Emotion recognition in patients with low-grade glioma before and after surgery

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Research Article

Keywords: low-grade glioma, social cognition, brain tumor, neurocognitive function

Posted Date: May 26th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1688338/v1

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Abstract

**Purpose.** Research on patients with low-grade gliomas (LGG) showed neurocognitive impairments in various domains. However, social cognition has barely been investigated, while it is acknowledged as an important neurocognitive domain. Facial emotion recognition is a vital aspect of social cognition, but whether emotion recognition is affected by LGG and/or resection, is unclear. Therefore, the aim was to investigate the effect of LGG and resection, by examining emotion recognition pre- and postoperatively. Additionally, the relationship between emotion recognition and general cognition and tumor location was investigated.

**Methods.** A longitudinal study, in which 30 patients with LGG who underwent resective surgery were included and matched with 63 healthy control participants (HC). Emotion recognition was measured with the Facial Expressions of Emotion-Stimuli and Tests (FEEST). General cognition was measured with neuropsychological tests. Correlations, within-group and between-group comparisons were calculated.

**Results.** Before surgery, patients performed significantly worse than HC on FEEST total (M=46.9, SD=5.4 vs. M=49.5, SD=4.9, \( p<0.05 \), \( d=0.52 \)) and FEEST Anger (M=7.6, SD=1.9 vs. M=8.3, SD=1.5, \( p<0.05 \), \( d=0.43 \)). Paired comparisons showed no significant differences between FEEST-scores before and post-surgery. No significant correlations with general cognition (memory) and tumor location were found.

**Conclusion.** This study shows similar impairments in emotion recognition in patients with LGG before and after resection, which indicates that the tumor itself contributes significantly to social cognitive dysfunction and that surgery caused no additional deficit. Impairments were not related to general cognitive deficits or tumor location. Consequently, incorporating tests for emotion recognition into neuropsychological assessment of patients with LGG is important.

Introduction

Low-grade gliomas (LGG) are primary brain tumors, with a malignancy grade of I or II according to the World Health Organization (WHO) definition[1]. Standard care consists of neurosurgical intervention to reduce tumor mass and establish a histological diagnosis, often followed by radiotherapy and chemotherapy. The majority of patients with LGG is relatively young at the time of diagnosis, with a peak incidence in adults between 30 and 40 years[2]. Due to improved treatment methods, survival rates have increased, and consequently many patients will experience long-term cognitive, emotional, and behavioral problems interfering with daily functioning and societal participation. In patients with LGG, studies demonstrated cognitive deficits in several neuropsychological domains: memory, attention, speed, executive function, and language[3, 4].

However, until now social cognition has barely been a topic of investigation in patients with LGG, despite the fact that this has recently been acknowledged as an important neurocognitive domain which is known to be vital for daily life functioning[5]. Social cognition is the ability to process social information and react adequately in social situations, which is crucial for the maintenance of meaningful social
relationships[6, 7]. The recognition of emotional states of others, i.e. emotion recognition, is a central aspect of social cognition. In particular facial expressions of emotions contain crucial information necessary to understand others’ state of mind. A few studies examined facial emotion recognition and other aspects of social cognition, in mixed groups of patients with different types of brain tumors, or selective groups of patients with a tumor in a specific brain region only (for example, insular tumors) [8–10]. To date, it is unclear to which extent facial emotion recognition is affected in patients with LGG, as detailed conclusions on LGG are not possible based on previous work. Moreover, the sole influence of the tumor on emotion recognition in patients with LGG is unknown, as previous literature about both pre- and post-surgery social cognition is also scarce[11, 12]. Specifically, only one study[11] reported scores before resection of patients with LGG, high-grade gliomas (HGG), and meningiomas separately. The results suggested intact emotion recognition in most patients pre-surgery and minor deficits in the acute phase post-surgery for LGG, which recovered largely to premorbid levels within a few months. Impairments in neurocognition, including social cognition, can be caused by the tumor, its treatment or both. Thus, to determine if emotion recognition impairment is already present before treatment and hence a direct consequence of the tumor, the present study investigates emotion recognition both before and after surgery.

