J Neurooncol (2012) 110:59–67
DOI 10.1007/s11060-012-0934-0

CLINICAL STUDY

Decision-making abilities in patients with frontal low-grade glioma

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Received: 21 March 2012 / Accepted: 5 July 2012 / Published online: 15 July 2012

Abstract Decisions in daily life are often quite complex, especially when one has to decide about his/her own health, as it is the case for patients with brain tumours. The integrity of the prefrontal cortex (and of the orbito-frontal in particular) is crucial in humans for practical decision-making. We investigated decision-making in 22 right-handed patients with a left frontal low-grade glioma, by means of a more complex, computerized version of the Iowa gambling task and we compared their performance with that of 26 neurologically-unimpaired subjects. After the experiment, we also administered a questionnaire to evaluate subjects' conscious comprehension level of the task and two self-report scales to verify potential effects of individual personality differences. Patients chose significantly less cards than controls from the advantageous deck, without modifying their behaviour over time, and this correlated with abstract reasoning abilities. In both groups, level of comprehension, significantly affected performance. An improvement was found post-surgery. In conclusion, the performance in the Gambling Task suggests that patients with left frontal low-grade gliomas can be impaired in decision-making, apparently requiring more time to understand the task: therefore, a particular attention and care should be taken to explain risks and consequences of his/her illness and treatment in order to obtain an informed decision from the patient.

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Keywords Low-grade glioma · Decision-making · Gambling task · Prefrontal cortex

Introduction

Cognitive function is regarded as an important outcome measure in patients with brain tumours [1]. However, most patients with frontal brain tumours demonstrate impairments of cognitive functioning, especially executive one in 78 % of patients [2], at the time of diagnosis, before any treatment. The prefrontal cortex is involved in abstract reasoning and control of social behaviour [3], in daily life decision-making and problem solving [4, 5]. Frontal patients are insensitive to the outcome of their actions and tend to engage in high-risk behaviours which are rewarding in short term, but have negative consequences in the future, despite well preserved general cognitive abilities and good performance in traditional neuropsychological tests [6]. This pathological behaviour can be particularly dangerous when an individual has to decide about his/her own health.

A widely used behavioural measure to assess decision-making is the Iowa gambling task (IGT) [7], a card game that simulates real life uncertain situations in which it is necessary to take decisions on the basis of consequent rewards and punishments. In this task, people have to choose play-cards, providing win or loss of money, from four different decks with the goal of gaining as much money as possible by identifying the best deck. In order to achieve good performances on the IGT, subjects need to renounce to immediate high rewards in favour of long-term advantages. Patients with orbitofrontal lesions are significantly impaired on it, being guided by immediate gains rather than long-term consequences [8]. On the contrary, patients with lesions of the dorsolateral prefrontal cortex

(DLPF) and related working memory (WM) deficits seem to perform normally [9]. However, an opposite pattern has also been found [10], with orbitofrontal patients performing at a normal level, and DLPF patients impaired in WM tasks and IGT.

These contradictory results could be explained by the different GT versions used [11]; in any case it appears that a prefrontal damage can impair decision-making regardless the precise site. Indeed, WM load differently affects performance, depending on the complexity of the version that can require the recruitment of intuitive versus analytic strategies [12]. The original IGT [7] is an easy task presumably involving only intuitive components, and subjects can achieve a good performance without consciously knowing the advantageous strategy [13], while more complex versions [14, 15] probably require additional resources. Indeed, recent data demonstrate that in healthy subjects GT performance correlates with conscious knowledge about the decks reward/punishment schedule [16]. This is a relevant point, since everyday decision-making often concerns complex situations; complex versions of the GT could better predict decisional deficits in daily life.

Treatment for low-grade glioma (LGG) involves surgical resection and can require radiotherapy and chemotherapy, but the timing is still controversial, especially regarding the effects on survival and the development of neurotoxicity. Recently, it has been found that radiotherapy + chemotherapy, disease duration and epileptic treatment contribute to mild cognitive difficulties in LGG patients [17]. Therefore, the patient should be aware of all the possible side effects of the treatment in order to give a really informed consent and accept the best treatment knowing its risks. Decision-making ability is particularly relevant in these patients, who are called to take important decisions about their life.

