



## Research Paper

## Decision-making and risk-taking in forensic and non-forensic patients with schizophrenia spectrum disorders: A multicenter European study

Laura Iozzino<sup>a</sup>, Nicola Canessa<sup>b,c</sup>, Paola Rucci<sup>d</sup>, Marica Iommi<sup>d</sup>, Alexander Dvorak<sup>e</sup>, Janusz Heitzman<sup>f</sup>, Inga Markiewicz<sup>f</sup>, Marco Picchioni<sup>g,h</sup>, Anna Pilszyk<sup>f</sup>, Johannes Wancata<sup>i</sup>, Giovanni de Girolamo<sup>a,\*</sup>, for the EU-VIORMED group

<sup>a</sup> IRCCS Istituto Centro San Giovanni di Dio Fatebenefratelli, Unit of Epidemiological Psychiatry and Evaluation, via Pilastroni 4, 25125 Brescia, Italy

<sup>b</sup> Scuola Universitaria Superiore IUSS, IUSS Cognitive Neuroscience (ICoN) Center, Piazza della Vittoria 15, 27100 Pavia, Italy

<sup>c</sup> Istituti Clinici Scientifici Maugeri IRCCS, Cognitive Neuroscience Laboratory of Pavia Institute, via S. Maugeri 10, 27100 Pavia, Italy

<sup>d</sup> University of Bologna, Department of Biomedical and Neuromotor Sciences, Piazza di Porta S. Donato 2, 40127 Bologna, Italy

<sup>e</sup> Ministry of Justice, Medical Director of the Justizanstalt Göllersdorf, Museumstraße 7, 1070 Vienna, Austria

<sup>f</sup> Institute of Psychiatry and Neurology, Department of Forensic Psychiatry, Jana III Sobieskiego 9, 02-957 Warsaw, Poland

<sup>g</sup> Institute of Psychiatry, Psychology and Neuroscience, King's College London, Department of Forensic and Neurodevelopmental Science, 16 De Crespigny Park, SE5 8AF London, UK

<sup>h</sup> St Magnus Hospital, Haslemere, GU27 3PX Surrey, UK

<sup>i</sup> Medical University of Vienna, Clinical Division of Social Psychiatry, Währinger Gürtel 18-20, 1090 Vienna, Austria

## ARTICLE INFO

## Keywords:

Violence  
Schizophrenia  
Forensic mental health services  
Decision-making  
Risk-taking

## ABSTRACT

Studies of patients with schizophrenia and offenders with severe mental disorders decision-making performance have produced mixed findings. In addition, most earlier studies have assessed decision-making skills in offenders or people with mental disorders, separately, thus neglecting the possible additional contribution of a mental disorder on choice patterns in people who offend.

This study aimed to fill this gap by comparing risk-taking in patients with schizophrenia spectrum disorders (SSD), with and without a history of serious violent offending assessing whether, and to what extent, risk-taking represents a significant predictor of group membership, controlling for their executive skills, as well as for socio-demographic and clinical characteristics.

Overall, 115 patients with a primary diagnosis of SSD were recruited: 74 were forensic patients with a lifetime history of severe interpersonal violence and 41 were patients with SSD without such a history. No significant group differences were observed on psychopathological symptoms severity. Forensic generally displayed lower scores than non-forensic patients in all cognitive subtests of the Brief Assessment of Cognition in Schizophrenia (except for the “token motor” and the “digit sequencing” tasks) and on all the six dimensions of the Cambridge Gambling Task, except for “*Deliberation time*”, in which forensic scored higher than non-forensic patients. “*Deliberation time*” was also positively, although weakly correlated with “poor impulse control”.

Identifying those facets of impaired decision-making mostly predicting offenders' behaviour among individuals with mental disorder might inform risk assessment and be targeted in treatment and rehabilitation protocols.

## 1. Introduction

Decision-making typically entails the evaluation of multiple options that may differ in the valence, magnitude and/or probability of their outcomes, to select one which might be then translated into an actual behaviour. Economic models of decision-making (i.e., the Rational

Choice Theory-RCT) suggest that this process includes a cost-benefit analysis, driving choices towards the option associated with the highest cost-benefit ratio. It is widely accepted, however, that both attention and working memory limitations, and the influence of emotional and motivational factors bias humans' choices away from the prescriptions of normative economic models (Hastie, 2001). In keeping with Damasio

\* Corresponding author.

E-mail address: [gdegirolamo@fatebenefratelli.eu](mailto:gdegirolamo@fatebenefratelli.eu) (G. de Girolamo).

<https://doi.org/10.1016/j.scog.2022.100257>

Received 7 March 2022; Received in revised form 9 May 2022; Accepted 9 May 2022

2215-0013/© 2022 The Authors. Published by Elsevier Inc. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

et al.'s (1991) "somatic marker hypothesis", neurobiological models of decision-making suggest that evaluative processes engage emotional and bodily states associated with prospective outcomes (e.g., [Canessa et al., 2013, 2017](#); [Sokol-Hessner et al., 2015](#)). By covertly biasing choices towards those previously associated with rewards, and away from those associated with punishments, these anticipatory signals not only reduce the number of available options and deliberation time, but also tend to bypass formal cost-benefit analyses. So-called "risk aversion" is the most typical instance of choice patterns departing from "rational" economic predictions embodied in the usual preference for certain compared with probabilistic outcomes ([Kahneman and Tversky, 1984](#); [De Martino et al., 2006](#)).

### 1.1. Decision-making in patients with schizophrenia

Studies of patients with schizophrenia decision-making performance has produced mixed findings, either of altered performance on decision-making tasks by patients with psychosis or schizophrenia ([Brown et al., 2013](#); [Msk et al., 2021](#); [Pedersen et al., 2017](#); [Sabater-Grande et al., 2020](#)), or of choice patterns comparable to those of healthy people ([Currie et al., 2017](#); [Trémeau et al., 2008](#)). Despite such inconsistencies, it is noteworthy that these studies have also highlighted a limited relationship, mainly involving working-memory, between decision-making skills and executive performance ([Shurman et al., 2005](#)). With regard to psychopathology, a recent meta-analysis on decision-making in psychosis has shown no association between overall psychotic symptoms, general psychopathology (assessed using the PANSS) and the quality of choices ([Woodrow et al., 2019](#)). On the other hand, there is evidence of a moderate association between decision-making performance and social functioning ([Woodrow et al., 2019](#)).

### 1.2. Decision-making in offenders with mental disorders

The quality of decision-making in offenders is also controversial ([Yechiam et al., 2008](#)). Drawing on criminological theory, both impaired evaluative processes and low levels of self-control are popular explanations for offenders' decision to commit crime ([Piquero and Tibbetts, 1996](#)). In this framework, interpreting offenders' choices and behaviours must take into account the availability of relevant information ([Cornish and Clarke, 1987, 2014](#)), alongside their ability to integrate multiple choice-related variables such as the magnitude and probability of positive and negative outcomes, while considering that these processes are subject to considerable individual differences.

