choice by using a value function, which is convex in the domain of losses and concave in the domain of gains. Loss aversion is represented by a value curve, which is steeper for losses than for gains.

In this study we want to investigate whether and how loss aversion changes in pathological gamblers as compared to healthy population. In addition, in order to investigate similarities (and potential differences) within PGs, we tested loss aversion tendencies at two different stages of clinical treatment. Until now, only one study (Brevers et al., 2012) has used this task, though with problem gamblers recruited in a casino, and in order to investigate risk taking behavior rather than loss aversion by using its critical lambda value, that is, the coefficient that indicates the degree to which an agent is loss averse. In this study authors found that problem gamblers indeed accepted a greater number of risky gambles as compared to normal controls. In the present study we instead tested for the difference in the willingness to accept gambles and in the sensitivity to losses in pathological and non-gambling participants, by testing the critical lambda value. We also checked for variations between the earlier and later stages of the clinical treatment in pathological gamblers only.

We hypothesized differences, in terms of both decision behavior and self-administered questionnaires, between PGs and non-PGs. More precisely, following findings from the literature (Brevers et al., 2012), one hypothesis is that PGs would show a higher willingness to gamble and lower sensitivity to losses as compared to non-PGs. However, another possibility could be that PGs are characterized by a lower willingness to gamble and a higher sensitivity to losses than non-PGs. If so, this could be ascribed to the course of the clinical treatment. A significant difference between PGs at the earlier and later stages of the therapy would further confirm this latter hypothesis. Following this reasoning, we can expect that PGs at the earlier stage of the therapy will not differ from non-PGs as they have already started therapy which could have immediately reduced their gambling behavior. If so, these findings would show that, based on the endophenotype of the disorder, that is, the cognitive and/or emotional factors related to decision-making, PGs differ significantly from non-PGs, and that variation in the PG endophenotype can also be detected at different stages of the clinical treatment. As a consequence, such endophenotypical characteristics can even help pathological gamblers to refrain from gambling.

Lastly, in order to assess whether and how personality traits change between PGs and non-PGs and across the clinical treatment, we also used several self-administered questionnaires. Here, we would expect that PGs differ from non-PGs, indicating the

presence/absence of the clinical problem. Regarding the differences between the two PGs subgroups, following Goudriaan et al. (2008) and De Wilde et al. (2013) findings, it is possible that we will not find differences on self-report measures between them, but only on decision-making processes. This would show that there are no changes on the phenotype of the disorder, and thus that self-administered questionnaires are less useful than cognitive tasks in assessing variation in the pathology.

## 2. Method

### 2.1. Participants

Twenty adults diagnosed with pathological gambling in line with DSM IV (American Psychiatric Association, 1994) and ICD 10 (World Health Organization, 1992) criteria were recruited from an Italian clinical center specialized in treatment of addictions, known as Società Italiana di Intervento Patologie Compulsive (S.I.I.Pa. C.). They were either at the earlier stage (< 6 months) of the clinical treatment (ETG;  $N=10$ ) or at the later stage (> 18 months) of the clinical treatment (LTG;  $N=10$ ). Patients with comorbid Axis-I disorders, including current major depressive episodes, alcohol or substance abuse, history of traumatic head injury with loss of consciousness, neurological or medical illnesses and under pharmacological treatment were excluded from the study. Diagnoses and treatment were performed by two staff psychotherapists, when the patients first entered the center. The two psychotherapists were in full agreement on the diagnoses and treatment of each patient in the study.

All patients received the same clinical treatment based on a multimodal approach, including individual and couple therapy, psycho-education, group therapy and self-help groups. The eventual aim of the therapy is to help patients to learn a new style of life, away from the gambling addiction.