In the light of the above, the aim of the present study was to investigate decision-making in patients with a frontal LGG by using a more difficult version than the original IGT. At the end of the task, two self-report scales, behavioural inhibition system (BIS) and behavioural approach system (BAS) [18] and consideration of future consequences (CFC) [19], were administered to participants in order to verify potential effects of individual differences in personality, in front of reward and punishment and consideration of future consequences.

Materials and methods

Participants

A continuous series of patients with a frontal LGG was recruited at the Neurosurgery Ward of the IRCCS Ospedale Maggiore Policlinico Mangiagalli-Regina Elena, Milano. The selected patients were 11 males and 11 females with a mean age of 42.14 years (range: 22–68, SD: 10.94) and a mean educational level of 13.05 years (range: 8–18, SD: 3.29). Lesion site was assessed by means of magnetic resonance imaging (MRI). All patients had a left[1] frontal LGG, involving the lateral (L), medial (M) or both lateral and medial (L + M) frontal cortex. Patients were evaluated before surgery that was performed in awake with language and motor mapping. Patients' spontaneous speech was fluent, as was word repetition, comprehension and naming. Clinical and demographical data are reported in Table 1.

Twenty-six neurologically unimpaired subjects (14 female, mean age 35.81, SD: 16.06, range: 23–68, mean educational level 14.73, SD: 2.97, range: 13–18) also took part in the experiment. Patients and controls did not significantly differ in age [$t(46) = -1.56$, $p = 0.12$] and years of education [$t(46) = 1.86$, $p = 0.07$]. The study was approved by the local ethical committee.

Materials

Gambling task (GT)

A computerized version of the GT, more complex than the original IGT [7], was used. It included only one "good" deck, the others being a neutral and two "bad" decks. In the "good" deck, cards allow winning 50 $ and only in one case out of ten selections, there is a 25 $ penalty; in the "neutral" deck, too, the winning cards give 50 $, but five cards out of ten trials cause a penalty ranging from 25 $ to 75 $. The "bad 1" and "bad 2" are the highest reward decks since they allow winning 100 $, but after ten trials the money balance is negative; in the "bad 1" one card out of ten causes the highest loss (1,250 $), while in the "bad 2" the penalties are distributed over more cards ranging from 100 $ to 350 $ (see Table 2). Colour and location of the decks varied randomly across participants and the cards of each deck were shuffled in a different order for each participant. However, the values of the cards were kept constant for each subset of ten cards, to ensure that performances were not affected by different timing of exposure to cards with key values of reward or punishment. After each card selection, a message appeared on the top of the deck indicating the amount of money the participant had gained or lost on that trial, and the tally was reset accordingly. There was no time limit for card selection; after the choice, the reward/punishment amount appeared for 4 s, followed by a fixation point (4 s), and then the four decks were displayed again. The GT ended after 100 trials. Reaction times (RTs) and type of choice were recorded.

[1] This happened by chance and was not a criterion of selection.

Table 1 Patients' clinical and demographical data

Patient	Age	Sex	Education	Lesion site	Tumour volume	Lesion group	Histology
1	38	F	13	44, 45	30.8	L	Oligodendroglioma II
2	41	M	18	8, 9, 10, 24, 32, 46	22.5	L + M	Oligodendroglioma II
3	36	M	13	6, 8, 9 10, 24, 32, 44, 45,46	120.4	L + M	Oligodendroglioma II
4	52	F	8	8, 9, 10, 46	54.2	L + M	Oligodendroglioma II
5	52	F	13	44, 45	9.3	L	Oligodendroglioma II
6	28	F	13	4, 6	36.2	M	Glioblastoma IV
7	68	M	15	4, 6	29	M	Oligodendroglioma II
8	32	F	13	6, 8, 9, 10, 11, 12, 24, 32, 44, 45, 46, 47	71	L + M	Oligodendroglioma II
9	36	F	16	4, 6, 44	15.2	L	Oligodendroglioma II
10	42	F	13	11, 12, 25, 44, 45	47.8	L + M	Oligodendroglioma II
11	47	M	13	6, 8, 32	7.06	M	Astrocitoma II
12	51	M	13	4, 6, 24, 32	28.1	M	Oligodendroglioma II
13	47	M	14	6, 8, 24, 32	n.a.	M	Oligodendroglioma II
14	47	M	18	4, 6	7.8	L	Astrocitoma II
15	37	M	18	9, 10, 11, 12, 25, 32	29.5	M	Oligodendroglioma III
16	22	M	10	6, 8	7.8	M	Oligodendroglioma II
17	44	F	8	10, 11, 44, 45, 46, 47	66.4	L + M	Oligodendroglioma II
18	58	F	11	4, 6, 9, 44, 45	n.a.	L	Oligodendroglioma II
19	34	F	8	9, 10, 11, 12, 32, 45, 46	n.a.	L + M	Astrocitoma II
20	46	F	13	6, 8, 9, 44, 45, 46	43.8	L	Glioblastoma IV
21	45	M	8	6, 8	60.9	L	Oligodendroglioma II
22	24	M	18	6, 8	1.6	M	Oligodendroglioma II

