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THE IMPACT OF EXECUTIVE FUNCTIONS AND EMOTIONAL INTELLIGENCE ON IOWA GAMBLING TASK PERFORMANCE: FOCUS ON RIGHT FRONTAL LOBE DAMAGE

Decision-making under uncertainty in the Iowa Gambling Task (IGT) has been intensively studied over the last twenty years regarding both “hot” and “cold” components. The ventromedial prefrontal cortex is a key region involved in processing somatic marker information, though recent findings suggest that dorsolateral regions are also important. The dorsolateral prefrontal cortex is also known as a substrate of executive functions—the cold component of decision-making. However, there is contradictory evidence about the role of executive functions, as well as the hot component of decision-making—emotional intelligence. This study seeks to address this inconsistency. Previous findings suggest that patients with right frontal lobe lesions should find decision-making more problematic in IGT. This article investigates the importance of emotional intelligence as the hot and executive functions as the cold components of decision-making in IGT. We obtained data from patients with right frontal lobe tumours and healthy controls who undertook IGT, Wisconsin Card Sorting Test (WCST) and D-KEFS Colour-Word Interference Test. The current findings imply that performance in IGT is highly correlated with several parameters of set-shifting in the WCST: correct answers, conceptual level responses and non-perseverative errors. However, no correlation is found with cognitive inhibition parameters in the Colour-Word Interference Test, while an interaction between the emotional intelligence parameters and the performance on IGT is low.

JEL Classification: Z.

Keywords: Iowa Gambling Task; right frontal lobe tumour; tumour patients; executive functions; lateral prefrontal cortex; emotional intelligence.

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Introduction

This work investigates an intriguing and extensively studied processes – decision-making. Research on decision-making under uncertainty reveals important characteristics of human behaviour as a holistic act and distinguishes quantitative specifics of human behaviour from animal behaviour. If decision-making is evaluated through the prism of making the right choice, picking one option among others, then this choice could be explained as a result of calculations of gains and losses (the "cold" component of decision-making) with emotional reactions having impact on desirability of each option (the "hot" component of decision-making). It is well-known that these hot and cold components have a strong influence on this complex process. While cold decision-making is related to cognitive and rational processes, hot is associated with emotional and affective (Brand, 1985/1986; Damasio, 1994; Shafir et al., 1993). Hot components, such as affective and emotional reactions, help humans to act in situations requiring immediate action, while cold components such as the rational determination of risks and the benefits of each possible action are more valuable in stable situations (Séguin et al., 2007). These two factors or types of thinking are also referred to as System 1 and System 2 theoretical components, respectively (Kahneman, 2003). It is not surprisingly that executive functions (EF), such as planning, cognitive flexibility and working memory are thought to be linked to decision-making, especially to its cold part. However, in some models of complex decision-making, such as the Iowa Gambling Task (IGT), EF impairment does not always influence performance (Bechara et al., 1998), while other studies indicate that both hot and cold processes have an impact on different parts of the task (Guillaume et al., 2009). This implies that further investigation of the emotional components and executive functions should be performed to determine the key factors of decision-making performance on IGT.

The role of stable personality traits such as impulsivity and risk-seeking have been widely investigated, although less attention has been paid to the emotional intelligence parameter (Bar-On et al., 2005; Demaree et al., 2010; Webb et al., 2014). Based on the somatic markers hypothesis, Bar-On et al. suggest that decision-making impairment in patients with brain lesions in IGT could be related to abnormal parameters of social and emotional intelligence. Moreover, these findings imply that neural networks associated with cognitive intelligence differ from social-emotional networks (Bar-On et al., 2005). However, neuropsychological examinations and psychological findings suggest that emotional and cognitive intelligence are tightly bonded in accordance with the "Vygotskian intelligence hypothesis" of the unity of affective component and intelligence (Vygotsky, 1978). Vygotsky argued that human intelligence is the product of the dynamic interaction of cognitive skills and affective states during ontogenesis (Vygotsky, 1978). It follows that high performance human decision-making can only occur when the emotional part (hot) and the rational part (cold) act as a system. It raises the question of how emotional intelligence and executive functioning, which can be measured explicitly, have an impact on decision-making under uncertainty in IGT.