Matched non-pathological gamblers participants (NG,  $N=20$ ) were recruited from the local population, with this sample having no history of either psychiatric or neurological symptoms (see Table 1 for details). Both patients and controls participated in the study voluntarily by adding their name to a volunteer list for the experiment. Patients were informed about the experiment during group therapy and invited to write their name on the volunteer list, and none declined to give their availability. PGs who wished to participate in the study were asked to arrive 1 h before their appointment with the psychotherapist. Therefore they performed the experiment on the same day as their appointment with their psychotherapist. Controls were informed about the experiment via word of mouth. After they volunteered, only those who matched on age, sex and education with the group of PG participants were invited to participate at the study. Written informed consent was obtained from all participants.

### 2.2. Experimental procedures

#### 2.2.1. Clinical and personality assessment

Participants completed a series of questionnaires aimed to assess clinical and personality traits. This was done in order to investigate whether any differential performance in the decision task could be associated with different stages of treatment or to personality traits, commonly relevant in gambling addiction.

**2.2.1.1. Gambling severity assessment.** First, we assessed gambling severity of the experimental groups using the South Oaks Gambling Screen (SOGS; Lesieur and Blume, 1987). This is a 16-item self-administered questionnaire, ranging from 0 to 20. A score ranging between 0 and 2 indicates that there are no problems; a score ranging between 3 and 4 indicates a risk for problem gambling; a score of 5 or higher indicates risk of pathological gambling. The SOGS shows good validity and reliability with the DSM IV criteria for pathological gambling, with coefficient Cronbach's alpha of 0.69 in the general population and 0.86 in gambling treatment samples (Stinchfield, 2002).

**2.2.1.2. Self-report measures of obsessions and compulsions related to pathological gambling.** In order to assess traits potentially related to gambling addiction, the Pathological Gambling Yale Brown Obsessive Compulsive Scale (PG-YBOCS; Hollander et al., 1998) was used.

The PG-YBOCS is a 10-item questionnaire that measures the severity of PG. Specifically, half of the items measure the obsession to gambling and the other half of the items the compulsion to gambling. It assesses, for example, for the time occupied by gambling, interference due to gambling, distress associated with gambling, resistance against gambling, and degree of control over gambling. Each item has a five points answer, ranging from 0 to 4. The score for each subscale ranges from 0 to 20. A score of 0 indicates no obsessions or compulsion; a score between 1 and 5 indicates light problems; a score between 6 and 10 indicates moderate problems; a score between 11 and 15 indicates important problems;

a score between 16 and 20 indicates very heavy problems. The PG-YBOCS shows high validity and reliability for total score and for each subscale, it is also correlated with SOGS ( $r=0.90$ ), and therefore it is a reliable and valid measure of pathological gambling. The Cronbach's alphas for the subscales related to the obsession and compulsion to gambling are, respectively, 0.97 and 0.93. The test-retest reliability for each item ranges from 0.29 to 0.56 (Pallanti et al., 2005).

**2.2.1.3. Self-report measures of reward sensitivity.** The behavioral inhibition and the behavioral activation scales (BIS/BAS; Carver and White, 1994) were used to analyze participants' likelihood of approaching rewards (BAS; e.g. responsiveness to incentives, drive and fun seeking) or avoiding punishments (BIS; e.g. concern over and reactivity to aversive events) when making a choice. It contains 20 items, scored on a four-point Likert scale, ranging from 1 "quite untrue of me" to 4 "quite true of me". The BIS/BAS have a good reliability and a strong validity in relation to conceptually similar traits, such as neuroticism and positive affect (Campbell-Sills et al., 2004). Their Cronbach's alphas have been found to be 0.82 for the BAS and 0.85 for the BIS.

**2.2.1.4. Self-report measure of impulsivity.** We measured participants' level of impulsiveness by using the Barratt Impulsiveness Scale version 11 (BIS-11; Patton et al., 1995), which provides a measure of impulsiveness on three different sub-scores: "attentional impulsiveness", indicating a lack of attention and cognitive instability, "motor impulsiveness", indicating a lack of control in motor behavior, and "non-planning impulsiveness", indicating a deficit in planning their own behavior. The total number of items is 30, answered on a four-points scale, ranging from 'never' to 'always'. The total is given by the sum of each rating in each item and it ranges from 30 to 120. This BIS-11 has a high reliability and validity, its Cronbach's alpha in Italian sample is 0.79 (Fossati et al., 2001).