Brodmann areas (BA) are reported: lesions in BA 12, 24, 25, 32 are located in the medial surface of the frontal cortex; lesions in BA 44, 45, 46, 47 are located in the lateral surface of the frontal cortex; lesions in BA 4, 6, 8, 9, 10, 11 can involve the lateral or the medial surfaces or both. For three patients the tumour volume was not available (n.a.)

At the end of the task, participants answered the Maia and McClelland's questionnaire [16], which evaluates participants' level of comprehension of the GT rationale (see below).

Behavioural inhibition system (BIS) and behavioural approach system (BAS)

The BIS and BAS [18] is a self-report measure consisting of 20 items divided in two sub-scales. The BIS (7 items) evaluates the anxiety level when we have to avoid negative consequences, since a punishment is possible. The BAS (13 items) reflects how people respond to reward situations and includes three different sub-scales: drive, reward responsiveness and fun seeking.

Consideration of future consequences (CFC)

The CFC [19] is a self-report 12 items scale that measures individual differences concerning how people consider future consequences rather than immediate outcomes to behave.

Procedure

Patients were evaluated in the month before surgery. The standard neuropsychological battery included the token test [20], digit span forward [21] and backward [22], verbal fluency on phonemic and semantic cue [23], word comprehension [24], picture naming of objects [25] and actions [26], sentence comprehension [27], Attentional matrices

Table 2 Payoff schedule for the GT four decks

Decks	Reward	Punishment	Net profit (over 10 trials)
Good	50 $ (9 in 10 cards)	25 $ (1 in 10 cards)	+425 $
Neutral	50 $ (5 in 10 cards)	75 $ (1 in 10 cards)	0 $
		50 $ (3 in 10 cards)	
		25 $ (1 in 10 cards)	
Bad 1	100 $ (9 in 10 cards)	1,250 $ (1 in 10 cards)	−350 $
Bad 2	100 $ (5 in 10 cards)	350 $ (1 in 10 cards)	−350 $
		150 $ (2 in 10 cards)	
		100 $ (2 in 10 cards)	

[28], Trail making test [29], Weigl's test [30], Wisconsin card sorting test (WCST) [30].

Participants were seated in front of the computer; the GT was presented by means of E-prime experimental software (Psychological Tools, Inc.). They were told to select cards from one of four decks, in order to win as much money as possible and avoid loosing money, finding out the best deck. At the end, participants were submitted to the Maia and McClelland questionnaire [16]. Their responses were scored following the authors' procedure [16], which evaluates whether participants correctly identify the good deck and how they answer when specifically questioned about the expected outcome for each deck. Scores were assigned to level 0, when subjects do not claim any preference for the good deck and are unable to understand the different value of the decks; level 1, that indicates subjects preferring the good deck without having conscious knowledge about the values of the decks; and level 2, corresponding to an acquired knowledge about the good deck and about the reward/punishment scheme of each deck. Finally, participants completed the self-report scales in a counterbalanced order.

Statistical methods

GT performance was analysed by means of Statistica software (StatSoft Italia srl, 2004). Controls' and patients' performances were first analyzed separately. The 100 choices made by each subject were divided in five 20-trials blocks in order to detect possible shifts in behaviour during the task. Repeated measures ANOVAs with deck (4 levels: good, neutral, bad1 and bad2) and block (5 levels) as within-subjects variables were run, the number of selections from each deck in the five blocks being the dependent variable. Bonferroni's corrected post hoc analyses on the effect of deck were performed. The significant interactions deck × block were further investigated with simple main effect analyses in order to detect for which deck there was a significant increase/decrease in the number of choices. Patients' performance was then compared to that of the control group by means of a mixed model ANOVA deck (4 levels) × block (5 levels) × group (2 levels: patients, controls).