Explaining, and indeed even predicting, offenders' choices and behaviours might thus greatly benefit from a neuropsychological assessment including choice-related metrics ([Beszterczey et al., 2013](#)). An improved understanding of decision-making in mentally disordered offenders may even open new treatment avenues, if decision-making was identified as a critical node in the complex pathway leading eventually to violent behaviour. Identifying those facets of impaired decision-making mostly predicting offenders' behaviour among individuals with mental disorder might inform risk assessment and be targeted in treatment and rehabilitation protocols. Besides improving the quality of patient care, any advance in this respect might help to reduce rates of recidivism and harm to society, and thus the burden on penal systems.

Importantly, most earlier studies have assessed decision-making skills in offenders (see [Jones et al., 2019](#)) and people with mental disorders (e.g., [Hiser and Koenigs, 2018](#)) separately, thus neglecting the possible additional contribution of a mental disorder on choice patterns in people who offend. We thus aimed to fill this gap by comparing risk-taking in patients with schizophrenia spectrum disorders (SSD), with and without a history of serious violent offending. Risk aptitude was assessed using the Cambridge Gambling Task (CGT), a well-established tool to evaluate different facets of decision-making ([Rogers et al., 1999](#)). In particular, we aimed to assess whether, and to what extent, risk-taking represents a significant predictor of group membership between

patients with SSD with or without a history of severe interpersonal violence, controlling for socio-demographic and clinical characteristics.

## 2. Methods

### 2.1. Participants

EU-VIORMED is a European multicentre observational study. The field work was conducted in five European countries: Austria, Germany, Italy, Poland and England. Subjects were aged between 18 and 65 years with a primary DSM-5 diagnosis of an SSD. "Cases" were patients with a primary diagnosis of an SSD and a history of significant interpersonal violence. They were recruited from multiple forensic services in each country. Significant interpersonal violence was defined as a homicide, attempted homicide or other assault that caused serious physical injury to another person. "Controls" were sex and age-matched patients with SSDs who have never committed such an act of violence and were recruited from general psychiatric services. Exclusion criteria included: (i) a confirmed intellectual disability; (ii) a traumatic brain injury or organic brain disorders; (iii) not being able to speak the national language fluently; and (iv) planned discharge from psychiatric services in the next month.

Initial plans were to recruit 200 cases and 200 gender- and age-matched controls. However, the worldwide coronavirus outbreak and the resulting restrictions from February 2020 caused recruitment to temporarily halt in every country. Once recruitment restarted, the persistence of restrictions on social contact made it feasible to over-recruit cases rather than controls. Due to restrictions on electronic devices (Ipad) entering secure clinical services in Austria, Germany and UK the study was conducted only in Italy and Poland.

The study was approved by the Research Ethics Committee for the coordinating Centre (IRCCS Centro San Giovanni di Dio Fatebenefratelli, Brescia, Italy: n. 74–2018), and by the relevant Research Ethics Committees for each of the participating sites (listed at the end of the paper). All participants provided written informed consent before entering the study.

### 2.2. Measures

Socio-demographic, core clinical and criminological and violence risk data were collected using a study-specific Patient Information Form (PIF), an Index Violence Sheet (IVS) and a Risk Factors Questionnaire (RFQ) based on patient interviews cross referenced with the medical records and clinical review. DSM-5 diagnoses were based on clinicians' evaluations extracted from the medical records.

Current psychotic symptoms were assessed using the Positive and Negative Syndrome Scale (PANSS) ([Kay et al., 1987](#)), based on a semi-structured patient interview and clinical observation. PANSS scoring used the original standard PANSS model; the PANSS overall total score ranges from 30 to 210.

The World Health Organization Disability Assessment Schedule 2.0 (WHODAS 2.0) ([Ustün et al., 2010](#)) was used to assess day-to-day functioning across six functional domains: cognition, mobility, self-care, getting along, life activities and participation. Scores were calculated as a sum of items, yielding a total from 0 to 48, with higher scores indicating more severe problems.

### 2.3. Cognitive assessment

The Brief Assessment of Cognition in Schizophrenia (BACS) ([Keefe et al., 2004](#)) is a paper and-pencil standardized neuropsychological instrument used to evaluate cognitive impairments and their relationship with functional outcomes in patients with schizophrenia. It includes six tests measuring different cognitive constructs: verbal memory (list learning) and working-memory (Digit Sequencing Task), motor speed (Token Motor Task), verbal fluency (semantic and letter fluency),

attention and speed information processing (Symbol Coding Task) and executive functions (Tower of London).

#### 2.4. Decision-making task

The computerized Cambridge Gambling Task was presented on an iPad (Fray et al., 1996). On each trial, subjects were initially presented with a configuration of ten boxes, either red or blue, at the top of the screen, and told that a yellow token was randomly hidden inside one box. The ratio of red to blue boxes varied from trial to trial, and subjects were first asked to decide whether the token was hidden inside a red or a blue box. They are then asked to place a “bet” on the confidence in their choice in order to increase an initial endowment of 100 points (arbitrary units). To this purpose, possible bets appear in an ascending or descending sequence at the screen centre, and subjects are asked to respond when the preferred bet appears. The possible bets represent a fixed percentage (5, 15, 50, 75 and 95%) of the current total score. After selecting a bet, one of the boxes at the top of the display opens to reveal the actual location of the yellow token, and the chosen bet is added or subtracted from the total points score according to whether or not the initial colour prediction was correct.

The task comprises eight blocks of nine trials each. Three features of this task allow for a detailed analysis of decision-making performance. Firstly, the request to bet a variable proportion of the total score allows the assessment of the subjects' willingness to make a risky investment in order to acquire further reward, and provides a rating of their confidence in the associated decision. Secondly, the inclusion of both ascending and descending conditions allows to distinguish “impulsive” and “risk taking” betting strategies. Namely, a pattern of low bets in the ascend condition and high bets in the descend condition is suggestive of high impulsivity, would the opposite hold for risk-taking. Therefore, a large or small difference between the mean percentage bet in these two conditions indicates impulsivity or risk-seeking, respectively. Finally, since some ratios of red to blue boxes provide a better indication than others about the response likely to be reinforced (e.g., 9 red: 1 blue vs 6 red: 4 blue), this aspect of the task allows for the assessment of subject's sensitivity to changing information. A subject's decision on colour, associated bets and deliberation times are thus expected to vary as a function of the ratio of red to blue boxes.