Accordingly, if social cognitive impairments are already present before surgery, they might be influenced by different disease-related factors. For instance, effects of tumor location and volume on general cognitive functioning have been described in patients with LGG[3]. Social cognition deficits have been related to damage in several brain circuits, including the orbitofrontal cortex, amygdala, and temporoparietal areas[13–15]. Also, in patients with brain tumors, a distributed cortical-subcortical network has been suggested to facilitate emotion recognition[16]. Furthermore, it is plausible that the hemispheric location of the tumor influences social cognitive performance, but results are inconclusive; some authors show worse performance in right-hemispheric patients[17], while others found left-hemispheric patients to be more impaired[12]. Thus, when investigating the effect of resection on social cognition, relevant disease-related variables need to be taken into account, as the precise associations in patients with LGG are not clear.

Furthermore, an important question is to what extent performance on social cognition tests is influenced by general cognitive deficits, and consequently if impaired performance on these tests indicates a deficit in social cognition exclusively. Measuring social cognition is difficult, as tests are complex and tap several other cognitive functions, such as memory or attention. To measure emotion recognition, photographs of emotional expressions are presented that have to be recognized within a few seconds. It is likely that such a task also requires intact attention and mental speed in order to process the information quickly. Consequently, considering the wide range of possible cognitive deficits in patients with LGG[4], it is important to investigate to what extent they are related to performance on social cognition tests. To our knowledge, this association between general and social cognition has not been examined in LGG patients until now.
The aim of the present longitudinal study was to investigate the effect of glioma resection on emotion recognition in patients with LGG, by examining recognition of facial expressions both pre- and postoperatively. Subsequently, in the case of pre-surgery impairments, to investigate the relationship between social cognition and both general cognition and tumor location.

**Materials And Methods**

**Participants and procedure**

A cohort of Dutch patients who underwent resective surgery for LGG in the University Medical Center of Groningen (UMCG) between 2010 and 2018 was included in the study. Tumor grade was confirmed as being WHO grade II [1] and histological tumor type was determined by postoperative neuropathological analysis. Exclusion criteria were previous radiotherapy, chemotherapy, surgery, and a history of neurological conditions or psychiatric disturbances. Tumor localization was determined by a neuroradiologist on magnetic resonance imaging scans and categorized as mainly frontal, temporal, parietal or subcortical.

All participants underwent a neuropsychological assessment between 1 and 3 months before surgery (T1) and at least 2 months post-surgery (T2). Healthy controls (HC) were selected from a larger group of controls (collected in the context of studies at the UMCG, subdepartment Neuropsychology), and matched with the patients. Written informed consent was obtained and the study was approved by the Medical Ethics Committee of the UMCG.

**Measures**

**Social cognition**

*Emotion recognition.* The Ekman 60 Faces Test [18] is part of the Facial Expressions of Emotion-Stimuli Test (FEEST) and was used to measure facial emotion recognition. Participants have to decide which of six basic emotions (anger, disgust, anxiety, happiness, sadness and surprise) best describes the expressions in 60 photographs. The scores per emotion range from 0–10, the overall score ranges from 0–60.

**General cognition**

*Memory.* The Dutch version of the Rey Auditory Verbal Learning Test (15 Words Test, 15WT [19]) was used to measure immediate recall from memory. A series of 15 words is presented to the participant in 5 trials, who has to reproduce as many words as possible, maximum score is 75.

*Attention, speed, and executive functions.* The Trail Making Test (TMT [20]) version A and B were used to measure mental speed and cognitive flexibility. Participants need to connect numbers (A) or alternating
numbers and letters (B) in ascending order, as quickly as possible. Total scores are the number of seconds needed to complete part A and B.

Language. The category fluency (subtest Groninger Intelligence Test, GIT [21]) measures verbal fluency. Participants need to name as many words as possible in one minute, belonging to a certain category (animals).

**Statistical analysis**

All statistical analyses were performed using the Statistical Package for the Social Sciences version 23.0. Descriptive statistics were used to describe demographic and disease characteristics. Chi-square and independent t-tests were used to compare demographic characteristics of HC and patients. To test for differences in FEEST scores between several (sub)groups, independent t-tests or Mann-Whitney U tests were used. Cohen's $d$ was used to report effect sizes for all between-group comparisons ($\leq 0.2$ small effect, $0.2–0.5$ medium effect, $> 0.5$ large effect). FEEST scores were also examined in contrast to normative data and performances below the tenth percentile were considered to be impaired[23]. Paired-sample t-tests and Wilcoxon's signed-rank tests were performed to assess differences in FEEST scores over time. Standardized scores on tests for general cognition were compared to a normative sample ($M = 50$ and $SD = 10$) with one-sample t-tests. Pearson and Spearman correlations were used to assess associations between the FEEST and general cognition. Bonferroni-Holm corrections were performed in case of multiple comparisons.