Neuroradiological pre-operative work-up

All patients underwent a pre-operative MRI study as follows: T1-weighted, T2-weighted and Fluid-attenuated inversion recovery (FLAIR) volumetric sequences were obtained on a 3T machine. Diffusion tensor imaging with fiber tractography of selected white matter tracts and fMRI during naming, verb generation and motor tasks were also performed, as previously described [31].

All sequences were co-registered offline and made available for intraoperative image-guidance through a Neuronavigation System (Brainlab, Fieldkirchen, Germany).

Lesion volumes were computed onto FLAIR volumetric sequences with manual segmentation with region of interest analysis with iPlan Cranial software suite (Brainlab, Fieldkirchen, Germany) by one observer (MR). FLAIR hyperintense signal abnormalities were included in the lesion load, which was then reported in cm^3 [see 32].

Results

Neuropsychological evaluation

Patients' scores on the neuropsychological tests are reported in Table 3. Lesion site did not affect performance since patients with L, M or L + M LGG did not significantly differ in any neuropsychological test, as assessed by means of one-way ANOVAs with lesion group as independent variable and scores for each test as dependent variables.

Personality traits

Since individual differences in personality may account for part of the variance in GT performance, patients' and controls' scores at the self-report scales were analyzed and the two groups were compared for the scores on the BIS and BAS and CFC. Independent sample t tests showed that they did not significantly differ {BIS [$t(46) = -1.47$, $p = 0.15$], BAS [$t(46) = -1.12$, $p = 0.27$], CFC [$t(46) = 0.12$, $p = 0.9$])}. However, the possible confounding effect of personality in comparing the two groups was controlled introducing the score of each scale as covariate in the mixed model ANOVA deck × block × group. BIS and BAS scales did not significantly affect performances {deck × BIS [$F(3, 135) = 0.23$, $p = 0.87$], deck × block × BIS [$F(12, 540) = 0.59$, $p = 0.85$], deck × BAS [$F(3, 135) = 0.3$, $p = 0.83$], deck × block × BAS [$F(12, 540) = 1.21$, $p = 0.27$]}. In contrast, a significant two-way interaction was found for the CFC scale {deck × CFC [$F(3, 135) = 3.26$, $p = 0.024$]}, hence CFC score was maintained as a covariate in this model.

Gambling task

Table 4 shows the number of cards chosen from each deck. In the case of patients, the ANOVA revealed a significant main effect of deck [$F(3, 63) = 6.7$, $p = 0.001$], but no significant interaction deck × block [$F(12, 252) = 1.7$,

Table 3 Patients' neuropsychological evaluation

Patients	Token Test (n.v. ≥ 26.5)	Digit span backward	Verbal fluency on phonological cue (n.v. ≥ 17)	Verbal fluency on semantic cue (n.v. ≥ 25)	Attentional matrices (n.v. ≥ 31)	Trail making B-A (n.v. ≥ 186)	Weigl's test (n.v. ≥ 8.1)	WCST (n.v. < 90.5)
1 (L)	31.5	4	23	30	46.75	51	12.6	n.a.
2 (L + M)	31.75	5	42	46	43.25	66	11	n.a.
3 (L + M)	**21.5**	3	**15**	**20**	49.25	145	**7.6**	89.8
4 (L + M)	33	4	35	34	51.5	30	10.6	89.4
5 (L)	32.75	4	37	38	49.75	102	8.9	30.2
6 (M)	30.3	3	38	36	47.75	86	9.3	59.8
7 (M)	33	5	17	40	45.75	51	8.9	76.5
8 (L + M)	**22.5**	4	22	31	51.75	154	**2.3**	**109.8**
9 (L)	32.5	3	24	41	44.75	75	**7.6**	31.5
10 (L + M)	33.5	7	33	44	51.75	38	11.6	16.5
11 (M)	32.75	4	34	56	48.5	38	9.9	11.2
12 (M)	33.75	4	21	37	40.5	70	9.9	15.2
13 (M)	30.75	4	26	51	46.25	53	14.9	n.a.
14 (L)	32	5	31	41	47.25	97	n.a.	n.a.
15 (M)	31.75	5	33	37	43.25	72	11	**122.4**
16 (M)	33.75	4	37	40	50.25	61	11.7	32.3
17 (L + M)	30.75	3	21	37	45.75	34	**2.3**	**114.7**
18 (L)	30.25	4	35	31	56.5	88	**7.2**	n.a.
19 (L + M)	33.75	4	51	46	52.75	19	9	**128**
20 (L)	32.75	5	25	32	50.75	48	14.9	11.2
21 (L)	30.5	3	20	27	49	**278**	**7.6**	69.4
22 (M)	36	6	34	49	43.25	82	15	29.7