**2.2.1.5. Self-report measures of anxiety and depression.** Finally, we assessed differences in anxiety and depression dimensions among groups by using the Positive and Negative Affect Scale (PANAS) (Watson et al., 1988) and STAI-Trait (STAI1) and STAI-State (STAI2) Anxiety Inventory (Spielberger et al., 1983) clinical questionnaires.

The PANAS consists of a 20-item bidimensional mood inventory. The Positive Affect scale reflects the extent to which a person feels for example enthusiastic, active, and alert. The Negative Affect scale reflects instead the extent of aversive mood states, such as anger, disgust, guilt, and fear. Psychometric properties of the PANAS scales are adequate, with a good reliability and validity, with a Cronbach's alpha of 0.85 for the Positive Affect subscale and 0.92 for Negative Affect subscale.

The STAI1 and STAI2 have been used in order to assess for trait- and state-anxiety. These two questionnaires consist of 20 items, which measure the frequency of anxiety symptoms. Each item is rated on a four-point scale, ranging from "almost never" to "almost always". A good reliability and validity for both clinical questionnaires have been found. The Cronbach's alpha ranges from 0.91 to 0.95 for state anxiety and from 0.85 to 0.90 for trait anxiety. Their test-retest reliability is 0.49 for state anxiety and 0.82 for trait anxiety.

#### 2.2.2. Risky choice task

We used a gambling task, typically used to measure the degree of "loss aversion". Here, participants had to decide whether to accept or reject a coin-flip with a fixed probability ( $p=0.5$ ) of winning or losing a variable amount of money associated with that gamble. This task was modified from previous versions (De Martino et al., 2010). To begin, participants were told that the study was aimed at investigating how people make decisions and that, specifically, they would be asked to decide whether to flip the coin. Participants were then seated comfortably in front of a computer screen.

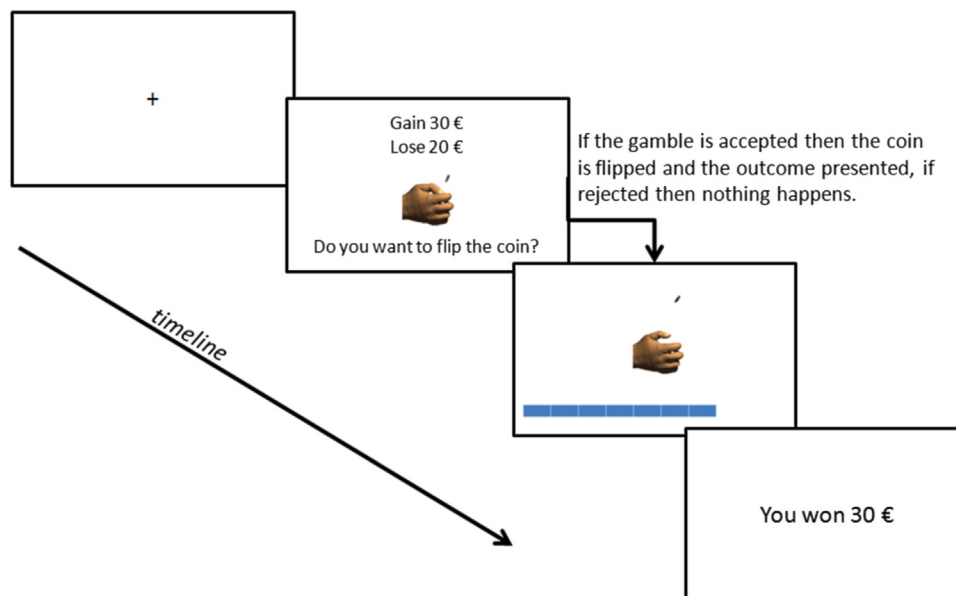
On each experimental trial (see Fig. 1 for an example), participants first saw a fixation point, which lasted for 500 msec, and then were presented with the gamble (represented by the coin flip) displayed in the center of the computer screen. Participants were asked to choose whether to accept or reject the coin-flip. If they accepted then the coin was flipped and they could win or lose the money associated with that gamble. If they rejected then the coin was not flipped and they moved directly to the next trial. In order to ensure that participants made a choice on each trial, the gamble remained on the screen until the participant selected the answer, by pressing the X or N keys on the keyboard with either their left or right index finger (X if they accepted to flip the coin and N if they rejected it). If they pressed the X then the coin was flipped. After that, the amount of money won or lost was presented in the center of the screen. After participants had observed the outcome they pressed a button to move on to the next trial.