**Results**

30 patients were included and 26 patients completed both T1 and T2; one patient could no longer participate due to tumor progression and three patients cancelled their follow up appointment. A group of 63 HC did not differ from the patient group with respect to age ($t = -0.14, p > 0.05$), sex ($\chi = 0.28, p > 0.05$) and education ($U = 898.5, p > 0.05$), Table 1.
Table 1
Characteristics of patient group on T1 and healthy controls

|                              | Patients N = 30 | Healthy controls N = 63 |
|------------------------------|----------------|-------------------------|
| **Demographic characteristics** |                |                         |
| Sex, number of women (%)     | 17 (56.7%)     | 32 (50.8%)              |
| Age on T1 (M ± SD)           | 41 ± 11        | 40.6 ± 13.9             |
| Educational level (M ± SD)a  | 5 ± 1          | 5 ± 1                   |
| **Treatment characteristics** |                |                         |
| Type of craniotomy, awake    | 16 (53.3%)     |                         |
| **Post-operative course**    |                |                         |
| Hemorrhageb                  | 0 (0%)         |                         |
| Increase in neurological deficitsc | 10 (33.3%) |                       |
| Wound infection              | 0 (0%)         |                         |
| Epilepsyd                    | 5 (5.2%)       |                         |
| **Disease characteristics**  |                |                         |
| Histopathology               |                |                         |
| Astrocytoma                  | 16 (53.3%)     |                         |
| Oligodendrocytoma            | 6 (20%)        |                         |
| Oligoastrocytoma             | 8 (26.7%)      |                         |
| **Location of LGG**          |                |                         |
| Frontal                      | 17 (56.7%)     |                         |
| Temporal                     | 10 (33.3%)     |                         |
| Parietal                     | 2 (6.7%)       |                         |
| Subcortical                  | 1 (3.3%)       |                         |
| **Laterization**             |                |                         |
| Left                         | 21 (70%)       |                         |
| Right                        | 9 (30%)        |                         |
Patients  
N = 30  
Healthy controls  
N = 63

Abbreviations: LGG, low-grade glioma.

a To describe educational level, the Dutch classification system of Verhage was used [22], ranging from 1 (primary school) to 7 (university education).

b Hemorrhage for which re-craniotomy was needed.

c Increase compared to pre-operative status, in first month post-surgery. In this group: (mostly temporary) speech or language difficulties, quadrantanopsia, motor deficit.

d Two or more seizures after surgery or significant increase of seizures compared to pre-operative status.

Pre- and postoperative emotion recognition

At T1, patients performed significantly worse on the FEEST-total and FEEST-Anger compared to HC, with a moderate to large effect size. No significant differences were found between patients with LGG and HC for the other emotions, see Table 2.

Table 2  
Comparison between LGG patients and healthy controls on tests for emotion recognition at T1

|                      | HC   | LGG  | T / Z | p    | Cohen's d |
|----------------------|------|------|-------|------|-----------|
| **N**                | 63   | 30   |       |      |           |
| **Emotion recognition** |      |      |       |      |           |
| FEEST total          | 49.5 (4.9) | 46.9 (5.4) | 2.36  | 0.02* | 0.52      |
| Anger                | 8.3 (1.5)  | 7.6 (1.9)  | -2.06 | 0.04* | 0.43      |
| Disgust              | 7.8 (1.9)  | 7.3 (1.9)  | -1.20 | 0.23  | 0.27      |
| Fear                 | 6.7 (2.2)  | 6.0 (2.2)  | -1.60 | 0.11  | 0.32      |
| Happiness            | 10.0 (0.2) | 9.9 (0.3)  | -0.96 | 0.33  | 0.43      |
| Sadness              | 7.8 (1.8)  | 7.2 (2.2)  | -0.91 | 0.37  | 0.31      |
| Surprise             | 8.9 (1.3)  | 8.9 (1.4)  | -0.73 | 0.47  | 0         |

Abbreviations: LGG, low-grade glioma; HC, healthy controls; FEEST, Facial Expressions of Emotion – Stimuli and Tests.

Note: an independent t-test was used to compare FEEST total scores, Mann-Whitney U tests were used to compare scores on FEEST subtests.