For the purpose of this study six outcome measures were extracted:

1. *Delay aversion*, which allows to distinguish between risk-taking and impulsivity by determining whether subjects simply just place a bet at the first opportunity. It is calculated as CGT risk-taking for all trials from the descending minus ascending condition.
2. *Deliberation time*, i.e., the mean latency (in milliseconds) from the presentation of red-blue boxes to the subject's colour selection. It is calculated over all the assessed trials in both the ascending and descending conditions.
3. *Risk-taking*, i.e., the mean proportion (0–1) of current points gambled by the subject. It is calculated over all the assessed trials from both the ascending and descending conditions in which the number of boxes in each colour differed and the subjects chose the most likely outcome.
4. *Quality of decision-making*: the proportion (0–1) of all trials in which the subject chose the most likely outcome. It is calculated over all the assessed trials from both the ascending and descending conditions.
5. *Risk adjustment*, i.e., a measure of sensitivity to risk, based on the ability to a) adapt choices to the available information about the probability of different outcomes, and b) track the optimal outcome on each trial. This measure is calculated from the average proportion of points that the subject chose to bet, while taking into account the number of coloured boxes.
6. *Overall proportion bet*, i.e., the mean proportion (0–1) of current points gambled by the subject. It is calculated over all the assessed trials from both the ascending and descending conditions.

#### 2.5. Statistical analyses

Continuous variables were compared between violent and non-violent groups using *t*-tests or Mann-Whitney tests, as appropriate. Categorical variables were compared between the two groups using  $\chi^2$  test. The correlation among the six dimensions of CGT (*Quality decision-making; Deliberation time; Risk taking; Overall Proportion Bet; Risk adjustment; Delay Aversion*), stratified for forensic and non-forensic patients, was evaluated using Spearman's correlation coefficient.

Generalized linear models (GLM) were implemented to compare CGT scores between forensic and non-forensic patients, adjusting for the effect of confounders. Variables associated with both CGT scores and type of patient (forensic and non-forensic) were considered as confounders.

All statistical analyses were conducted using the Statistical Package for the Social Sciences (SPSS), version 25.0. The level of significance was set at  $p < 0.05$ .

### 3. Results

The final sample consisted of 115 patients with a primary diagnosis of SSD: 74 cases had a lifetime history of severe interpersonal violence and 41 controls with no such history, with a significantly higher proportion of violent cases assessed in Poland (39 out of 50 patients; 52.7%) compared to Italy (35 out of 65 patients; 47.3%) ( $\chi^2$  test = 7.2,  $p = 0.007$ ).

Forensic and non-forensic patients did not differ on age (mean age forensic 39.9, SD = 12.3; mean age non-forensic 38.9, SD = 12.8), marital, occupational status and education (Table 1). Compared to controls, cases more often had children ( $p = 0.029$ ).

The type of SSD diagnosis was differed significantly between the two groups ( $\chi^2$  test = 13.6,  $p = 0.019$ ): forensic patients were more likely to have a delusional disorder (13.5% vs. 0% for non-forensic) and less likely to have a schizoaffective disorder (6.8% vs. 22% for non-forensic); comorbidity with personality disorders was more common among forensic than non-forensic patients (28.4% vs. 5.0%, respectively;  $\chi^2$  test = 8.8,  $p = 0.003$ ). Forensic patients were more likely to have witnessed violence (37.0% vs. 17.9%, respectively;  $\chi^2$  test = 4.4,  $p = 0.037$ ), and to have been beaten, kicked or punched by someone (62.2% vs. 38.5%, respectively;  $\chi^2$  test = 5.8,  $p = 0.016$ ). No significant group differences were observed either on the current PANSS total score ( $p = 0.577$ ), or on positive ( $p = 0.855$ ), negative ( $p = 0.543$ ) and general score ( $p = 0.415$ ).

Forensic generally displayed lower scores than non-forensic patients in all subtests of the BACS, except for the “token motor” and the “digit sequencing” tasks, for which no differences were found.

The frequency distribution of CGT scores was asymmetric for “Quality of decision-making” (forensic: Shapiro-Wilk test = 0.62,  $p < 0.001$ ; non-forensic: Shapiro-Wilk test = 0.74,  $p < 0.001$ ) towards higher scores, and “Deliberation time” (forensic: Shapiro-Wilk test = 0.78,  $p < 0.001$ ; non-forensic: Shapiro-Wilk test = 0.68,  $p < 0.001$ ), towards shorter times for both forensic and non-forensic patients. Other dimensions were normally distributed among the two groups.

Forensic and non-forensic patients did not differ in the six dimensions of CGT, except for “Risk-taking” (Table 2), in which forensic scored higher than non-forensic patients ( $M = 0.62$ ,  $SD = 0.17$  vs.  $M = 0.55$ ,  $SD = 0.21$ ;  $t$ -test =  $-2.09$ ,  $p = 0.039$ ). Fig. 1S shows the distribution of CGT scores of the six dimensions for both groups.

In both forensic and non-forensic patients, “Risk-taking” and “Overall Proportion Bet” scores were strongly correlated (Spearman's rho = 0.98,  $p < 0.01$ ) (Table 3). In non-forensic patients “Quality of decision-making” was negatively and moderately correlated with “Deliberation time” (Spearman's rho =  $-0.58$ ,  $p < 0.01$ ) and “Delay Aversion” (Spearman's rho =  $-0.42$ ,  $p < 0.01$ ). In forensic patients “Quality of decision-making” was also moderately and negatively correlated with “Deliberation time” (Spearman's rho =  $-0.43$ ,  $p < 0.01$ ) and positively correlated with “Risk-adjustment” (Spearman's rho = 0.55,  $p < 0.01$ ).