The frontal lobes and related structures (with strong effective and anatomical connectivity), such as the cingulate cortex, hippocampus, dorsal striatum and amygdala have been identified as an important neural substrate in decision-making by a large number of lesion studies (Luria et al., 1966; Bechara et al., 1994; Burgess and Shallice, 1996) and recent fMRI studies (Li et al., 2010; Shuangye et al., 2015). More specifically, the rational subcomponent is generally associated with the dorsolateral prefrontal cortex, while the emotional component, impairment in moral decision-making and personality changes are more associated with the ventromedial and orbitofrontal cortex

(Luria, 1966; Bechara et al., 1994). Thus, decision-making, as a complex act, requires the integrity of these regions and their connections. IGT performance has been intensively studied to shed light on the specific impact of frontal regions, such as the orbitofrontal and dorsolateral regions (Manes et al., 2002; Fellows et al., 2005) and their connections to distant regions, such as the cerebellum (Cardoso et al., 2014) and the parietal cortices (Huettel et al., 2005; Smith et al., 2009; Vickery et al., 2009). Initially this model was tested in patients with ventromedial prefrontal lesions who made significantly more disadvantageous decisions compared to controls (Bechara et al., 1994; Bechara et al., 2000). These patients, who ignore the long-term consequences of their actions, are insensitive to the emotions of others and unable to learn after making errors. Damasio (Bechara et al., 1994) suggests a “somatic marker hypothesis” to explain the origins of this behaviour – lesions in ventromedial regions cause insensitivity to, or the absence of, inner physiological signals to signal an error, as has been proven by skin conductance response probes. It has been suggested that ventromedial lesions located in the right hemisphere are linked to higher impairment compared to those in the left hemisphere due to the dominant role of the right hemisphere in emotional information processing (Bechara et al., 2000a; 2000b).

The relation between EF and decision-making measured by IGT seems quite obvious; however, some studies (Gansler et al., 2011) show that IGT involves novel problem-solving and requires attention in healthy participants more than EF per se. No significant interactions were found between IGT performance and EF measured by neuropsychological tests in stroke patients (Cardoso et al., 2015).

To address the inconsistency in the findings regarding productivity in IGT and in EF assessments, the current study investigates the relationship between hot decision-making in IGT and cold, rational EF, such as inhibitory control and cognitive flexibility in classic neuropsychological instruments such as the Wisconsin Card Sorting Test (WCST), in a sample of patients with frontal lobe tumours of the right hemisphere.

We also evaluate, how emotional intelligence as the ability to incorporate emotional processing is involved in decision-making performance in IGT.

Materials and methods

Our study recruited two participant groups consisting of fourteen patients with right frontal lobe tumours and twenty one healthy controls (2:3study design). Participants were recruited from the Moscow Burdenko Institute of Neurosurgery prior to tumour surgery. All patients suffered from convexital brain tumours in the right hemisphere, mostly localized in the lateral prefrontal cortex region, and diagnosed by neurological and neuroimaging assessment. Patients were examined 1-2 days after their admission to hospital, before surgery. Data about the site of lesions were collected by reviewing patient records and confirmed by the neurologist. Participants of the control group were recruited by email and social networks from the Lomonosov Moscow State University and related institutions. Participants in the sample were native Russian speakers, with at least 1 year of higher (post-secondary) education and were at least 18 years of age. Exclusion criteria were: left-handedness or ambidextrous (screened by the neuropsychological assessment by Luria’s battery and Annett’s questionnaire of functional asymmetry), other neurological diseases (e.g. epilepsy, aneurism), aphasia and agnosia symptoms, psychiatric disorders and drug abuse (self-reported and retrospective review of patient history).

Table 1 shows the descriptive socio-demographic and clinical data of the clinical and control groups. The control group included individuals aged between 18 and 54 (M= 29.60, SD = 11.32) with at least 1 year of university education, 47 % of whom were female.

Tab. 1. Clinical group description.

Frontal (lateral prefrontal cortex) tumour's localization

	age	gender	years of schooling (university education)	hemisphere	Tumour type and localization
1	32	M	5	right	Diffuse astrocytoma WHO Grade II-III, convexital access to the lateral prefrontal cortex, and premotor cortex in the posterior part.
2	27	M	5	right	Anaplastic astrocytoma Ki 67 - 10% located in lateral prefrontal-premotor cortex – involvement of superior frontal gyrus and posterior part of middle frontal gyrus, parasagittal location.
3	35	M	5	right	Diffuse astrocytoma WHO Grade II, with convexital access – lateral prefrontal-premotor cortex, parasagittal location, d=3.5 cm
4	43	F	4	right	Oligoastrocytoma WHO Grade II, located in lateral prefrontal-premotor cortex (from hand representation region to the medial part of inferior frontal gyrus)

