The impact of lesion aetiology in our understanding of visuoconstruction:

A comparison between stroke and tumor patients

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Abstract

Objectives: Visuoconstruction is a crucial function in neuropsychology, that relies on multiple mechanisms. Generally, visuoperception and executive functioning are seen as the main underlying components of this function. However, the extent to which these mechanisms contribute to visuoconstruction is poorly understood. Research studying visuoconstruction has mainly focused on stroke patients, whereas tumor patients might form valid study subjects as well and might provide convergent evidence for the findings on visuoconstruction. Therefore, the aim of this study is to assess whether stroke and tumor patients, subdivided into Low Grade Glioma (LGG) and High Grade Glioma (HGG) patients, can be used together in studying visuoconstructional abilities and assessing whether our current understanding of visuoconstruction is dependent on lesion aetiology.

Methods: 57 first-ever ischemic stroke patients and 91 tumor patients who were scheduled for awake brain surgery, subdivided into 35 LGG and 56 HGG, were assessed on the Rey-Osterrieth Complex Figure (ROCF) test, the Judgement of Line Orientation (JLO) test, the Digit Span test WAIS-III or WAIS-IV and Letter Fluency as part of standard clinical care in the University Medical Centre (UMC) Utrecht. Performance was adjusted for age, sex and education when necessary. First, the amount of impaired patients (<5th percentile) per task was evaluated per group. In addition, the mean performance was compared between the groups to assess patients' abilities in more detail. Furthermore, hemispheric dominance for visuoconstruction was investigated. Finally, stepwise multiple regression analyses were performed in all groups to reveal what role the two central components, visuoperception and executive functioning, play in visuoconstruction.

Results: Results showed that 1) stroke, LGG and HGG only differed on the JLO in the amount of impaired patients, with the most impaired patients in the stroke group, 2) stroke, LGG and HGG differed on all tasks when performance was assessed; the stroke performed worse than LGG on all tasks and worse than HGG only on the ROCF and JLO; the LGG and HGG patients differed from each other only on executive tasks, with the LGG patients performing worse than HGG patients, 3) right hemispheric dominance was found in stroke patients, whereas no hemispheric dominance was found in the tumor patients, 4) in the stroke patients, the JLO and Digit Span contributed significantly to performance on the ROCF; in the LGG patients, the JLO contributed significantly to ROCF performance, and in the HGG patients, Letter Fluency was found to be a significant predictor.

Conclusions: The differences between the findings within the stroke and tumor populations in visuoconstructional abilities and underlying mechanisms demonstrate the importance of including more than one aetiology in studying visuoconstruction. The current study suggests tumor patients can provide convergent evidence for the findings on visuoconstruction based on stroke populations. Generalisation from the one aetiology to the other, however, should be made with caution.

Keywords: lesion aetiology, neuropsychology, visuoconstruction, visuoperception, executive functioning, stroke, tumor.

Introduction

Visuoconstruction is a crucial and complex function in neuropsychology. This function is described as the ability to assemble the elements of a bidimensional or tridimensional whole, respecting their orientations and spatial relationships (Feinberg & Farah, 1997). As it is involved in many daily activities, such as drawing, buttoning shirts and constructing models, it is described as a central cognitive function (Mervis et al., 1999). Disturbances of this function were first described by Kleist in 1934, who studied visuoconstruction in brain damaged patients and introduced a syndrome called 'constructional apraxia' (CA). According to Kleist this syndrome was related to "a disturbance in the activities of drawing, assembling and building, in which the spatial form of the product proves to be unsuccessful without there being an apraxia for single movements" (Kleist, 1934). Although Kleist intended to distinguish the nature of this syndrome from motor planning disorders and elementary visuoperceptual deficits, in subsequent years, the term has been used as a single diagnostic category for all disturbances observed during drawing, assembling, and building complex models (Gianotti, 1985).