Univariate GLMs were estimated for each dimension of CGT using

**Table 1**  
Comparison of demographic and clinical characteristics between forensic and non-forensic patients.

|                                     | Forensic<br>(n = 74) |        | Non-forensic<br>(n = 41) |        | Test                  | p-Value      |
|-------------------------------------|----------------------|--------|--------------------------|--------|-----------------------|--------------|
| Sex, n %                            |                      |        |                          |        | 1.91 <sup>a</sup>     | 0.166        |
| Male                                | 65                   | 87.8%  | 32                       | 78.0%  |                       |              |
| Female                              | 9                    | 12.2%  | 9                        | 22.0%  |                       |              |
| Age, mean (SD)                      | 39.9 (12.3)          |        | 38.9 (12.8)              |        | -0.40 <sup>c</sup>    | 0.692        |
| Country, n %                        |                      |        |                          |        | 7.19 <sup>a</sup>     | <b>0.007</b> |
| Italy                               | 35                   | 47.3%  | 30                       | 73.2%  |                       |              |
| Poland                              | 39                   | 52.7%  | 11                       | 26.8%  |                       |              |
| Brothers/sisters, n %               |                      |        |                          |        | 1.28 <sup>a</sup>     | 0.258        |
| No                                  | 13                   | 17.6%  | 4                        | 9.8%   |                       |              |
| Yes                                 | 61                   | 82.4%  | 37                       | 90.2%  |                       |              |
| Marital status, n %                 |                      |        |                          |        | 0.01 <sup>a</sup>     | 0.910        |
| Single/widowed/divorced             | 69                   | 93.2%  | 38                       | 92.7%  |                       |              |
| Married                             | 5                    | 6.8%   | 3                        | 7.3%   |                       |              |
| Highest occupational status, n %    |                      |        |                          |        | 0.61 <sup>a</sup>     | 0.894        |
| Never worked                        | 11                   | 14.9%  | 6                        | 14.6%  |                       |              |
| Unskilled worker                    | 40                   | 54.1%  | 22                       | 53.7%  |                       |              |
| Skilled worker                      | 20                   | 27.0%  | 10                       | 24.4%  |                       |              |
| Professional                        | 3                    | 4.1%   | 3                        | 7.3%   |                       |              |
| Years of education, mean (SD)       | 12.0 (4.0)           |        | 11.4 (3.9)               |        | 0.71 <sup>c</sup>     | 0.481        |
| Children, n %                       |                      |        |                          |        | 4.77 <sup>a</sup>     | <b>0.029</b> |
| No                                  | 54                   | 73.0%  | 37                       | 90.2%  |                       |              |
| Yes                                 | 20                   | 27.0%  | 4                        | 9.8%   |                       |              |
| Disease duration, median [IQR]      | 10 [4–17]            |        | 10 [4–20]                |        | 1461 <sup>b</sup>     | 0.743        |
| Type of SSDs, n %                   |                      |        |                          |        | 13.55 <sup>a</sup>    | <b>0.019</b> |
| Schizophrenia                       | 53                   | 71.6%  | 31                       | 75.6%  |                       |              |
| Schizoaffective disorders           | 5                    | 6.8%   | 9                        | 22.0%  | Non-forensic>forensic |              |
| Delusional disorder                 | 10                   | 13.5%  | 0                        | 0.0%   | Forensic>non-forensic |              |
| Brief psychotic disorder            | 1                    | 1.4%   | 0                        | 0.0%   |                       |              |
| Schizophreniform disorder           | 4                    | 5.4%   | 0                        | 0.0%   |                       |              |
| Drug-induced psychosis              | 1                    | 1.4%   | 1                        | 2.4%   |                       |              |
| Type of SSDs (2 categories), n %    |                      |        |                          |        | 0.21 <sup>a</sup>     | 0.644        |
| Schizophrenia                       | 53                   | 71.6%  | 31                       | 75.6%  |                       |              |
| Other disorders                     | 21                   | 28.4%  | 10                       | 24.4%  |                       |              |
| Comorbidity with PD, n %            |                      |        |                          |        | 8.81 <sup>a</sup>     | <b>0.003</b> |
| No                                  | 53                   | 71.6%  | 38                       | 95.0%  |                       |              |
| Yes                                 | 21                   | 28.4%  | 2                        | 5.0%   |                       |              |
| Witnessed of violence, n %          |                      |        |                          |        | 4.36 <sup>a</sup>     | <b>0.037</b> |
| No                                  | 46                   | 63.0%  | 32                       | 82.1%  |                       |              |
| Yes                                 | 27                   | 37.0%  | 7                        | 17.9%  |                       |              |
| Victim of violence, n %             |                      |        |                          |        | 2.59 <sup>a</sup>     | 0.107        |
| No                                  | 49                   | 67.1%  | 31                       | 81.6%  |                       |              |
| Yes                                 | 24                   | 32.9%  | 7                        | 18.4%  |                       |              |
| Beaten, kicked, punched, n %        |                      |        |                          |        | 5.78 <sup>a</sup>     | <b>0.016</b> |
| No                                  | 28                   | 37.8%  | 24                       | 61.5%  |                       |              |
| Yes                                 | 46                   | 62.2%  | 15                       | 38.5%  |                       |              |
| Attempted suicide/self-harm, n %    |                      |        |                          |        | 0.43 <sup>a</sup>     | 0.511        |
| No                                  | 46                   | 62.2%  | 28                       | 68.3%  |                       |              |
| Yes                                 | 28                   | 37.8%  | 13                       | 31.7%  |                       |              |
| Lifetime substance/alcohol use, n % |                      |        |                          |        | 0.11 <sup>a</sup>     | 0.736        |
| No                                  | 23                   | 31.1%  | 14                       | 34.1%  |                       |              |
| Yes                                 | 51                   | 68.9%  | 27                       | 65.9%  |                       |              |
| PANSS, mean (SD)                    |                      |        |                          |        |                       |              |
| Positive                            | 7.3                  | (6.3)  | 7.5                      | (5.7)  | 0.18 <sup>c</sup>     | 0.855        |
| Negative                            | 12.3                 | (7.0)  | 11.5                     | (6.9)  | -0.61 <sup>c</sup>    | 0.543        |
| General                             | 18.8                 | (10.6) | 17.2                     | (9.5)  | -0.82 <sup>c</sup>    | 0.415        |
| Total score                         | 38.4                 | (21.1) | 36.2                     | (19.4) | -0.56 <sup>c</sup>    | 0.577        |
| BACS, mean (SD)                     |                      |        |                          |        |                       |              |
| List learning                       | 35.4                 | (10.2) | 37.7                     | (12.2) | 1.05 <sup>c</sup>     | 0.297        |
| Digit sequencing task               | 15.2                 | (4.3)  | 15.7                     | (5.4)  | 0.55 <sup>c</sup>     | 0.586        |
| Token motor task                    | 57.7                 | (16.2) | 57.1                     | (18.8) | -0.17 <sup>c</sup>    | 0.868        |
| Verbal fluency                      | 34.4                 | (11.7) | 38.1                     | (13.7) | 1.52 <sup>c</sup>     | 0.132        |
| Symbol coding                       | 35.5                 | (14.6) | 39.0                     | (16.0) | 1.21 <sup>c</sup>     | 0.228        |
| Tower of London test                | 14.4                 | (5.1)  | 15.7                     | (4.5)  | 1.33 <sup>c</sup>     | 0.187        |

Significant associations (p-Value<0.05) are highlighted in bold.

<sup>a</sup> Chi-square test.

<sup>b</sup> Mann-Whitney *U* test.

<sup>c</sup> *t*-Test.

inverse-gamma distribution and log-link function (“Quality of decision-making”, “Deliberation time”, “Risk-taking” and “Overall Proportion Bet” dimensions), and normal distribution and identity link function (“Risk-adjustment” and “Delay Aversion” dimensions), to compare scores

between forensic and non-forensic groups. Only “Deliberation time” was significantly different between forensic and non-forensic patients (2396.6 vs. 3347.9 milliseconds, respectively), with a mean difference of 951.3 milliseconds (95% CI [277.1; 1.625.4]; *p* = 0.003).