To enhance motivation, participants were informed that one trial would be randomly selected by the computer at the end of the experiment, with this trial forming the basis for their payment. Participants were informed they had an initial endowment, which would have allowed them to pay out in the case that the selected trial resulted in a loss. For ethical reasons, all subjects received the same amount of money at the end of the task.

Participants played 256 trials in total, split into four sessions. As in the study of De Martino et al., each gamble was randomly selected from a matrix where both gains and losses varied from €20 to €50, in increments of €2. Accordingly, the

**Table 1**  
Demographic data, clinical and personality assessment.

	NG	PG	Sig.
Number	20	20	
Age	37.15 (10.86)	36.45 (9.1)	0.82
Education	12.6 (1.63)	12.25 (3.02)	0.65
Sex	17M	17M	/
Ethnicity	All Caucasian	All Caucasian	/
SOGS	0.15 (0.67)	12.15 (3.42)	$p < 0.001$
PG Y-BOCS [obsession subscale]	0.35 (0.93)	8.55 (4.54)	$p < 0.001$
PG Y-BOCS [compulsive subscale]	0.35 (0.81)	8 (4.95)	$p < 0.001$
BIS [behavioral inhibition scales]	21.6 (3.57)	22.4 (4.06)	$p = 0.5$
BAS [behavioral activation scales]	33.5 (6.58)	39.85 (7.34)	$p < 0.01$
BIS11 [motor impulsiveness subscale]	18 (3.68)	22.2 (4.83)	$p < 0.005$
BIS11 [not planning impulsiveness subscale]	23.55 (3.87)	29.2 (3.69)	$p < 0.001$
BIS11 [attention impulsiveness subscale]	14.2 (3.14)	15.4 (2.23)	$p = 0.17$
PANAS [positive scale]	31.45 (6.1)	29.4 (6.73)	$p = 0.32$
PANAS [negative scale]	15.35 (4.06)	20.45 (7.01)	$p < 0.01$
STAI 1	41.75 (5.44)	38.7 (5.9)	$p = 0.1$
STAI 2	38.35 (6.83)	34.75 (8.02)	$p = 0.13$



**Fig. 1.** Risky choice task. One example of the risky choice task. Here, participants have to choose whether to accept the gamble with a 50% of probability of gaining 30€ and 50% of probability of losing 20€. They choose to accept the gamble and the coin is flipped. After that, they are shown the result: they won €30.

expected value (EV) of each gamble varied from  $-15$  to  $+15$ . See Fig. 2 for details. Each gamble was unique, that is, the combination of each gain with each loss was presented only one time. This task belongs to the “decision under risk” tasks (Yeung and Sanfey, 2004; Brevers et al., 2012). Stimulus presentation and data acquisition were controlled using E-prime software package (PST, Inc., Pittsburgh, PA), running on a Windows computer. Instructions were presented in written form and the entire experiment lasted about 40 min.

### 3. Results

On all the data and findings reported hereafter power analyses were undertaken and they confirmed that the sample size was sufficient.