Although visuoconstruction is a central function in neuropsychology, the fundamental understanding of the underlying mechanisms is poor. As many different processes are said to be involved in visuoconstructive ability, interpretation of poor performance in single cases can be difficult (Villa, Gainotti & De Bonis, 1986). Generally, attentional, planning, visuospatial perceptual and motor mechanisms are said to play a role in visuoconstruction (Trojano & Conson, 2008). Trojano & Conson (2008) point out that many studies address different processes, but share the view that at least visuospatial processes, dedicated planning and general control processes are involved in visuoconstruction. Indeed, it has been noted that many studies investigating patients with focal brain lesions have shown that drawing disorders depend on visual-spatial or planning disturbances (Trojano & Gianotti, 2016). Planning and general control processes are considered as components of the broader concept executive functioning (Tirapu-Ustárroz, Munoz-Céspedes & Pelegrín-Valero, 2002). The extent to which the described components contribute to visuoconstruction is still a matter of debate (Grossi & Trojano, 2002; Laeng, 2006). The same holds for what hemisphere is involved in visuoconstruction. There seems to be no structural difference, but a functional difference between the hemispheres; currently, there is a consensus on a "weak" lateralisation hypothesis (Laeng, 2006; Trojano & Conson, 2008), that states that both hemispheres contribute to visuoconstruction, but right brain damaged patients are characterised by disorders of visuo-spatial analysis (Carlesimo, Fadda & Caltagirone, 1993; Trojano et al., 2004), whereas left brain damaged patients are characterised by a praxic, executive deficit (Guérin, Ska & Belleville, 1999; Trojano & Conson, 2008; Villa et al., 1986).

Most research studying visuoconstruction and visuospatial abilities focuses on stroke patients (see for example Biesbroek et al., 2014; Grossi et al., 1996; Hamsher et al., 1992; Kirk & Kertesz, 1989; Laeng, 2006; Postma et al., 2000; Treccani et al., 2005; Trojano & Grossi, 1998; Trojano et al., 2004). Generally, stroke patients are often used in neuropsychological studies as they have focal, often lateralized lesions (Damasio &

Damasio, 1989; Darby & Walsh, 2005; Heilman & Valenstein, 2011) and their onset is acute, allowing no time for functional compensation by other brain areas (Anderson, Damasio & Tranel, 1990). This way, the relationship between brain damage and cognition can be studied well. As disorders in visual perception/construction, alongside executive dysfunctions, form the most common acute cognitive impairment in stroke patients (Nys et al., 2007) and are important predictors of long-term functional impairment in stroke patients (Nys et al., 2005), stroke patients form an interesting group to study in the light of visuoconstruction. However, the focus on one patient group can lead to a certain bias. It is known, for instance, that some areas of the cortex are particularly likely to be damaged by stroke (Caviness et al., 2002). Furthermore, it is uncertain whether findings from one patient group can be generalised to different patient groups (Anderson et al., 1990). Therefore, it might be beneficial to include more than one aetiology while studying this function.

Another focal brain damaged patient group in which visuoconstructional disabilities frequently occur is tumor patients. It has been suggested that visuoconstruction is one of the most important domains to assess when evaluating cognitive change in brain tumor clinical trials (Lageman et al., 2010). However, in the literature studying visuoconstruction, tumor patients are not frequently studied. This might be due to the debate about the validity of tumor patients in neuropsychological research. It has been argued that tumor and stroke cannot be combined in researching cognitive functions, as cognitive impairments due to tumors are generally quite mild as compared to stroke (Anderson et al., 1990) and tend to have more global cognitive deficits, unlike patients with stroke who tend to have site-specific deficits (Taphoorn & Klein, 2004). This may be due to a diffuse growth of tumor cells throughout the cortex (Taphoorn & Klein, 2004; Karnath & Steinbach, 2011), to the fact that tumor cells infiltrate neural tissue rather than destroy it (Karnath & Steinbach, 2011) and to the fact that tumors grow slowly compared to the time course of a stroke, allowing for compensation and tissue displacement (Anderson et al., 1990; Karnath & Steinbach, 2011). This is especially the case for Low Grade Glioma (LGG) patients, in which the tumor cells grow relatively slowly and less aggressively compared to High Grade Glioma (HGG) patients (Rutten, Doesbug & Slooff, 1992).