**Table 2**  
Comparison of *Cambridge Gambling Task* scores between forensic and non-forensic patients.

|                         | Forensic (n = 74)  | Non-forensic (n = 41) | test               | p-Value      |
|-------------------------|--------------------|-----------------------|--------------------|--------------|
| Quality decision-making |                    |                       | 1725 <sup>a</sup>  | 0.207        |
| Mean (SD)               | 0.93 (0.12)        | 0.88 (0.17)           |                    |              |
| Median [IQR]            | 0.97 [0.91; 1]     | 0.94 [0.88; 1.00]     |                    |              |
| Deliberation time       |                    |                       | 1226 <sup>a</sup>  | 0.089        |
| Mean (SD)               | 2396.6 (1308.1)    | 3347.9 (2913)         |                    |              |
| Median [IQR]            | 2009 [1471; 2810]  | 2421 [1701; 3836]     |                    |              |
| Risk taking             |                    |                       | -2.09 <sup>b</sup> | <b>0.039</b> |
| Mean (SD)               | 0.62 (0.17)        | 0.55 (0.21)           |                    |              |
| Median [IQR]            | 0.63 [0.51; 0.75]  | 0.56 [0.40; 0.70]     |                    |              |
| Overall proportion bet  |                    |                       | -1.92 <sup>b</sup> | 0.060        |
| Mean (SD)               | 0.59 (0.16)        | 0.52 (0.21)           |                    |              |
| Median [IQR]            | 0.59 [0.50; 0.68]  | 0.52 [0.43; 0.71]     |                    |              |
| Risk adjustment         |                    |                       | -1.24 <sup>b</sup> | 0.219        |
| Mean (SD)               | 0.90 (1.06)        | 0.63 (1.19)           |                    |              |
| Median [IQR]            | 0.73 [0.22; 1.56]  | 0.37 [-0.18; 1.58]    |                    |              |
| Delay aversion          |                    |                       | 0.94 <sup>b</sup>  | 0.500        |
| Mean (SD)               | 0.12 (0.26)        | 0.16 (0.27)           |                    |              |
| Median [IQR]            | 0.08 [-0.05; 0.25] | 0.08 [0; 0.30]        |                    |              |

Significant associations (p-Value<0.05) are highlighted in bold.

<sup>a</sup> Mann-Whitney *U* test.

<sup>b</sup> *t*-Test.

**Table 3**  
Spearman's rho correlations of CGT dimensions by forensic and non-forensic patient groups.

|                     | DMQMT | DMMT            | RTKMT          | OPBMT          | RAJMT           | DAVT            |
|---------------------|-------|-----------------|----------------|----------------|-----------------|-----------------|
| <b>Forensic</b>     |       |                 |                |                |                 |                 |
| DMQMT               | 1     | <b>-0.429**</b> | <b>-0.232*</b> | <b>-0.234*</b> | <b>0.552**</b>  | -0.024          |
| DMMT                |       | 1               | 0.037          | 0.054          | <b>-0.349**</b> | -0.219          |
| RTKMT               |       |                 | 1              | <b>0.978**</b> | <b>-0.237*</b>  | 0.072           |
| OPBMT               |       |                 |                | 1              | <b>-0.262*</b>  | 0.036           |
| RAJMT               |       |                 |                |                | 1               | -0.160          |
| DAVT                |       |                 |                |                |                 | 1               |
| <b>Non-forensic</b> |       |                 |                |                |                 |                 |
| DMQMT               | 1     | <b>-0.578**</b> | 0.130          | 0.168          | 0.244           | <b>-0.416**</b> |
| DMMT                |       | 1               | -0.104         | -0.120         | -0.112          | 0.113           |
| RTKMT               |       |                 | 1              | <b>0.980**</b> | -0.026          | 0.035           |
| OPBMT               |       |                 |                | 1              | -0.045          | 0.037           |
| RAJMT               |       |                 |                |                | 1               | -0.179          |
| DAVT                |       |                 |                |                |                 | 1               |

DMQMT: Quality decision-making; DMMT: Deliberation time; RTKMT: Risk taking; OPBMT: Overall Proportion Bet; RAJMT: Risk adjustment; DAVT: Delay Aversion. Significant associations (p-Value<0.05) are highlighted in bold.

\*\* Correlation is significant at the 0.01 level (2-tailed).

\* Correlation is significant at the 0.05 level (2-tailed).

Among potential confounders (e.g., sex, country, having children, comorbidity with PD, being witness of violence, being beaten, kicked or punched), only country was identified as an actual confounder because it was associated with CGT “*Deliberation time*” and “*Delay Aversion*” scores, and showed significant differences between forensic and non-forensic patients.

After adjusting for country, the “*Deliberation time*” of forensic patients remained significantly lower compared to non-forensic patients (2418.6 vs. 3092.8 milliseconds, respectively), with a mean difference of 674.2 millisecond (95% CI [4.1; 1344.3];  $p = 0.036$ ). The “*Delay Aversion*” scores did not differ between the two groups after adjusting for the country (Table 4).

“*Deliberation time*” was positive, although weakly correlated with the item G14 (“poor impulse control”) of the PANSS scale in the forensic group (Rho = -0.363,  $p = 0.020$ ): therefore, lower behavioural regulation and control were associated with higher response latency. In the non-forensic group, we found a positive, although weak, correlation between “BACS-ToL” and “*deliberation time*” (Rho = 0.28,  $p = 0.015$ ). No associations were found between type of crimes and *deliberation time* in forensic patients.

#### 4. Discussion

We assessed decision-making abilities in patients with a primary diagnosis of an SSD, with or without a history of serious violence, to investigate possible cognitive drivers of altered choice patterns favouring violent behaviour. Group comparisons highlighted greater risk-taking and a shorter *deliberation time* in forensic than non-forensic patients.

These findings contribute to existing data showing both greater risk-seeking levels (Becker, 1968), or normal adjustments of risk-taking to outcome probability (Block and Gerety, 1995; Grogger, 1991) in offenders. Some of the inconsistencies found in previous studies might reflect intrinsic differences in the specific demands posed on cognitive processing by different decision-making tasks. In this respect, it is noteworthy that the few studies reporting greater risk-taking in offenders have generally used the Iowa Gambling Task (Jones et al., 2019), which requires the coordinated activity of both reasoning and affective processes generally subsumed under the notions of “hot” and “cool” executive functions (Dunn et al., 2006). The latter includes processes characterized by their inherently cognitive nature such as working memory, response inhibition or planning, typically associated with

**Table 4**

Univariate and multiple generalized linear models to estimate the relation between type of subject (forensic vs. non-forensic) and CGT scores, adjusted for socio-demographic and clinical confounders.

| Predictors            | Dependent variables |                       |                    |                    |                    |                       |
|-----------------------|---------------------|-----------------------|--------------------|--------------------|--------------------|-----------------------|
|                       | DMQMT               | DMMT                  | RTKMT              | OPBMT              | RAJMT              | DAVT                  |
| Univariate models     | B [95% CI]          | B [95% CI]            | B [95% CI]         | B [95% CI]         | B [95% CI]         | B [95% CI]            |
| Type of subject       |                     |                       |                    |                    |                    |                       |
| Non-forensic patients | Ref. cat.           | Ref. cat.             | Ref. cat.          | Ref. cat.          | Ref. cat.          | Ref. cat.             |
| Forensic patients     | 0.05 [−0.02; 0.13]  | −0.33 [−0.55; −0.12]* | 0.13 [−0.05; 0.31] | 0.13 [−0.05; 0.31] | 0.27 [−0.15; 0.69] | −0.05 [−0.15; 0.05]   |
| Multiple models       |                     | B [95% CI]            |                    |                    |                    | B [95% CI]            |
| Type of subject       |                     |                       |                    |                    |                    |                       |
| Non-forensic patients | –                   | Ref. cat.             | –                  | –                  | –                  | Ref. cat.             |
| Forensic patients     | –                   | −0.25 [−0.48; −0.02]* | –                  | –                  | –                  | −0.01 [−0.11; 0.09]   |
| Country               |                     |                       |                    |                    |                    |                       |
| Italy                 | –                   | Ref. cat.             | –                  | –                  | –                  | Ref. cat.             |
| Poland                | –                   | −0.21 [−0.42; −0.01]* | –                  | –                  | –                  | −0.14 [−0.23; −0.04]* |

B: coefficients of the regressions.