5	26	F	5	right	Diffuse astrocytoma WHO Grade II, with convexital access – lateral prefrontal-premotor cortex, d=6 cm, with medial part adjoining the right lateral ventriculus (frontal lobe)
6	49	M	5	right	Oligoastrocytoma IM Ki 67, Grade III, with involvement of lateral prefrontal cortex, premotor cortex (leg representation region) in the posterior part
7	36	F	5	right	Diffuse astrocytoma WHO Grade II-III, located in fronto-temporal region (insular cortex involvement), 3*4 cm
8	18	M	1	right	Astrocytoma with involvement of lateral prefrontal cortex (cortico-subcortical location)
9	21	F	4	right	Diffuse astrocytoma WHO Grade II, convexital fronto-parasagittal localization (lateral prefrontal-premotor cortex), d=3 cm
10	20	M	3	right	Gemangioblastoma with surrounding glial hyperplasia with convexital access (lateral prefrontal-premotor cortex, hand

					representation)
11	40	M	5	right	Meningioma, adjoining to fronto-parasagittal region (premotor and lateral prefrontal cortex), 8*7*6 cm
12	39	M	5	right	Diffuse astrocytoma WHO Grade II-III, with involvement of lateral prefrontal cortex
13	58	M	5	right	Glioblastoma (Grade IV), located in frontal cortex with involvement of premotor cortex and lateral prefrontal cortex
14	38	F	5	right	Oligoastrocytoma with petrificates Ki67 >5 %, located in lateral prefrontal cortex-frontal pole, d=4 cm

All participants signed written informed consent authorized by the local ethical community. Patients were assessed during a single session lasting two hours, during which all data related to socio-demographic status and neuropsychological assessment were obtained. The methods used are described below:

- Luria's Neuropsychological battery (Luria, 1973). This battery includes neuropsychological probes to assess a variety of cognitive functions: attention, perception of different modalities, handedness, memory and EF. A questionnaire about socio-cultural characteristics was included.
- IGT (Bechara and Damasio, 1994). A computerized version of IGT was used (PEBL free software, http://pebl.sourceforge.net/). The participant is instructed to pick up a card from four decks of cards over the course of 100 trials. Two of these decks are advantageous (C and D) because they consist of cards with small losses and high long-term gains, while two others (A and B) are disadvantageous due to the probability of receiving a high monetary loss once every 10 trials. Performance in IGT was assessed by a set of different measures: The total score as a parameter of general productivity is calculated by subtracting the number of disadvantageous deck selections from the number of advantageous selections

(C+D)-(A+B) as well as the partial performance of sets of twenty trials (0-20, 20-40). We also calculated the quantity of choices to access preferences across each deck.

- WCST (Heaton et al, 1993) provides information about cognitive reasoning and flexibility, and the set-shifting of the participant. It also can be used for the assessment of the level of brain damage to the prefrontal cortex.
- D-KEFS Colour-Word Interference Test (Delis et al., 2004) is a part of the Delis-Kaplan Executive Function System Test to measure the ability to inhibit an automatic verbal response, which typically occurs in patients with prefrontal cortex damage. It is significantly different from previous versions of the Stroop Test because of the introduction of a new "inhibition and switching" section.
- Mayer-Salovey-Caruso Emotional Intelligence Test (MSCEIT v.2.0), Russian adaptation (Mayer et al., 2002; Sergienko et al., 2009). Mayer and Salovey (Salovey et al., 1990; Mayer and Salovey, 1997) model emotional intelligence as a set of skills to evaluate, express and regulate one's emotions. The evaluation of one's emotions is divided into verbal and non-verbal subcomponents, while the assessment of others' emotions includes non-verbal perception and empathy. A later edition of their model (Mayer et al., 2002; Mayer et al., 2003) includes four domains which develop in ontogenesis: the perception and identification of emotions (sections A and E), the use of emotions for thinking facilitation (B and F), the understanding and analysis of emotions (C and G), and conscious emotional control and regulation for personal growth and the improvement of interpersonal communication (D and H).

Results

Iowa Gambling Task

A total score

The differences in decision-making performance in IGT were firstly assessed by total scores using the formula (C+D)-(A+B). The results of One-Way Anova indicated a significant difference between healthy controls [M(SD) = 26.8571 (24.67850)] and the clinical group: [M(SD) = 9.2857 (13.48748)] (F(1,33)=5.884, p= .021) (see Figure 1).