However, the notion that tumor patients cannot be studied in neuropsychological research might be short-sighted. Shallice, Mussoni, D'Agostino, & Skrap (2010) argue that tumor patients can be studied as complementary study subjects, and that tumor patients provide converging evidence for the localisation of a function that is initially obtained by studying other populations, such as stroke. In addition, in the study conducted by Anderson et al. (1990) tumor patients did show some selective deficits on visuospatial tasks. Moreover, as HGG tend to be more aggressive and faster growing than LGG (Rutten et al., 1992), they might equate the effects of stroke patients. Therefore, dividing tumor patients in LGG patients and HGG patients might give rise to opportunities in combining tumor patients with stroke patients in research.

In both patient groups, visuoconstructive impairments are observed frequently (stroke: Nys et al., 2007, tumor: Lageman et al., 2010). As it is unclear to what extent the different components play a role in visuoconstructional abilities (Grossi & Trojano, 2002; Laeng, 2006), studying this function in the light of an additional patient group might shed new light on the interpretation of the function. Therefore, the aim of this study is to assess whether stroke and tumor patients, subdivided into LGG and HGG patients, can be used together in studying visuoconstructional abilities and assessing whether our current understanding of visuoconstruction is dependent on lesion aetiology. Firstly, the frequency of visuoconstructive, visuoperceptive and executive disabilities and performance on these tasks will be assessed in the stroke, LGG and HGG patient groups. As stroke patients are said to have more localised lesions (Anderson et al., 1990; Taphoorn & Klein, 2004) than tumor, it is hypothesized that stroke patient perform worse than tumor patients. As the HGG grow more rapidly and aggressively than LGG (Rutten et al., 1992), it is hypothesized that stroke patients perform worse than LGG but not necessarily worse than HGG patients. Secondly, hemispheric dominance will be tested in the three groups. As the current study uses mainly the same stroke patients as the study conducted by Biesbroek et al. (2014), who found right hemispheric neuroanatomical correlates for visuoconstruction, right hemispheric dominance is expected in the stroke group. In the tumor groups no lateralisation is expected based on the current consensus that both hemispheres are involved in visuoconstruction. Thirdly, the role that the two central components of visuoconstruction, visuoperception and executive functioning, play in visuoconstruction are analysed in the stroke, LGG and HGG group. As these analyses are exploratory, no hypotheses are formed. We hope to create more clarity in our understanding of visuoconstruction and to provide an answer to the question whether stroke and tumor patients can be grouped together in studying visuoconstruction.

Methods

Participants

We used data from 57 stroke patients with first-ever ischemic stroke who had been admitted to the University Medical Center (UMC) Utrecht from November 2005 to December 2012. The following inclusion criteria were used for the stroke patients: 1) first-ever ischemic stroke, 2) an infarction on follow-up CT or MRI. The stroke patients were selected from the study cohort used by Biesbroek et al. (2014). From this cohort, patients were excluded based on the exclusion criteria mentioned later. In addition, we included 91 tumor patients that were scheduled to undergo awake brain surgery at the University Medical Center (UMC) Utrecht between November 2009 and February 2016. For the tumor patients the following inclusion criteria were used: 1) first-ever awake brain surgery, 2) patients that suffer from gliomas. The findings from pre-operative neuropsychological assessment are used in the present study. The tumor group was divided into a Low Grade Glioma (LGG) group (WHO grade ≤ 2), consisting of 35 patients, and a High Grade Glioma (HGG) group (WHO grade ≥ 3), consisting of 56 patients. Complete data on the Rey-Osterrieth Complex Figure (ROCF; Osterrieth, 1944; Rey, 1941) test, the Judgement of Line Orientation (JLO; Benton, Sivan, Hamsher, Varney & Spreen, 1983) test, the Digit Span test WAIS-III or WAIS-IV (Wechsler, 1997; Wechsler, 2008) and the Dutch version of the Controlled Oral Word Association Test (COWAT-DAT; Schmand et al., 2008) test or the Dutch Letter Fluency test "NA" was required for inclusion in both patient groups.