#### 3.1. Clinical and personality assessment

Participants in the two groups did not show any difference in terms of age ( $p = 0.83$ ) or education ( $p = 0.65$ ). Findings on the severity of gambling symptoms (SOGS) showed that the PG group

significantly differed from non-PG [ $t(38) = 15.39$ ,  $p < 0.001$ ], whereas the two sub-groups of patients did not differ ( $p = 0.18$ ). In terms of the other traits potentially related to gambling addiction, our findings showed that PG rated significantly higher than non-PG in obsessiveness (obsession subscale,  $t(38) = 7.92$ ,  $p < 0.001$ ) and compulsiveness (compulsiveness subscale,  $t(38) = 6.82$ ,  $p < 0.001$ ) (PG Y-BOCS). In both the subscales, findings showed that the two subgroups of PG did not differ from each other ( $p = 0.47$  and  $p = 0.6$ , respectively).

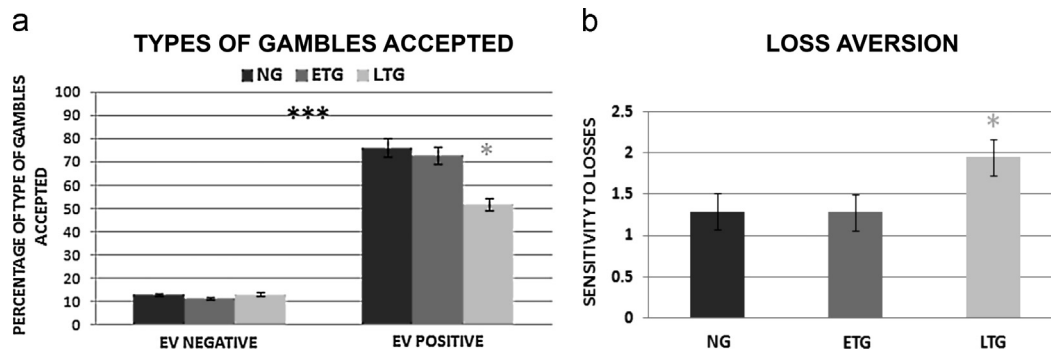
Regarding the behavioral inhibition/activation scales (BIS/BAS), participants differed only on the behavioral activation scale (BAS) [ $t(38) = 2.88$ ,  $p < 0.01$ ]. Non-PG reported a lower sensitivity to approach something desired than did PG, whereas no difference between ETG and LTG ( $p = 0.75$ ) was found. No significant results were found either in the behavioral inhibition scale (BIS) between PG and NG ( $p = 0.5$ ) and between the two subgroups of PG ( $p = 0.08$ ). PG and NG differed when comparing impulsiveness (BIS-11), with the group of patients specifically showing a higher “motor impulsiveness” [ $t(38) = 3.09$ ,  $p < 0.005$ ], indicating a lack of control



	50	-15	-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0
	48	-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1
	46	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2
	44	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3
	42	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4
	40	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5
	38	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6
	36	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7
	34	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8
	32	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9
	30	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10
	28	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11
	26	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12
	24	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13
	22	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	20	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50

GAINS

**Fig. 2.** Matrix gains/losses. Data reported in the table represent the combination of gains and losses presented in each single gamble, along with the corresponding expected value.



**Fig. 3.** Decision in loss aversion task. Data, reported in the Panel A, represents the percentage of gambles accepted when the expected value is negative and positive. Data in the Panel B represents, instead, the loss aversion index (lambda) calculated by the following standard procedure (De Martino et al., 2010) [ $*=p < 0.05$ ;  $**=p < 0.005$ ].

in motor behavior, and “non-planning impulsiveness” [ $t(38)=4.72$ ,  $p < 0.001$ ], indicating a deficit in planning their behavior. No differences were found between the two subgroups of patients ( $p=0.47$  for “motor impulsiveness” and  $p=0.24$  for “non-planning impulsiveness” subscales). No differences between PG and NG groups were demonstrated in the “attentional impulsiveness” scale ( $p=0.17$ ), nor between ETG and LTG ( $p=0.7$ ).