Pathological scores are reported in bold

n.v. normal value, *n.a.* not administered

Table 4 Mean number of choices for each deck performed by patients and controls

Decks	Patients	Controls
Good	27.73 (13.69)	43 (22.74)
Bad 1	33.32 (13.07)	30.46 (17.31)
Neutral	20.95 (7.94)	13.23 (7.15)
Bad 2	18 (6.71)	13.30 (6.5)

Standard deviations are reported in brackets

$p = 0.068$]. Patients preferred the "bad 1" deck with a significant difference between the "bad 1" and "neutral" decks ($p = 0.021$) and between the "bad 1" and "bad 2" decks ($p = 0.001$) (see Fig. 1a).

In the case of controls, the ANOVA showed a main effect of deck [$F(3, 75) = 17.97$, $p < 0.001$] and a significant two-way interaction deck × block [$F(12, 300) = 4.09$, $p < 0.001$]. Controls preferred the "good" deck; post hoc analyses revealed that the "good" deck was chosen significantly more often than the "neutral" ($p < 0.001$) and "bad 2" ($p < 0.001$) decks. Moreover, the "bad 1" deck was chosen significantly more frequently than the "neutral" ($p < 0.001$) and "bad 2" ($p < 0.001$) decks. Simple main effects on block for each deck revealed that the factor block significantly affected the number of choices (which increased) of the "good" deck [$F(4, 100) = 5.88$, $p < 0.001$], whereas the number of choices from the "neutral" [$F(4, 100) = 5.23$, $p = 0.001$] and the "bad 2" decks [$F(4, 100) = 3.53$, $p = 0.01$] decreased over the task. No significant change was found for the "bad 1" deck [$F(4, 100) = 1.73$, $p = 0.15$] (see Fig. 1b).

Patients and controls were compared by means of a mixed model ANOVA with factors: deck (4 levels), block (5 levels) and group (2 levels: patients, controls) and CFC score as covariate (see above). The interaction group × deck was significant [$F(3, 135) = 5.55$, $p = 0.001$], while the three-way interaction deck × block × group was not [$F(12, 540) = 1.23$, $p = 0.26$]. Independent sample t tests were performed. Patients significantly differed from controls in the mean number of choices from the "good" deck [$t(46) = 2.75$, $p = 0.008$], preferred by controls, and in the mean number of choices from the "neutral"