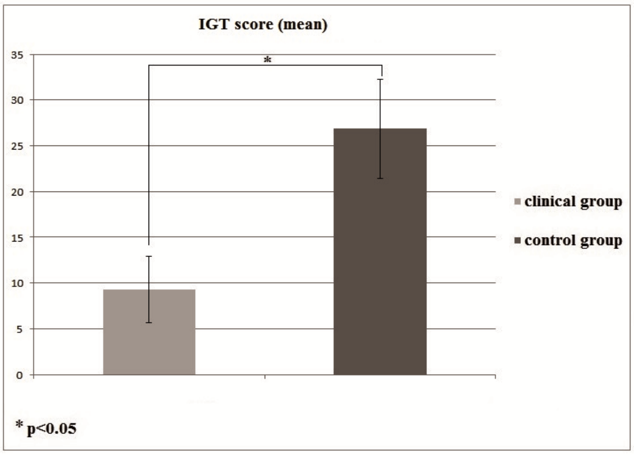

Figure 1. Total (net) score in IGT across groups (healthy controls and clinical group).

Performance per block

A parameter for general decision-making performance was calculated for each 20 trials in all three groups across the task using the formula (C+D)-(A+B). One-Way ANOVA across two groups indicated a significant difference in performance in the following blocks: 20-40 (F(1,33)=5.887; p= 0.021) and 80-100 (F(1,33)=5.284; p=.028) (see Figure 2). However, Repeated-Measures ANOVA performed inside each group revealed a significant difference across blocks only for the control group (F(4,80)=9.748, p<0.001).

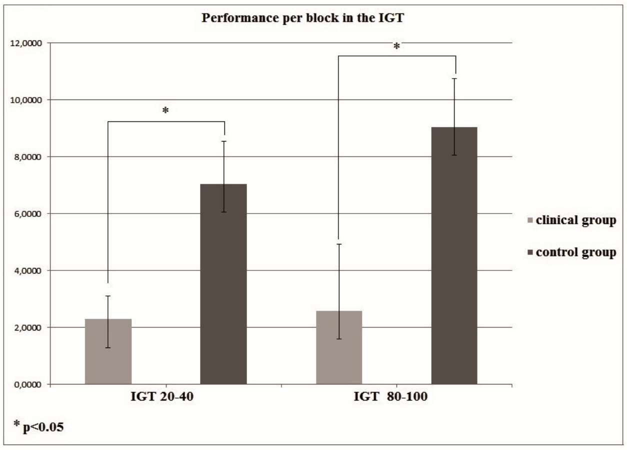

Figure 2. Performance per blocks (20-40 and 80-100) on IGT across groups (healthy controls and clinical group).

Preference per deck

Figure 3 shows the results of statistical analysis across two groups for their preferences measured as a number of selections for each deck. This suggests that selections from disadvantageous deck B (F(1,33)=7.108, p=.012) significantly differ between the clinical group (M(SD)= 28.3571(5.69220)) and healthy controls (M(SD)= 21.3333(8.66795)). A significant difference was also found for selections from the advantageous deck D (F(1,33)=4.384; p =.44) between the clinical group (M(SD)= 25.5000(5.62618)) and controls (M(SD)=32.6190(11.81726)).

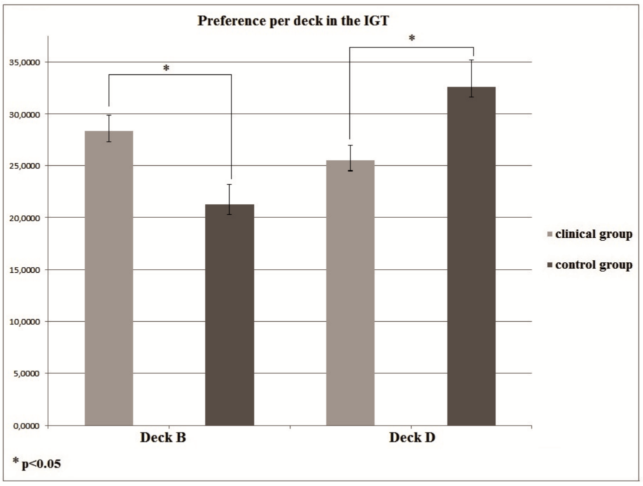

Figure 3. Preferences per disadvantageous desk B and advantageous desk D across groups (healthy controls and clinical group).