95% CI: 95% confidence interval.

\* p-Value < 0.05.

DMQMT: Quality decision-making; DMMT: Deliberation time; RTKMT: Risk taking; OPBMT: Overall Proportion Bet; RAJMT: Risk adjustment; DAVT: Delay Aversion.

abstract and decontextualized problems and with the engagement of the fronto-parietal executive brain networks (De Brito et al., 2013). On the contrary, the notion of “hot executive functions” refers to processes involving an assessment of affective, motivational and/or reward incentive values of the available options, recruiting the meso-cortico-limbic pathway (Berridge and Kringelbach, 2008; Doya, 2008). It might be argued, however, that a detailed characterization of decision-making skills requires tasks minimizing demands in terms of processes other than the evaluation of available options, including the processing/inhibition of affective drives, behavioural learning or high-order executive functions. To overcome these limitations, we used the CGT, which appears better suited to measure risk aptitude, for several reasons. First, it allows to assess decision-making and risk-taking outside a learning context, while minimizing executive and working memory demands on participants, as the information which is required to make decisions is always visible (Fellows and Farah, 2005). Moreover, since this information also includes the number of red/blue boxes, unlike the Iowa Gambling Task and other widely used tests such as the Balloon Analog Risk Taking Task (BART) (e.g., Bechara et al., 2005; Lejuez et al., 2002; Fein et al., 2006; Le Berre et al., 2014; Zorlu et al., 2013), the CGT entails making decisions under conditions of known risk, rather than ambiguity. Finally, the CGT allows to distinguish between decision-making in itself, i.e., choosing what to bet on, and risk-taking, i.e., how much to bet on that choice.

#### 4.1. Previous research with CGT in psychiatric and forensic samples

To date, only one study used the CGT to investigate decision-making performance in violent offenders with antisocial personality disorder, while comparing two subgroups with and without psychopathy (De Brito et al., 2013). According to this study, there was some evidence of poorer decision-making in both offender groups compared with healthy controls, as shown by significantly longer deliberation time, a trend for decreased adjustment of risk-taking to changing probabilities, but also no significant difference in risk-taking. The present data extend this evidence both in terms of a larger sample-size, and by recruiting non-violent patients with SSD as a primary control group, to better disentangle the effects of mental disorders from other clinically-relevant factors which might otherwise contribute to seemingly antisocial behaviour.

While the result of shorter deliberation time and higher risk-taking in forensic SSD patients might be suggestive of increased impulsivity in this population, this interpretation is ruled out by the lack of significant differences in the CGT “delay aversion” metric. In line with the sensitivity of CGT performance to orbitofrontal damage (Newcombe et al.,

2011; Rogers et al., 1999), the combination of slowed decision-making and increased risk-taking resembles choice patterns displayed by patients with ventromedial prefrontal lesions (e.g., Rogers et al., 1999; Rahman et al., 1999; Manes et al., 2002), who tend to persist in maladaptive behaviours despite full conscious knowledge of their adverse outcomes (Bechara et al., 1997).

#### 4.2. Limitations

Several methodological limitations should be considered in interpreting the results of the present study. The first is the limited sample size. There may be a lack of statistical power to detect group differences resulting from the relatively small number of non-forensic patients. The number of participants, however was similar or in some cases higher compared to other neuropsychological studies. As pointed out in the participants section, however this limitation was related to the prohibition to introduce electronic devices (Ipad) in the forensic facilities located in three countries. The second limitation was linked to the heterogeneity of the disorder under study. All patients had a clinical diagnosis of SSD, which includes several different disorders characterized by common clinical features, but also displaying different degrees of neuropsychological impairments and different functional cortical alterations. The third limitation refers to the lack of a deep evaluation of executive functions in both groups. This was primary due to the length of the assessment procedure: all evaluations took about 5 h per patients and were organized in multiple sessions. Further researchers with a good executive functions evaluations are needed.

This study had also several strengths: first, it is the first study aimed to assess decision-making abilities in patients with a primary diagnosis of SSD detained for violent crimes in forensic settings; second, it is the first study to compare the characteristics of forensic and non-forensic patients with SSD using standardized and validated instruments which cover different functional assessment areas.

#### 5. Conclusions

The findings from this study provide novel evidence that, in comparison to non-violent patients with SSD, violent patients are characterized by higher risk-taking and a shorter deliberation time. The combinations of these aspects may help explain, taken together, why forensic patients persist in engaging in antisocial behaviours despite knowing the risk of negative consequences to themselves and/or others. These findings pave the way to further studies in which a preliminary characterization of offenders' decision-making deficits might

help designing cognitive-behavioural rehabilitation programs to reduce the risk of recidivisms.

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.scog.2022.100257>.

## Funding

The EUROpean Study on VIOlence Risk and MEntal Disorders (EU-VIORMED) project has received a grant from European Commission (Grant Number PP-2-3-2016, November 2017–September 2021) and is registered on the Research Registry - <https://www.researchregistry.com/> - Unique Identifying Number 4604. In Italy this study has also been supported by 5 × 1000 2017 funds and Ricerca Corrente funds from the Ministry of Health, Italy. In Poland this study has also been supported by funds from the Polish Ministry of Education and Science, contract No. 3865/HP3/17/2018/2. The funding sources had no role in the design and in the conduct of the study, and had no role in data analyses, in the interpretation of results and in the writing of the study report.

## Declaration of competing interest

The authors have declared that there are no conflicts of interests in relation to the subject of this study.

## Acknowledgments

### Collaborators

R. Oberndorfer, A. Reisegger, T. Stompe, (Clinical Division of Social Psychiatry, Department of Psychiatry and Psychotherapy, Medical University of Vienna, Austria); B. Horten, A. Giersiefen, J. Schmidt (Central Institute of Mental Health, Mannheim, Germany); R. Ruiz (Institute of Psychiatry, Psychology and Neuroscience, King's College London); I. Markiewicz, M. Ozimkiewicz, M. Pacholski (Institute of Psychiatry and Neurology, Warsaw).