Patients with pre-existent neurologic conditions that might interfere with cognition (n = 13) were excluded. Patients who suffer from infratentorial lesions (n = 12), metastasis (n = 6), hemangioma (n = 1) and meningioma (n = 1) were excluded. In the tumor group, data from patients that underwent a re-resection (n = 21) was excluded. In addition, patients that showed signs of neglect (n = 10) were excluded. From the patients that underwent neuropsychological testing, no patients showed signs of hemianopsia, hemiplegia or apraxia. The sample of stroke patients consists of 31 males and 26 females and the mean age is 58.46 (SD = 15.47, range = 20 – 84). The sample of LGG patients consists of 22 males and 13 females and the mean age is 39.40 (*SD* = 11.28, range = 19 – 66). The sample of HGG patients consists of 42 males and 14 females and the mean age is 57.39 (*SD* = 12.64, range = 26 – 81). For more demographic details see table 1, 2 and 3.

Table 1. *Demographic information of the study population*

	Stroke (n = 57)	**LGG (n = 35)**	**HGG (n = 56)**
Age in years (SD)	58.5 (15.5)	39.4 (11.3)	57.4 (12.6)
Gender (%)			
Female	26 (45.6)	13 (37.1)	14 (25.0)
Male	31 (54.4)	22 (62.9)	42 (75.0)
Education level (%)*			
Low (1-5)	34 (59.6)	13 (37.1)	32 (57.1)
High (6-7)	23 (40.4)	22 (62.9)	24 (42.9)
Dominant hand (%)			
Right	48 (84.2)	19 (54.3)	32 (57.1)
Left	7 (12.3)	2 (5.7)	7 (12.5)
Ambidexter	1 (1.8)	0 (0)	2 (3.6)
Missing	1 (1.8)	14 (40.0)	15 (26.8)
Time in days between symptom onset and assessment (median)	6.0 (*M* = 8.4, *SD* = 7.1), range = 2 – 34		

*Education level was measured according to the education coding method of Verhage (1964).

Table 3. *Left and right hemisphere distribution in the stroke, LGG and HGG groups (n, %)*

	Stroke (n = 57)	**LGG (n = 35)**	**HGG (n = 56)**
Left hemisphere	27 (47.4)	25 (71.4)	45 (80.4)
Right hemisphere	30 (52.6)	10 (28.6)	11 (19.6)

Table 2. *Location of the lesion per lobe in the stroke, LGG and HGG groups (n, %)*

	Stroke (n = 57)	**LGG (n = 35)**	**HGG (n = 56)**
Frontal	7 (16.7)	13 (37.1)	22 (39.3)
Temporal	12 (28.6)	8 (22.9)	10 (17.9)
Parietal	2 (4.8)	8 (22.9)	12 (21.4)
Occipital	7 (16.7)	0 (0)	0 (0)
Insular	5 (11.9)	5 (14.3)	7 (12.5)
Central	9 (21.4)	1 (2.9)	5 (8.9)
Subcortical*	15 (26.4)	0 (0)	0 (0)

*Subcortical lesions include lesions in the basal ganglia, thalamus, putamen, capsula interna and periventricular lesions.