Executive functions

Wisconsin Card Sorting Test

One-Way ANOVA revealed a significant difference between the clinical group and healthy controls in branches of parameters, such as the number of correct answers in the WCST (F(1,33)=12.910, p=.001); perseverative errors (F(1,33)=5.691; p=.023), non-perseverative errors (F(1,33)=5.282; p=.028) and conceptual responses (F(1,32)=7.99, p=.006) (see Figure 4).

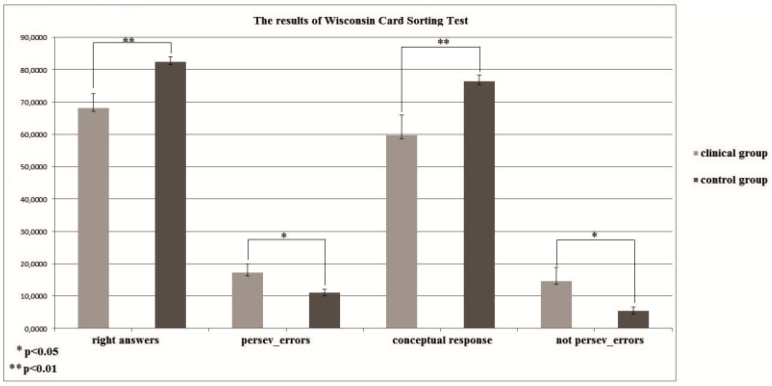

Figure 4. Wisconsin Card Sorting Test performance across groups (healthy controls and clinical group).

WCST and IGT performance

Pearson correlation analysis was performed for healthy and clinical groups. For the latter group, the number of correct choices in WCST is correlated with the general score (in virtual money) in IGT (r=0.569, p<0.05, two-tailed), and the latter is inversely correlated with the number of wrong choices in WCST (r=-0.569, p<0.05, two-tailed) and positively correlated with the “conceptual responses” parameter (r=0.569; p<0.05). The number of correct choices in WCST is correlated with the number of advantageous choices through last trials (from 60 to 100) (r=0.558, p<0.05). The amount of time spent completing the first category in WCST is correlated to the overall time spent on IGT (r=0.686, p<0.01, two-tailed).

D-KEFS Color-Word Interference Test

No significant differences in overall performance and correlations with performance in IGT were observed.

Emotional intelligence

Mayer-Salovey-Caruso Emotional Intelligence Test (MSCEIT v.2.0)

Both groups completed sections A and E in MSCEIT, while only 7 out of 14 patients and 14 out of 21 controls completed sections B and F.

One-Way Anova revealed no significant differences between healthy controls and the clinical group in scores and frequencies in emotional perception and identification (sections A and E), but there is a significant difference between frequencies converted from overall scores in sections B and F (F(1,19)=4.507, p=0.047) between controls (M(SD)= 0.3914 (0.044)) and the clinical group (M(SD)=0.3243(0.10). A significant difference was revealed in scores of subsection F (F(1,19)=5.652, p=0.028) between controls (M(SD)=8.7857(1.88837)) and the clinical group (M(SD)= 5.5714(4.39155)).

Emotional intelligence and performance in IGT

A Pearson correlation analysis was performed for the controls and the clinical group. The results suggest that the parameters of emotion identification and evaluation (scores in E subsections) are inversely correlated with the quantity of advantageous choices in block 20-40 of IGT in the clinical group ($r = -0.616$, $p<0.05$), but this was not found in healthy controls.

Discussion

The current study assesses decision-making under uncertainty in patients with frontal lobe lesions of the right hemisphere compared to healthy controls, and revealed the specific influence of EF on performance in IGT. Moreover, this study sought to replicate the findings of poor performance in IGT in patients with right dorsolateral prefrontal cortex lesions (Manes et al., 2002) because of the contradictory findings of Bechara et al. (Bechara et al., 1994; 2000a; 2000b). We found that total IGT scores and performance per second block (20-40) and last block (80-100) differed significantly between the group of patients with right frontal lobe lesions and the control group. Moreover, performance across blocks differed significantly only in the control group. A preference for disadvantageous decks is more common in the clinical group compared to the control group, while in the case of the advantageous deck D, the opposite was true. This indicates that patients with right frontal lobe lesions lose the ability to learn to avoid disadvantageous decks due to their tumours and also are not sensitive enough to advantageous decks. Also, Hawthorne et al. (2015) show that a higher cognitive load results in greater preferences for Deck B in normal subjects. The findings suggest that the decision-making process in patients with right frontal lobe convexital tumours is worse than that of healthy controls mainly because of deficit in cognitive resources. The results support the hypothesis that frontal lobe damage, especially of the right hemisphere and not only ventromedial, but also lateral prefrontal, can greatly impair behavioural performance. However, as mentioned above, this region is not uniquely involved in affective-based decision-making.