Acknowledgments are also due to: Austria: M. Koch, S. Stadtmann, A. Unger, H. Winkler (Clinical Division of Social Psychiatry, Department of Psychiatry and Psychotherapy, Medical University of Vienna, Austria), A. Dvorak (Justizanstalt Goellersdorf, Goellersdorf, Austria), A. Kastner (Klinik für Psychiatrie mit forensischem Schwerpunkt, Linz, Austria). Germany: H. Dressing, E. Biebinger (Klinik für Forensische Psychiatrie Klingenmünster), C. Oberbauer (Klinik für Forensische Psychiatrie und Psychotherapie Wiesloch), M. Michel (Klinik für Forensische Psychiatrie und Psychotherapie Weinsberg). Italy: G. Tura, A. Adorni, S. Andreose, S. Bignotti, L. Rillosi (IRCCS Fatebenefratelli, Brescia), F. Franconi, I. Rossetto (REMS ASST Mantova, Italy), A. Veltri (REMS AUSL Toscana Nord-Ovest), C. Vilella, G. Alocci (REMS ASL Roma 5), A. Vita, P. Cacciani, G. Conte (Department of Mental Health, ASST Spedali Civili, Brescia). Poland: I. Markiewicz, M. Ozimkiewicz, A. Pilszyk, M. Pacholski (Institute of Psychiatry and Neurology, Warsaw), A. Welento-Nowacka (Forensic Department, Mental Health Hospital in Starogard Gdański). United Kingdom: N. Blackwood (Institute of Psychiatry, Psychology and Neuroscience, King's College London).

## Author contributions

P.R. and M.I. conducted the analyses. L.I., G.d.G. and N.C. designed the study. L.I., N.C., I.M., A.P., A.D. collected the data. L.I., G.d.G., J.H., J.W., M.P., N.C., I.M., A.P., A.D., P.R. and M.I. interpreted the data, wrote, read, and edited the paper.

## Availability of data and materials

The project will fully embrace the open access data policy of H2020 to make data FAIR (Findable, Accessible, Interoperable, and Re-usable),

and all data gathered in the framework of the project are stored in a public repository (<https://doi.org/10.5281/zenodo.4442372>) accessible to all scientists willing to carry out additional analyses.

## Ethics approval

The project was approved by relevant local or national ethical committees of each country the first approval was obtained by the St. John of God Ethical Committee (coordinating centre) on July 20th, 2018 (permission n. 74–2018); subsequent permissions have been obtained in each of the other recruiting countries according to national and local policies. Here with the details:

- Austria (Medical University of Vienna): approval EK Nr: 1603/2018, date 24.8.2018.
- Germany (Central Institute of Mental Health, Mannheim): approval 2018-582 N-MA, date 10.7.2018.
- Poland (Institute of Psychiatry and Neurology, Warsaw): approval 35/2017, date 7.6.2018.
- UK (King's College, London): approval 18/SW/0264, date 10.12.2018.

## Consent for publication

Participants have been informed about the aims of the project and signed informed consent to the participation and publication of results.

## References

- Bechara, A., Damasio, H., Tranel, D., Damasio, A.R., 1997. Deciding advantageously before knowing the advantageous strategy. *Science* 275 (5304), 1293–1295.
- Bechara, A., Damasio, H., Tranel, D., Damasio, A.R., 2005. The Iowa gambling task and the somatic marker hypothesis: some questions and answers. *Trends Cogn. Sci.* 9 (4), 159–162 discussion 162–4.
- Becker, G., 1968. Crime and Punishment: An Economic Approach. *Journal of Political Economy* 76, 169–217. In this issue.
- Berridge, K.C., Kringelbach, M.L., 2008. Affective neuroscience of pleasure: reward in humans and animals. *Psychopharmacology* 199 (3), 457–480.
- Beszterczey, S., Nestor, P.G., Shirai, A., Harding, S., 2013. Neuropsychology of decision making and psychopathy in high-risk ex-offenders. *Neuropsychology* 27 (4), 491–497.
- Block, M.K., Gerety, V.E., 1995. Some experimental evidence on differences between student and prisoner reactions to monetary penalties and risk. *J. Leg. Stud.* 24 (1), 123–138.
- Brown, J.K., Waltz, J.A., Strauss, G.P., McMahon, R.P., Frank, M.J., Gold, J.M., 2013. Hypothetical decision making in schizophrenia: the role of expected value computation and "irrational" biases. *Psychiatry Res.* 209 (2), 142–149.
- Canessa, N., Crespi, C., Motterlini, M., Baud-Bovy, G., Chierchia, G., Pantaleo, G., Tettamanti, M., Cappa, S.F., 2013. The functional and structural neural basis of individual differences in loss aversion. *J. Neurosci.* 33 (36), 14307–14317.
- Canessa, N., Crespi, C., Baud-Bovy, G., Dodich, A., Falini, A., Antonellis, G., Cappa, S.F., 2017. Neural markers of loss aversion in resting-state brain activity. *NeuroImage* 146, 257–265.
- Cornish, D.B., Clarke, R.V., 1987. Understanding crime displacement: an application of rational choice theory. *Criminology* 25 (4), 933–948.
- Cornish, D.B., Clarke, R.V., 2014. *The Reasoning Criminal: Rational Choice Perspectives on Offending*. Routledge.
- Currie, J., Buruju, D., Perrin, J.S., Reid, I.C., Steele, J.D., Feltoich, N., 2017. Schizophrenia illness severity is associated with reduced loss aversion. *Brain Res.* 1664, 9–16.
- Damasio, A.R., Tranel, D., Damasio, H., 1991. Somatic markers and the guidance of behavior: theory and preliminary testing. In: Levin, H.S., Eisenberg, H.M., Benton, A. L. (Eds.), *Frontal Lobe Function and Dysfunction*. Oxford University Press, New York, pp. 217–229.
- De Brito, S.A., Viding, E., Kumari, V., Blackwood, N., Hodgins, S., 2013. Cool and hot executive function impairments in violent offenders with antisocial personality disorder with and without psychopathy. *PLoS One* 8 (6), e65566.
- De Martino, B., Kumaran, D., Seymour, B., Dolan, R.J., 2006. Frames, biases, and rational decision-making in the human brain. *Science* 313 (5787), 684–687.
- Doya, K., 2008. Modulators of decision making. *Nat. Neurosci.* 11 (4), 410–416.
- Dunn, B.D., Dalgleish, T., Lawrence, A.D., 2006. The somatic marker hypothesis: a critical evaluation. *Neurosci. Biobehav. Rev.* 30 (2), 239–271.
- Fein, G., Landman, B., Tran, H., McGilivray, S., Finn, P., Barakos, J., Moon, K., 2006. Brain atrophy in long-term abstinent alcoholics who demonstrate impairment on a simulated gambling task. *NeuroImage* 32 (3), 1465–1471.