*Means differ significantly between groups, \( p < 0.05 \).
Paired comparisons showed no significant differences between FEEST scores before and after surgery (Table 3). Before resection, 26.7% of all patients performed below the 10th percentile and thus showed an impairment in emotion recognition. At T2, 19.2% was impaired.

Table 3
Paired comparisons between pre-operative and post-operative scores on test for emotion recognition

|        | T1            | T2            | Z/t | p    |
|--------|---------------|---------------|-----|------|
| M (SD) | M (SD)        |               |     |      |
| N = 26 | N = 26        |               |     |      |
| FEEST total | 47.4 (4.4) | 47.4 (5.6) | 0.00 | 1.00 |
| Anger  | 7.6 (1.9)     | 8.2 (1.5)     | -1.59 | 0.11 |
| Disgust| 7.3 (1.9)     | 7.3 (2.0)     | -0.10 | 0.92 |
| Fear   | 6.1 (2.2)     | 5.6 (2.5)     | 0.64  | 0.52 |
| Happiness | 9.9 (0.3) | 10.0 (0.2) | -1.00 | 0.32 |
| Sadness| 7.6 (1.5)     | 7.5 (2.1)     | -0.25 | 0.81 |
| Surprise| 8.9 (1.2)    | 8.8 (1.0)     | -0.40 | 0.69 |

Abbreviations: LGG, low-grade glioma; HC, healthy controls; FEEST, Facial Expressions of Emotion – Stimuli and Tests.

Note: paired sample t-tests were used to compare FEEST total scores, Wilcoxon’s signed-rank tests were used to compare scores on FEEST subtests. Mean time between surgery and T2 was 6.3 months (SD = 4.2, median: 4.5).

Relation between emotion recognition and general cognition

To examine if deficits in general cognition were related to performance on the FEEST, the standardized scores on general cognition tests were compared to normative data (Table 4). One-sample t-tests showed only a significant difference on the 15WT: the patient group had a mean 5.13 points below that of the normative group, i.e. a mean 0.51 standard deviations lower. Subsequently, the correlation between FEEST-total and 15WT was small and non-significant ($r = 0.26, p = 0.17$).
Table 4  
Scores on tests for general cognition at T1 (N = 30) and comparison with normative means

|                                | Raw score M (SD) | Standardized score M (SD) | Mean difference with normative group | T   | p     |
|--------------------------------|------------------|---------------------------|--------------------------------------|-----|-------|
| **Memory**                     |                  |                           |                                      |     |       |
| 15WT                           | 46.4 (9.2)       | 44.9 (10.1)               | -5.13                                | -2.79 | 0.009* |
| **Attention and executive functions** |                  |                           |                                      |     |       |
| TMT-A                          | 31.8 (9.7)       | 47.3 (8.9)                | -2.67                                | -1.64 | 0.11  |
| TMT-B                          | 69.2 (30.4)      | 49.2 (9.7)                | -0.77                                | -0.43 | 0.67  |
| **Language**                   |                  |                           |                                      |     |       |
| Fluency                        | 23.1 (4.7)       | 47.8 (8.3)                | -2.20                                | -1.46 | 0.16  |

Abbreviations: 15WT, 15 Words Test; TMT-A, Trail Making Test version A; TMT-B, Trail Making Test version B.

Note: one-sample t-tests were used to compare the standardized scores with the normative group (M = 50, SD = 10).

*Means differ significantly between groups, p < 0.05.

**Relation Between Emotion Recognition And Tumor Location**

Comparing patients with left versus right hemisphere LGG revealed no significant differences in FEEST scores (ps > 0.05, Table 5). Effect sizes were large for FEEST-total, FEEST-Fear and FEEST-Sadness scores, with lower scores in patients with a left hemispheric tumor. Also, no significant differences were found between patients with a frontal LGG and non-frontal LGG on the FEEST (ps > 0.05), with small to medium effect sizes.
Table 5
Emotion recognition scores for patients with left- and right-sided LGG and frontal and non-frontal LGG at T2.