Task and Stimuli

Visuoconstruction, visuoperception and executive functioning were assessed in all patients. Visuoconstruction was operationalized by the copy trial of the Rey Osterrieth Complex Figure test (ROCF; Osterrieth, 1944; Rey, 1941). Visuoperception is operationalized by the Judgement of Line Orientation test (JLO; Benton et al., 1983). As executive functioning is a broad mental function, in the current study the operationalization was based on the classic conceptualization by Miyake, Friedman, Emerson, Witzki and Howerter (2000), who propose three *latent* executive functions. They argue that 1) shifting between tasks or mental sets ("Shifting"), 2) updating and monitoring of working memory representations, ("Updating"), and 3) inhibition of dominant or prepotent responses ("Inhibition") comprise these latent variables. They view planning to be a more high level executive function, which is less suitable for operationalization than the latent variables mentioned above. Two of these latent executive functions are measured in the current study, namely "Shifting" and "Updating". The former is measured by the Controlled Oral Word Association Test – DAT (COWAT-DAT; Schmand, Groenink & van den Dungen, 2008) or by the Dutch Letter Fluency NA task. The latter is measured by the Digit Span test of the WAIS-III or WAIS-IV (Wechsler, 1997; 2008). See table 4 for an overview of the neuropsychological tasks.

Rey-Osterrieth Complex Figure Test (ROCF) – Copy trial. The ROCF is used commonly for the evaluation of visuoconstructional ability (Chiulli, Haaland, Larue & Garry, 1995). In this test, a complex figure is shown to the patient and the patient is subsequently asked to copy the figure onto a sheet of paper. The figure is placed so that its length runs along the subject's horizontal plane and the patient is not allowed to rotate either the design or the paper (Strauss, Sherman & Spreen, 2006). The patient is allowed to take as much time as needed to complete the copying. The copied figure is scored using a scoring method which divides the figure into 18 scorable units, which refer to specific details of the figures. Each unit can be given 2 points; 0 points are given if the unit is misplaced and incorrect, 1 point is given if the unit is either placed well or correct and 2 points are given if the unit is both placed well and correct. The criteria of the manual made by Meyers and Meyers (1995) are used to score the separate units. With 18 units the maximum score amounts to 36.

Judgement of Line Orientation (JLO). The JLO is a measure of visuoperception (Lindeboom, Mulder & Bouma, 2012). In this test, the patient is shown a test book in which on the top page two lines with different orientations are depicted and on the bottom page a ray of eleven numbered lines is depicted, varying from 0° to 180°. The patient is asked to identify the stimulus lines on the top page by naming the corresponding number on the bottom page (Lindeboom et al., 2012). In this study, only 15 items were administered, ranging from item 10 till 25, as it is common practice to use this shortened form in the clinical care. Each answer is given a score 0 (incorrect) or 1 (correct). The answer is qualified as correct when *both* lines are identified correctly. The patient is not restricted by time limits. The total raw score is multiplied by 2 to extrapolate the score to the longer 30 item form, making the maximum score 30.

Digit Span WAIS-III or WAIS-IV. The Digit Span is a subtest of the Wechsler Adult Intelligence Scale – Third or Fourth Edition (Wechsler, 1997; 2008) and is one of the most commonly used working memory task. In the current study, some patients were administered the Digit Span WAIS-III and some the Digit Span WAIS-IV. The WAIS-III consists of two subtests: forward and backward. The patient is asked to repeat a sequence of digits in the same order or backward, respectively. Both conditions contain eight trials with two sequences of the same amount of digits. The number of digits increases in each trial, ranging from two digits to eight digits. Each response is given a score 0 (incorrect) or 1 (correct) and there are two items per trial, resulting in a score of 0, 1 or 2 per trial. The span score is calculated by counting the number of digits of the longest sequence that was answered correctly. The two total scores of the forward and backward condition are added up to obtain a total score on the test (Wechsler, 1997). The WAIS-IV has an added condition, called sequencing, in which the patient is asked to order the numbers from small to large (Wechsler, 2008). A total score is obtained by adding the scores of the three conditions. However, in the current study only the forward and backward conditions of the WAIS-IV were taken into account, in order to ensure uniformity with the WAIS-III data.