Apart from these personality traits related to gambling addiction, participants did not demonstrate abnormal anxiety traits, nor any correlation with depression. The Negative Affective scale of the PANAS questionnaire (Watson et al., 1988) was significantly higher [ $t(38)=2.82$ ,  $p < 0.01$ ] for PG than for NG, but no differences were found between ETG and LTG ( $p=0.48$ ). Interestingly, the groups did not significantly differ from the mean of the Italian population ( $M=20.9$ ; Terracciano et al., 2003). Since this scale is strongly correlated with neuroticism and anxiety (Clark and Watson, 1991; Terracciano et al., 2003), our results further confirm the absence of anxiety symptoms in our subjects. No differences ( $p=0.32$ ) were found between PG and NG, nor between ETG and LTG ( $p=0.48$ ), in the Positive Affective scale, which is usually correlated with depression. Neither STAI1 ( $p=0.09$ ) nor STAI2 ( $p=0.13$ ) showed significant differences within the PG and NG groups, or between ETG and LTG ( $p=0.18$  and  $p=0.94$ , respectively) confirming that they did not differ on anxiety dimensions. See Table 1 for details.

### 3.2. Risky choices task

#### 3.2.1. Willingness to gamble

With the aim of investigating whether the type of gambles affected participants' choices, we performed detailed analyses. First of all, in order to balance the number of trials we considered choice behavior in the trials with positive and negative expected values. Therefore, we compared the average percentage of gambles accepted when the expected value (EV) was positive and negative. ANOVA analysis showed a main effect of EV [ $F(1,38)=183.19$ ,  $p < 0.001$ ], with a higher number of accepted gambles when the expected value was positive than negative. The main effect of group was not significant [ $F(1,38)=3.35$ ,  $p=0.07$ ], nor was the interaction between the two groups and EV [ $F(1,38)=2.88$ ,  $p=0.1$ ]. We then performed a further ANOVA analysis between the three groups (see Fig. 3a). Interestingly, findings confirmed the main effect of EV [ $F(1,37)=162.62$ ,  $p < 0.001$ ] and no main effect for groups [ $F(2,37)=2.67$ ,  $p=0.08$ ], but also demonstrated a significant interaction effect between the three groups and EV [ $F(2,37)=3.46$ ,  $p < 0.05$ ]. Post-hoc analyses (Duncan's test) showed that both NG and ETG accepted more gambles than LTG ( $p < 0.05$  for both the comparisons) when the expected value was positive, with no differences found between NG and ETG ( $p > 0.05$ ). The three groups did not differ in their willingness to gamble when the expected value was negative ( $p > 0.05$ ).

### 3.2.2. Sensitivity to losses

With the aim of investigating whether participants were differently sensitive to losses, we analyzed participants' behavior during the task, following the analyses used by [De Martino et al. \(2010\)](#).

**3.2.2.1. Loss aversion.** First of all, we computed the loss aversion ( $\lambda$ ) for each participant. This parameter quantifies the weight each participant gives to losses compared to gains.

Loss aversion (lambda) :  $\lambda = [(0.5 - \alpha) / \beta]$

Loss aversion parameters,  $\alpha$  and  $\beta$ , were calculated by using logistic regression, where the dependent variable was the choice (accept or reject the gamble) and the independent variable was the adjusted expected utility parameter (EVa). Specifically,  $\beta$  represents the unstandardized regression coefficient and  $\alpha$  the intercept of the logistic regression.

EVa =  $[0.5G / -0.5L]$  ( $G$  = gain and  $L$  = loss for each gamble)

The parameters were calculated from choices made by each participant during the task, and on the probability of choosing each gamble half of the time ( $p=0.5$ ).