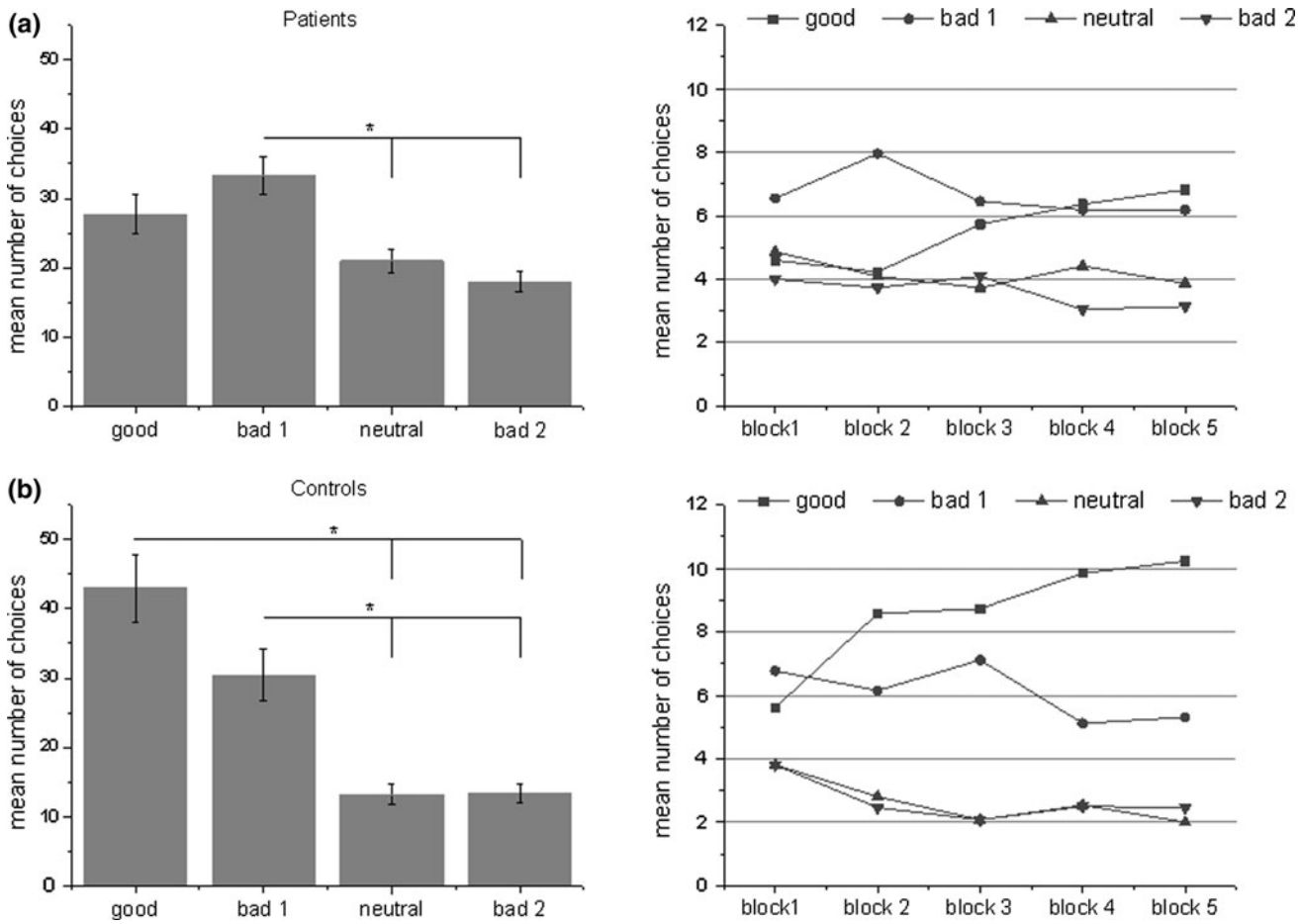

Fig. 1 **a** Patients' GT performance. Mean number of choices from each deck (*left*); mean number of choices across the five blocks (*right*). An *asterisk* denotes a significant effect ($p < 0.05$). *Error bars* represent means standard errors. **b** Controls' GT performance. Mean number of choices from each deck (*left*); mean number of choices across the five blocks (*right*). An *asterisk* denotes a significant effect ($p < 0.05$). *Error bars* represent means standard errors

[$t(46) = -3.54$, $p = 0.001$] and the "bad 2" decks [$t(46) = -2.46$, $p = 0.018$], which were chosen more frequently by patients. The two groups did not significantly differ in the number of selections from the "bad 1" deck [$t(46) = -0.63$, $p = 0.53$]. The two groups were compared also for the mean RTs; independent t test revealed that patients were significantly slower than controls [$t(46) = 3.17$, $p = 0.003$].

Conscious knowledge

Fourteen patients were classified level 0, three level 1 and five level 2. Nine control subjects were level 0, four level 1 and thirteen level 2. The relation between GT performance and conscious knowledge was examined by means of an ANOVA with comprehension level as between factor and number of choices from the "good" deck as dependent variable. The comprehension level was significant for both patients [$F(2, 19) = 25.15$, $p < 0.001$] and controls [$F(2, 23) = 13.73$, $p < 0.001$]. Bonferroni's corrected post hoc analyses revealed that level 2 patients had a significantly better performance as compared to level 1 ($p = 0.003$) or 0 ($p < 0.001$) patients. Level 1 and 2 controls performed significantly better than those at level 0 ($p = 0.001$ for both). Performances of patients and controls with the same comprehension level were compared by means of independent t tests. There were no significant differences in the number of selection from the "good" deck at level 2 [$t(16) = 0.35$, $p = 0.73$], and level 0 [$t(21) = 0.2$, $p = 0.84$].

Lesion volume and frontal function

The possible effect of lesion size was controlled introducing the tumour volume as covariate in the ANOVA deck × block. Both the interaction volume × deck [$F(3, 51) = 1.07$, $p = 0.37$] and volume × deck × block [$F(12, 204) = 0.83$, $p = 0.61$] were not significant.