The current results are consistent with several studies revealing the impact of EF on performance in IGT (Brand et al., 2007; Cardoso et al., 2015). The specific role of frontal lobe damage in performance in IGT was shown by Cardoso et al. (2014) comparing cerebellar lesions. However, some findings imply that there is no influence of EF on overall IGT decision-making in frontal stroke patients, but there are some correlated partial parameters, such as net scores for the first block and the number of correct answers in the modified version of WCST (Cardoso et al., 2015). Toplak’s review (2010) also suggests that interactions between set-shifting measurements and IGT performance are inconsistent across studies. Our findings also imply correlations with partial parameters, such as the number of advantageous choices in the final blocks and general score (in virtual money). Brand et al. (2007) suggest that the last blocks of IGT usually correlate with EF because of different mechanisms that IGT relies on: decisions under ambiguity in the first probes which should correspond with the somatic marker hypothesis and decisions under risk in the last probes. These data are consistent with our results, suggesting that this specific influence of EF appears significant in the last blocks of IGT. We suggest that IGT impaired performance in patients could be explained by impairment in cold cognition – the ability to process probabilities and to make probability-based decisions, while hot cognition plays a less significant role.

Our findings do not suggests that performance in the Colour-Word Interference Test is impaired in patients with right frontal lobe tumours, and that Colour-Word Interference Test's results do not predict performance in IGT. Previous findings also reported an absence of correlation or any interaction between the Stroop Test, which corresponds mainly with the structure of the D-KEFS Colour-Word Interference Test, and IGT (Bechara et al., 2001; Mimura et al. 2006). The review by Toplak (2010) also provides evidence that the correlation between the performance of IGT and measures of inhibition are relatively low across 11 studies. We expect that such results could be obtained because of differences in the neural basis of cognitive switching performance: recent findings suggest that the grey matter volume of the left temporal lobe predicts the outcome of the switching condition in the D-KEFS Colour Word Interference Test (Adolfsdottir et al., 2010).

The parameters of EF differ greatly between the clinical group and the control group. The performance of EF is significantly worse in patients with right frontal lobe tumours. This indicates that the ability to shift when faced some challenges is impaired in patients with right frontal lobe lesions and could impact the complex performance of decision-making in IGT. However, we did not reveal this specificity in the performance of different IGT blocks, as some previous studies have reported (Brand et al., 2007; Cardoso et al., 2015). We expect that the latter could be investigated by increasing the number of subjects. Nevertheless, our results indicate that EF has a huge impact on IGT performance in patients with right frontal lobe lesions, which usually correspond with deficiency in emotional signal processing.

The preliminary results suggest that patients with right frontal lobe tumours and healthy controls do not differ in their ability to identify and perceive emotions correctly, but the ability to understand and use emotions to facilitate activity is impaired in the clinical group. The results of subsection F have a huge impact on these results, so we could assume that the ability to identify and verbalize subliminal emotional conditions is highly impaired in patients with right frontal lobe tumours. The interaction between IGT performance and emotional intelligence is an inverted correlation between the second IGT block performance (20-40) as are the scores in the test's subsection of emotion identification (subsection E), which was not found in healthy controls. We assume that this inverse interaction could be explained by the conceptual specifics of IGT: if participants put more effort into verbalizing subliminal emotions, they start to be distracted from the purpose of this emotion and lose this emotional guidance, which should help to seek advantageous and avoid disadvantageous decks. Our results are partially consistent with the findings of Bar-On et al. (2005) on the impact of emotional intelligence on IGT performance: the interaction was observed in the clinical group, but not in the controls. Webb et al. (2014) and Demaree et al.(2010) also show that emotional intelligence scores significantly predict IGT performance until starting to control for intelligence quotient. That means that the cognitive component could play a higher role in IGT performance in patients with right frontal lobe tumours than emotional intelligence.

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Conflict of interest

The authors declare no competing financial interests.

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