We then performed an independent  $t$ -test analysis where  $\lambda$  was the dependent variable and the groups (PG vs. NG) the independent variable. Our findings highlighted differential loss aversion between the two groups [ $t(38)=2.37, p<0.05$ ], with PG ( $M=1.65 \pm 0.7$ ) showing a higher loss aversion than NG ( $M=1.25 \pm 0.26$ ). We also performed one-way ANOVA analysis on the three groups (ETG vs. LTG vs. NG), with  $\lambda$  as dependent variable. Findings showed significant differences between the groups [ $F(2,37)=7.25, p<0.005$ ], with LTG ( $M=1.95 \pm 0.82$ ) showing more loss-aversion than ETG ( $M=1.34 \pm 0.38$ ) and NG ( $p<0.005$  for both comparisons), with no differences found between ETG and NG ( $p=0.65$ ). See [Fig. 3b](#).

**3.2.2.2. Risk premium.** The “risk premium” (Rp) parameter was estimated. Specifically, we calculated the expected value parameter at which each participant shows the same probability ( $p=0.5$ ) of accepting or rejecting gambles, that is, the point of indifference, known as “risk premium” (Rp), between earning zero or accepting the risk to receive a loss or a gain.

Risk premium : Rp =  $[(0.5 - \alpha) / \beta]$

Risk premium parameters,  $\alpha$  and  $\beta$ , were calculated by using logistic regression, where the dependent variable was the choice made (accept or reject the gamble) and the independent variable was the expected utility parameter (EV). Specifically,  $\beta$  stands for the unstandardized regression coefficient and  $\alpha$  for the intercept of the logistic regression.

EV =  $[(0.5G) + (0.5L)]$  ( $G$  = gain and  $L$  = loss for each associated gamble)

The parameters were calculated from the choices made by participants during the task, on the probability of choosing each gamble half of the time ( $p=0.5$ ).

We performed an independent  $t$ -test analysis where Rp was the dependent variable and groups (PG vs. LTG) the independent variable. Results showed a trend [ $t(37)=1.93, p=0.06$ ] between PG ( $M=6.38 \pm 6.6$ ) and NG ( $3.1 \pm 3.68$ ). We further performed one-way ANOVA analysis on the three groups, with risk premium as dependent variable. Here, we found [ $F(2,36)=4.2, p<0.05$ ] that LTG ( $M=8.94 \pm 7.46$ ) had a significantly higher risk premium than both ETG ( $M=4.07 \pm 5.01$ ) and NG groups ( $p<0.05$  for both comparisons), whereas no differences between ETG and NG were found ( $p=0.65$ ).

## 4. Discussion

This study is the first to explore endophenotypical cognitive characteristics, related to loss aversion, and phenotypical personality characteristics, related to impulsivity traits, in both pathological gamblers under clinical treatment as well as individuals without any gambling addiction. Although several studies ([Petry, 2001](#); [Brand et al., 2002](#); [Brand et al., 2005](#); [Bechara, 2003, 2005](#); [Labudda et al., 2007](#); [Roca et al., 2008](#); [Lawrence et al., 2009](#); [Ligneul et al., 2013](#); [Brevers et al., 2012](#)) have shown that problematic gamblers are associated with impairments in decision-making, with PGs characterized by higher impulsivity than healthy controls. However, these studies have not used an actual true pathological population under clinical treatment. Only two studies ([Goudriaan et al., 2008](#); [De Wilde et al., 2013](#)) have investigated this question by using a true clinical population, though at the conclusion of treatment and with the aim to investigate which characteristics could be predictive of PGs relapse. However, these studies used different samples – PGs at the end of the therapy – and they did not investigate loss aversion.

With this aim we employed a rigorous and well-established risky choice paradigm in the economic field, and two groups of PGs and non-PGs. Within the PGs group, participants differed only in regard to the stage of treatment, either less than 6 months or more than 18 months.