|       | Left M (SD)    | Right M (SD)   | Z     | Cohen's d | Frontal M (SD)    | Non-frontal M (SD) | Z     | Cohen's d |
|-------|---------------|----------------|-------|-----------|-------------------|---------------------|-------|-----------|
|       | (N = 21)      | (N = 9)        |       |           | (N = 13)          | (N = 17)            |       |           |
| FEEST | 46.1 (5.3)    | 48.7 (5.3)     | -1.23 | 0.51      | 47.4 (5.6)        | 46.1 (5.1)          | -1.07 | 0.25      |
| Anger | 7.7 (1.6)     | 7.3 (2.4)      | -0.09 | 0.22      | 7.8 (1.6)         | 7.2 (2.2)           | -0.54 | 0.32      |
| Disgust | 7.1 (1.8)    | 7.9 (2.1)      | -1.15 | 0.44      | 7.4 (2.0)         | 7.2 (1.9)           | -0.19 | 0.11      |
| Fear  | 5.5 (2.3)     | 7.0 (1.7)      | -1.69 | 0.72      | 5.9 (2.4)         | 6.0 (2.0)           | -0.11 | 0.05      |
| Happiness | 9.9 (0.3)  | 9.9 (0.3)      | -0.31 | 0.00      | 9.9 (0.3)         | 9.9 (0.3)           | -0.36 | 0.00      |
| Sadness | 6.9 (2.5)    | 8.0 (1.0)      | -1.05 | 0.52      | 7.4 (2.0)         | 7.1 (2.6)           | -0.26 | 0.13      |
| Surprise | 9.0 (0.9)   | 8.6 (1.6)      | -0.40 | 0.26      | 9.0 (1.1)         | 8.7 (1.2)           | -0.90 | 0.27      |

Abbreviations: LGG, low-grade glioma; FEEST, Facial Expressions of Emotion – Stimuli and Tests.
Note: Mann-Whitney U tests were used to compare FEEST scores between groups.

Discussion

This study is the first to investigate the influence of tumor and tumor resection on social cognition in patients with LGG. We found impairments in emotion recognition, a crucial aspect of social cognition. These impairments were already present before surgery and did not significantly change afterwards, indicating that these were caused by the tumor itself, and that surgery had no additional detrimental effect in these cases. Furthermore, pre-operative social cognitive deficits were not related to tumor location and could not be explained by deficits in general cognition.

To the best of our knowledge, this is the first study to examine emotion cognition in a sample of patients with LGG only, both before and after tumor resection. Pre-surgery, patients with LGG performed significantly worse on emotion recognition than healthy controls, indicating social cognitive impairments induced by the tumor itself. Furthermore, using the FEEST norms, the prevalence rate of emotion recognition deficits before resection was 26.7%. Ergo, our findings show a pre-operative lower performance of the tumor-group, with more than a quarter of these patients already performing on an impaired level. Based on previous studies, detailed conclusions about emotion recognition in patients with LGG had not been possible, as patients with different types of brain tumors were described as one group. The one study that analyzed patients with LGG as a subgroup, found, in contrast to our findings, no indication for emotion recognition deficits in the pre-operative phase[11]. A possible explanation for
this may be the use of different neuropsychological tests. The authors used an experimental task for emotion recognition, containing 36 photographs of six emotions. In our study, we used the FEEST, that has been shown to be well-validated and reliable in various patient groups[24–28], and is therefore probably more sensitive to detect deficits in patients with LGG. Furthermore, our study was the first to investigate the distinct basic emotions in addition to overall emotion recognition in patients with LGG. Examining emotions separately is important, because impairments in specific emotions has been related to certain behavioral disturbances in other neurological patient groups[24, 29]. Our results showed that patients performed significantly worse compared to healthy controls in recognition of anger only. This can be of importance for daily functioning, considering the fact that impaired anger recognition has been associated with impaired self-awareness and behavioral problems as rated by spouses in stroke and TBI[24, 30, 31].

Not only were emotion recognition deficits already present before surgery, we also found no significant differences between pre- and post-operative emotion recognition. Ergo, the tumor appears to be the main cause of social cognitive impairments. This was unclear for social cognition in patients with LGG until now, but is in line with previous results on general cognitive impairment before and after tumor resection[32, 33]. Given the possible strong negative impact of impaired emotion recognition on daily functioning and societal participation, in particular on the fulfillment of social roles and maintenance of meaningful social relationships, timely identification and education of patients are crucial. Additionally, our results indicate that re-testing social cognition in the first few months post-surgery is not imperative. Patients often experience emotional distress in this phase, dealing with the fact that they have an incurable disease and undergoing adjuvant treatment. Consequently, appointments in the hospital for diagnostic follow-up that are not useful, should be avoided. Notably, neuropsychological assessment might be useful in later stages, when cognitive decline is possible, due to radiotherapy, chemotherapy or tumor progression[3, 32–35]. Also, no conclusions about the possible effect of supratotal resection on emotion recognition can be made based on the present study. More research on social cognition after supratotal resection, often performed in awake craniotomy, is needed[36, 37].