Letter Fluency – COWAT-DAT or NA version. Letter fluency or phonemic fluency is a task that is used frequently in clinical settings to measure executive functioning (Abrahams et al., 2000). More specifically, clustering and switching have been proposed as the main two components underlying fluency performance (Troyer, Moscovitch & Winocur, 1997). In our patient groups, either the Dutch version of the Controlled Oral Word Association Test (COWAT-DAT; Schmand et al., 2008) was administered, or another Dutch version of Letter Fluency that is used commonly in clinical practice at the University Medical Centre Utrecht is used, using the letters N and A. Patients are asked to generate as many words as possible beginning with the letters D, A or T in the COWAT-DAT test, and the letters N or A in the NA version. Patients are instructed to name all words they know, except words that start with a capital letter or names. One point is given for every correct word that is generated. The total score is obtained by adding up all acceptable words produced for all letters.

Table 4. *Neuropsychological functions and tasks that are used to operationalize them*

Cognitive function	**Task**
Visuoconstruction	Rey-Osterrieth Complex Figure (ROCF) test
Visuoperception	Judgement of Line Orientation (JLO) test
Executive functioning	
"Shifting"/Mental flexibility	Controlled Oral Word Association Test – DAT or Dutch NA Letter Fluency test
"Updating"/ Working memory	Digit Span test WAIS-III or WAIS-IV

Procedure

The neuropsychological assessment was performed in the setting of standard clinical care at the Utrecht Medical Center (UMC). Stroke patients were seen within one month from the onset of the stroke. The tumor patients were assessed approximately one week before they underwent awake brain surgery. They were tested in a quiet room with minimal external distraction. During the neuropsychological assessment multiple tasks were conducted, including the above mentioned tasks ROCF, JLO, Digit Span (WAIS-III or WAIS-IV) and a Letter Fluency task (COWAT-DAT or NA). Instructions were given verbally by the examiner, according to the manuals of the tests. The total time of the neuropsychological assessment is approximately two hours.

Data preparation

The raw scores were transformed into norm-corrected scores in the following manners.

ROCF. The raw score is corrected for age and education level using the correction method by Caffarra, Vezzadini, Dieci, Zonato & Venneri (2002). The corrected scores are subsequently transformed into scale scores, which are in turn transformed into percentiles. In the analyses of this study, both the corrected scores and percentiles are used.

JLO. The raw score is corrected for age and sex. The corrected score is transformed into percentiles. In the analyses of this study, both the corrected scores and the percentiles are used.

Digit Span. The raw score is corrected for education level. The total scores of all patients were transformed into scaled scores (M = 10, SD = 3) and percentiles, using the norms of the WAIS-III to make the data uniform.

Letter Fluency. The total scores of the COWAT-DAT are norm-corrected for age, sex and level of education. The total scores of the NA version are corrected for level of education. In order to be able to compare the data of the two tests, the total scores transformed into z scores based on their own norm groups.