Our results showed that these groups chose differently with regard to the type of gambles played and that they exhibited a different sensitivity to losses. When the expected value was positive (gambles with a potential gain higher than a potential loss) participants showed a higher willingness to gamble than when it was negative (gambles with potential gain lower than potential losses), but compared to NG and ETG, LTG were less willing to gamble. This difference was not found when comparing only NG to PG, likely due to the fact that ETG and LTG decided in a significantly different way. Importantly, using a standard procedure to measure loss aversion ([De Martino et al., 2010](#)), this study showed a systematic difference in loss aversion, as indicated by both loss aversion and risk premium indices, between the two groups of PG. Indeed, LTG was more sensitive to losses than ETG and NG.

Contrary to the findings on risky choice task, it is interesting to notice that the two clinical subgroups did not differ from each other in any of the self-administered questionnaires, whereas they demonstrated a higher likelihood of approaching rewards and higher impulsivity as compared to non-PG. Taken together, these findings suggest that variations in pathology may go unnoticed if based on self-administered tasks or verbal interviews, but it can be detected in terms of behavioral reactions that require quick and not-easy-to-verbalize decision-making. This finding is similar to that reported by [Goudriaan et al. \(2008\)](#) where endophenotypical (measured by cognitive tasks) but not phenotypical (measured by self-administered questionnaires) characteristics appeared to be predictive of relapse in PG. Our findings to the impulsivity questionnaires (BIS-11) are also similar to those reported by [De Wilde et al. \(2013\)](#), though they did not find differences on a decision-making task, different from that used here.

Interestingly, and differently from what might be expected following findings of [Brevers et al. \(2012\)](#) which showed a higher willingness to gamble during the loss aversion task in problematic gamblers recruited in a casino than in the healthy controls, we did not find such differences between PG and NG. If it is true that PGs have a higher willingness to gamble before starting clinical treatment, then our findings suggest that changes in decision behavior, as uncovered by our risky choice task, potentially occur quickly after the therapy starts. This is perhaps an effect of cognitive overcompensation due to the actual reduction in

gambling, which occurs at the beginning of a clinical treatment and increases with the duration of the clinical treatment.

Finally, although PG is associated with abnormalities in “reward circuitry” of the brain (Kambouropoulos and Staiger, 2001; Reuter et al., 2005), according to which the diminished dopamine receptor availability (due to a previous or existing dependence) leads to a chronic deficiency of dopamine in the brain, resulting in rewarding behavior aimed at normalizing the level of dopamine (Goldstein and Volkow, 2002; Volkow et al., 2002) and thus in impaired decision-making abilities, our findings show that gambling behavior can be reduced due to clinical treatment, despite these presumably continuing impaired mechanisms in the brain.

In summary, this study clearly highlights, for the first time, not only the differential utility of cognitive tasks and self-reported measures used to assess the course of pathology in PG during therapy, but also that clinical treatment plays an important role in decision-making behavior as it enhances not only the attention related to the type of gambles played, but also appears to increase sensitivity to losses. The latter can be potentially employed as a cognitive mechanism that may help in refraining from gambling. These findings therefore suggest promising new avenues of research with pathological gamblers that can potentially be usefully employed in clinical treatment, as well as in standard models of decision-making.

#### 4.1. Limitations and future direction

Each of the two subgroups of PG used here is of a relatively small size, which can be seen as a limitation of this study as it may partially restrict the generalization of the results. However, this study is in line with the sample size of other studies with clinical populations (Miu et al., 2008; Giorgetta et al., 2012; Grecucci et al., 2013) and the two subgroups were composed of homogeneous patients with quite ‘pure’ pathological gambling problem, not under pharmacological treatment, recruited in the same clinical center, and enrolled therefore in the same clinical treatment. Also, future studies can investigate differences, between the pre- and post-clinical treatments, in decision processes related also to other relevant factors in decision-making, such as for example reward and time discounting, which may lead gamblers to make impaired decisions. This will greatly assist in deepening our knowledge with regards to the behavior of pathological gamblers in respect to decision-making, results of which can be usefully employed in both fields of clinical treatment and decision-making.

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