- Fellows, L.K., Farah, M.J., 2005. Different underlying impairments in decision-making following ventromedial and dorsolateral frontal lobe damage in humans. *Cereb. Cortex* 15 (1), 58–63.
- Fray, P.J., Robbins, T.W., Sahakian, B.J., 1996. Neuropsychiatric applications of CANTAB. *International Journal of Geriatric Psychiatry* 11 (4), 329–336. [https://doi.org/10.1002/\(SICI\)1099-1166\(199604\)11:4<329::AID-GPS453>3.0.CO;2-6](https://doi.org/10.1002/(SICI)1099-1166(199604)11:4<329::AID-GPS453>3.0.CO;2-6).
- Grogger, J., 1991. Certainty vs. severity of punishment. *Economic Inquiry* 29 (2), 297–309.
- Hastie, R., 2001. Problems for judgment and decision making. *Annu. Rev. Psychol.* 52, 653–683.
- Hiser, J., Koenigs, M., 2018. The multifaceted role of the ventromedial prefrontal cortex in emotion, decision making, social cognition, and psychopathology. *Biol. Psychiatry* 83 (8), 638–647.
- Jones, K.A., Hewson, T., Sales, C.P., Khalifa, N., 2019. A systematic review and meta-analysis of decision-making in offender populations with mental disorder. *Neuropsychol. Rev.* 29 (2), 244–258.
- Kahneman, D., Tversky, A., 1984. Choices, values, and frames. *Am. Psychol.* 39 (4), 341–350.
- Kay, S.R., Fiszbein, A., Opler, L.A., 1987. The positive and negative syndrome scale (PANSS) for schizophrenia. *Schizophr. Bull.* 13 (2), 261–276.
- Keefe, R.S., Goldberg, T.E., Harvey, P.D., Gold, J.M., Poe, M.P., Coughenour, L., 2004. The brief assessment of cognition in schizophrenia: reliability, sensitivity, and comparison with a standard neurocognitive battery. *Schizophr. Res.* 68 (2–3), 283–297.
- Le Berre, A.P., Rauchs, G., La Joie, R., Mézange, F., Boudehent, C., Vabret, F., Segobin, S., Viader, F., Allain, P., Eustache, F., Pitel, A.L., Beaunieux, H., 2014. Impaired decision-making and brain shrinkage in alcoholism. *Eur. Psychiatry.* 29 (3), 125–133.
- Lejuez, C.W., Read, J.P., Kahler, C.W., Richards, J.B., Ramsey, S.E., Stuart, G.L., Strong, D.R., Brown, R.A., 2002. Evaluation of a behavioral measure of risk taking: the balloon analogue risk task (BART). *J. Exp. Psychol. Appl.* 8 (2), 75–84.
- Manes, F., Sahakian, B., Clark, L., Rogers, R., Antoun, N., Aitken, M., Robbins, T., 2002. Decision-making processes following damage to the prefrontal cortex. *Brain* 125 (Pt 3), 624–639.
- Msk, L., Wc, C., Csy, C., Cmw, S., Skw, C., Emh, L., Clm, H., Yn, S., Tmc, L., Tl, L., Eyh, C., 2021. Altered risky decision making in patients with early non-affective psychosis. *Eur. Arch. Psychiatry Clin. Neurosci.* 271 (4), 723–731.
- Newcombe, V.F., Outtrim, J.G., Chatfield, D.A., Manktelow, A., Hutchinson, P.J., Coles, J.P., Williams, G.B., Sahakian, B.J., Menon, D.K., 2011. Parcellating the neuroanatomical basis of impaired decision-making in traumatic brain injury. *Brain* 134 (Pt 3), 759–768.
- Pedersen, A., Göder, R., Tomczyk, S., Ohmann, P., 2017. Risky decision-making under risk in schizophrenia: a deliberate choice? *J. Behav. Ther. Exp. Psychiatry* 56, 57–64.
- Piquero, Alex, Tibbetts, Stephen, 1996. Specifying the direct and indirect effects of low self-control and situational factors in offenders' decision making: toward a more complete model of rational offending. *Justice Q.* 13 (3), 481–510.
- Rahman, S., Sahakian, B.J., Hodges, J.R., Rogers, R.D., Robbins, T.W., 1999. Specific cognitive deficits in mild frontal variant frontotemporal dementia. *Brain* 122 (Pt 8), 1469–1493.
- Rogers, R.D., Owen, A.M., Middleton, H.C., Williams, E.J., Pickard, J.D., Sahakian, B.J., Robbins, T.W., 1999. Choosing between small, likely rewards and large, unlikely rewards activates inferior and orbital prefrontal cortex. *J. Neurosci.* 19 (20), 9029–9038.
- Sabater-Grande, G., Haro, G., García-Gallego, A., Georgantzis, N., Herranz-Zarzoso, N., Baquero, A., 2020. Risk-taking and fairness among cocaine-dependent patients in dual diagnoses: schizophrenia and anti-social personality disorder. *Sci. Rep.* 10 (1), 10120–020-66954-2.
- Shurman, B., Horan, W.P., Nuechterlein, K.H., 2005. Schizophrenia patients demonstrate a distinctive pattern of decision-making impairment on the Iowa gambling task. *Schizophr. Res.* 72 (2–3), 215–224.
- Sokol-Hessner, P., Hartley, C.A., Hamilton, J.R., Phelps, E.A., 2015. Interoceptive ability predicts aversion to losses. *Cogn. Emot.* 29 (4), 695–701.
- Trémeau, F., Brady, M., Saccente, E., Moreno, A., Epstein, H., Citrome, L., Malaspina, D., Javitt, D., 2008. Loss aversion in schizophrenia. *Schizophr. Res.* 103 (1–3), 121–128.
- Ustün, T.B., Chatterji, S., Kostanjsek, N., Rehm, J., Kennedy, C., Epping-Jordan, J., Saxena, S., von Korff, M., Pull, C., WHO/NIH Joint Project, 2010. Developing the World Health Organization disability assessment schedule 2.0. *Bull. World Health Organ.* 88 (11), 815–823.
- Woodrow, A., Sparks, S., Bobrowskaia, V., Paterson, C., Murphy, P., Hutton, P., 2019. Decision-making ability in psychosis: a systematic review and meta-analysis of the magnitude, specificity and correlates of impaired performance on the Iowa and Cambridge gambling tasks. *Psychol. Med.* 49 (1), 32–48.
- Yechiam, E., Kan, J.E., Bechara, A., Stout, J.C., Bussemeyer, J.R., Altmeyer, E.M., Paulsen, J.S., 2008. Neurocognitive deficits related to poor decision making in people behind bars. *Psychon. Bull. Rev.* 15 (1), 44–51.
- Zorlu, N., Gelal, F., Kuserli, A., Cenik, E., Durmaz, E., Saricicek, A., Gulseren, S., 2013. Abnormal white matter integrity and decision-making deficits in alcohol dependence. *Psychiatry Res.* 214 (3), 382–388.