Statistical Analysis

All statistical analyses were performed with SPSS, version 21 (IBM Corp, 2012). Descriptive statistics (frequencies, means and SDs) were generated to describe the sociodemographic and clinical characteristics of the study population and the distribution of scores on the neuropsychological tasks. For the first question, the amount of patients that are impaired on the ROCF was analysed per patient group (stroke, LGG and HGG), as well as the amount of patients that was impaired on the JLO, Digit Span and Letter Fluency. Norm-corrected performance <5th percentile was considered to be abnormal. Chi-square tests were performed to analyse differences in the amount of impairments between stroke, LGG and HGG patients. As a strict cut-off point was used in determining impairment (<5th percentile), not only the amount of impaired patients was assessed on all tasks, but performance level was evaluated as well in order to analyse patients' abilities in more detail. Mean performance scores on the neuropsychological tasks between stroke, LGG and HGG patients were compared using a multiple analysis of variance (MANOVA). Cohen's classification of effect sizes (η^2 = .02 small, η^2 = .13 medium, η^2 = .26 large) was used (Pierce, Block & Aguinis, 2004). Planned contrasts were used to assess how the groups differed from each other. First, stroke patients were used as a reference group in the planned contrasts. Afterwards, HGG patients were used as a reference group, in order to be able to evaluate contrasts between LGG and HGG. For the second question, chi-square tests were performed to assess differences between the proportion of left and right hemispheric patients that are visuoconstructively impaired in all patient groups. In order to answer the last question, stepwise multiple regression analyses were performed in the stroke, LGG and HGG group, with the ROCF as dependent variable and the JLO, Digit Span and Letter Fluency as independent variables. In the first step, the control variable lateralisation (left = 1, right = 2) was added to the model (method: Enter). In the second step, the scores on JLO, Digit Span and Letter Fluency were added (method: Stepwise).

Results

Patterns of impairments and functioning in stroke, LGG and HGG patients

Impairment level

There was a significant difference in the amount of patients that were impaired on visuoperceptive tasks between the stroke, LGG and HGG patient group χ^2 (2) = 16.08, p < .0001, with the highest amount of impaired patients in the stroke group. No significant differences were found between the groups in the number of patients that was impaired on visuoconstructive task, χ^2 (2) = 5.78, p = .056, on Letter Fluency task, χ^2 (2) = 3.80, p = .150, and on Digit Span task, χ^2 (2) = 5.24, p = .073. After applying a Bonferroni correction in order to correct for multiple comparisons, the results remained the same. See table 5 and figure 1 for the amount and percentage of impaired patients per task per group.

Table 5. *Amount and percentage of impaired patients on the ROCF, JLO, Letter Fluency and Digit Span test per patient group (n, %)*

	Stroke (n = 57)	**LGG (n = 35)**	**HGG (n = 56)**	**p-value**
ROCF	19 (33.3)	5 (14.3)	10 (17.9)	.056
JLO	16 (28.1)	0 (0)	5 (8.9)	<.0001
Letter Fluency	18 (31.6)	5 (14.3)	17 (30.4)	.150
Digit Span	8 (14)	0 (0)	7 (12.5)	.073

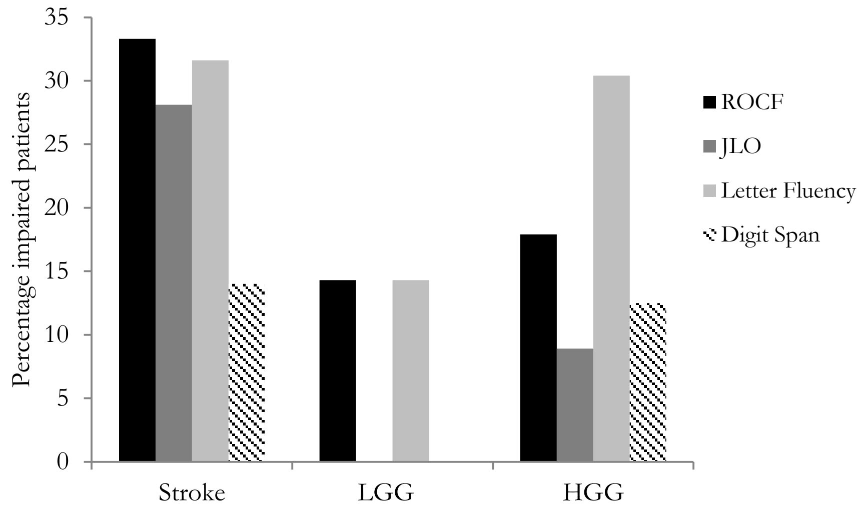

Figure 1. Percentage of patients that are impaired on the ROCF, JLO, Letter Fluency and Digit Span per patient group.