The three subgroups (M, L or L + M glioma) were compared by means of a mixed model ANOVA deck × block × lesion group. The interaction group × deck was not significant [$F(6, 57) = 0.27$, $p = 0.9$], as the three-way interaction group × deck × block [$F(24, 228) = 1.27$, $p = 0.19$].

We then investigated whether GT performance correlated with neuropsychological tests assessing executive functions. A significant correlation was found between GT outcome in terms of selections from the "good" deck and score at the WCST ($r = -0.5$, $p = 0.042$), since patients with a lower global score at the WCST (indicating *better* abstract reasoning ability) [see 30] chose more cards from the "good" deck.

Post-surgery evaluation

LGG patients were tested again in the week after surgery. Paired sample *t* tests on the number of selections from each deck in the GT pre- and post-surgery sessions revealed that patients significantly chose more cards from the "good" deck [$t(21) = -2.13$, $p = 0.045$] and less cards from the "neutral" deck [$t(21) = 2.27$, $p = 0.033$], whereas selections from the "bad 1" and "bad 2" decks did not significantly change {[$t(21) = 1.22$, $p = 0.23$] and [$t(21) = 0.27$, $p = 0.79$], respectively}. Moreover, a mixed model ANOVA deck × block × group (post-surgery patients vs. controls) with CFC score as covariate showed no significant differences between patients' post-surgery performance and controls. Indeed, both the interactions deck × group [$F(3, 135) = 0.82$, $p = 0.49$] and deck × block × group [$F(12, 5540) = 0.95$, $p = 0.49$] were not significant.

Discussion

We investigated decision-making in 22 patients with a left frontal LGG by means of a computerized version of the GT. The main results were: (i) patients chose significantly less cards from the "good" deck than controls, without changing their behaviour along the task; (ii) their performance correlated with abstract reasoning ability; (iii) patients and controls, who consciously understood the task, had a better outcome.

The GT in its original [7] and modified version [14] has been used as a behavioural measure of decision-making in patients with frontal damage [8, 33] and in other clinical populations as substance abusers [34, 35] or schizophrenic patients [36, 37]. In the present study, prefrontal LGG patients showed a poorer performance relative to controls. Conscious knowledge was crucial to obtain the best results in both groups, patients and controls, but a lower proportion of patients reached conscious knowledge compared to controls, their performance being overall poorer. Motor impulsivity could explain a low performance on the GT, since patients with a prefrontal lesion could have produce an immediate motor response, without considering the goal of the task. However, this cannot be the case in the present study, since LGG patients' RTs were significantly slower with respect to controls, and, in addition, motor and cognitive impulsivity are different and dissociable impairments [8].

LGG patients' performance in the week after surgery improved, at that time being not different from controls, suggesting that patients needed more trials (those before + those after surgery) to understand the task. This improvement was *specific* for the GT, since patients' performance on the other neuropsychological tests did not improve, but in fact decreased, as it is always the case immediately after surgery [38].

Tumour size did not significantly affect performance; patients had large lesions often involving both lateral and medial areas of the frontal lobe. All patients had a left lesion, confirming that left large prefrontal LGG impair several cognitive domains [39] but, moreover, even mild cognitive dysfunction can have a large impact, if affecting decision-making. The consideration future consequences affected performance, but did not change the difference between patients and controls.

In conclusion, from a theoretical point of view our results demonstrate that not only the right, as usually reported, but also the left prefrontal cortex is involved in decision-making [40]. However, we did not investigate patients with LGG in other brain regions and it could well be the case that the simple presence of a tumour impairs performance. Further research should verify this possibility.

From a clinical point of view, this is the first study, to our knowledge, assessing decision-making in LGG patients, although impaired capacity to make treatment decisions in malignant glioma has been already demonstrated [41]. The impaired pre-surgery performance (with the post-surgery improvement, at variance with the other neuropsychological tests) suggests that patients required more time to fully understand the task, and this difficulty could apply also to understand risks and consequences of their illness. Decisions in daily life are often complex, especially when one has to decide about his/her own health, as it is the case for patients with severe illness, thus an accurate evaluation of decision-making ability is crucial to give the patients the correct support in performing their own choices.

Conflict of interest The authors declare that they have no conflict of interest.

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