To our knowledge, this is the first study investigating if performance on emotion cognition tests before resection of LGG was related to general cognition and tumor location. First, no impairments on the majority of tests for general cognition were found; attention, mental speed, and executive functions were intact on a group level. Only a deficit in verbal memory was found and this deficit was not associated with poor performance on emotion recognition. This lack of association and the fact that emotion recognition was impaired in more than a quarter of our patient group, whereas most general cognitive functions were intact, leads to the conclusion that emotion recognition deficits are distinct from impairments in general cognitive functions (memory impairment) in patients with LGG. Based on this conclusion and the amount of patients with impaired emotion recognition in our group, we would recommend application of a validated test for emotion recognition in routine neuropsychological assessment. Therewith, our results endorse the conclusions of Goebel et al.[10], who recommended the inclusion of social cognitive measures in assessment of brain tumor patients.
Regarding the tumor location and social cognition, no differences in emotion recognition performance were found between patients with a frontal vs. a non-frontal tumor. LGG are unique in the sense that they cause slowly growing lesions and are known to frequently involve the frontal lobe. However, because of this slow process of tumor growth, reorganization might occur and transference of functions takes place, often referred to as dynamical plasticity\cite{38}. This may partly explain the lack of differences in social cognitive performance between patients with LGG at different locations. Additionally, this possible reorganization in a process of slow growth may also explain the fact that no significant differences between patients with a left and right hemispheric tumor were found. This is in contrast with findings in patients with acute and sudden damage such as stroke, showing more severe impairments in emotion recognition in patients with right hemispheric lesions\cite{39}. Also, the present results seem to be in line with the leading hypothesis that social cognition depends on the integrity of a broader frontotemporoparietal network, involving both hemispheres rather than solely on specific, isolated (frontal) brain areas\cite{13,16}. Consequently, lesions in different areas of this network can lead to social cognition deficits and emotion recognition should be assessed irrespective of tumor lateralization or location.

Some limitations of our study should be mentioned. First, patients with gliomas in the left hemisphere were overrepresented in our group. No significant differences in emotion recognition were found between left- and right-localized tumors, however some effect sizes of these differences were large. A lack of power may have led to the present results, thus further work including equally larger groups is needed. The same is true for comparisons between different types of resection (awake, asleep), which were not calculated due to small numbers. Of note, these different types of resection also differ regarding aims and consequences. Awake surgery is aimed at reaching the best balance between extent of resection and risks of deficits, performed when gliomas extend into eloquent areas. This often leads to supratotal resection, whereas this is not the case for surgery under general anesthesia. Secondly, our patient group was relatively small, limiting the investigation of the association between emotion recognition and specific lesion locations. More precise mapping of lesions by using voxel based lesion symptom mapping or examining brain connectivity by diffusion tensor imaging, in larger groups, might clarify the role of specific regions in social cognition in patients with LGG. Additionally, the WHO 2007 classification was used in the present study\cite{40}, whereas recently, it has been suggested that genetic markers might better represent growth rate\cite{1} and cognitive impairments\cite{41}. Unfortunately, information on genetic mutations was not available for all of our patients. Lastly, because of the explorative nature of our study, the influence of epilepsy, use of anti-epileptic drugs, mood disorders and fatigue on emotion recognition was not investigated, although these factors are relevant in patients with brain tumors and can impact general cognition\cite{42,43}. Future studies may shed light on the role of these factors regarding social cognition in patients with LGG.

Concluding, emotion recognition impairments were found before surgery and did not worsen after resection of LGG, supporting the hypothesis that the tumor itself contributes significantly to social cognitive dysfunction. This emotion recognition impairment could not be explained by deficits in general cognition and was not related to tumor location. Consequently, incorporating tests for emotion
recognition into neuropsychological assessment of all patients with LGG is important, as it is crucial for appropriate psychoeducation.

**Declarations**

**Funding:** no funding was received for this study.

**Competing interests:** none.

**Autor Contributions**

Concept and design: Gerritsen, Metzemaekers, Wagemakers, Spikman

Implementation, data collection: all authors

Analysis and interpretation of data: Buunk, Gerritsen

Literature review and original draft: Buunk, Gerritsen, Spikman

Review and approval of final manuscript: all authors

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