Performance level

The performance on the tasks was assessed per group evaluating the mean and standard deviation per group (see table 3). A MANOVA was used to examine the effect of aetiology (1: stroke, 2: LGG, 3: HGG) on task performance (ROCF, JLO, Fluency and Digit Span). Findings showed that there was a significant main effect of aetiology on the performance on the different tasks, $\Lambda = .679$, $F(8.284) = 7.57$, $p < .0001$, partial $\eta^2 = .176$. Planned contrast analysis, with stroke as reference category, revealed that stroke patients performed significantly worse than LGG patients on the ROCF ($p = .007$), JLO ($p < .0001$), Letter Fluency ($p = .008$) and Digit Span ($p < .0001$). Stroke patients performed significantly lower than the HGG group on the ROCF ($p = .002$) and the JLO ($p < .0001$), but did not differ significantly from the HGG group on the Letter Fluency ($p = .696$) and the Digit Span ($p = .151$). Planned contrasts with HGG as a reference group revealed no significant differences between the LGG and HGG group on the ROCF ($p = .995$) and the JLO ($p = .126$), but did show significant differences on the Letter Fluency ($p = .022$) and Digit Span ($p = .004$). See table 6 for the mean and SD per patient group per task.

Table 6. *Mean performance on the ROCF, JLO, Letter Fluency and Digit Span test per patient group*

	Stroke (n = 57)	LGG (n = 35)	HGG (n = 56)
Corrected ROCF score (M, SD)	28.9 (5.9)[a, b]	31.5 (2.4)	31.5 (3.2)
Corrected JLO score (M, SD)	21.5 (6.2)[a, b]	28.3 (2.5)	26.6 (4.8)
Letter Fluency z-scores (M, SD)	-1.3 (1.1)[a]	-0.6 (1.1)[b]	-1.2 (1.1)
Digit Span scaled scores (M, SD)	8.1 (2.9)[a]	10.8 (3.1)[b]	8.9 (2.9)

a = differs significantly from LGG, *b* = differs significantly from HGG

Lateralisation of visuoconstruction

Chi-square tests were performed to evaluate differences in the number of visuoconstructively impaired patients between the left and right hemisphere in the stroke, LGG and HGG group.

Stroke

There was a significant difference in the amount of left and right hemispheric patients that were impaired on visuoconstructive tasks in the stroke group χ^2 (2) = 11.400, p = .001, with 84.2% of the impaired patients on visuoconstruction having right hemispheric damage, and 15.8% of the impaired patients suffering left hemispheric damage.

LGG

There was no significant difference in the amount of left and right hemispheric patients that were impaired on visuoconstructive tasks in the LGG group χ^2 (1) = 0.210, p = .647.

HGG

There was no significant difference in the amount of left and right hemispheric patients that were impaired on visuoconstructive tasks in the HGG group χ^2 (1) = 0.827, p = .363. After applying a Bonferroni correction in order to correct for multiple comparisons, the results remained the same in all three groups.

The role that visuoperception and executive functioning play in visuoconstruction

In order to evaluate the amount of variance of the ROCF that is explained by performance on the JLO, Letter Fluency and Digit Span, stepwise multiple regression analyses were performed in the stroke, LGG and HGG group. Lateralisation was controlled for in all groups, by entering it in the first block. Prior to analyzing the results of the regression equation, assumptions were evaluated. Assumptions of normality of residuals, linearity and homoscendasticity were met. In addition, there was no evidence of mulitcollinearity or outliers.

Stroke

It was found that JLO and Digit Span explained a significant amount of the variance in the performance on the ROCF in stroke patients, F (3,53) = 21.539, $p < .0001$, adjusted $R^2 = 0.524$, after controlling for lateralisation. Lateralisation accounted significantly for variance in the ROCF, $\beta = -.283$, $t(56) = -2.989$, $p = .004$, and explained a significant 15.2% of the variance, $R^2 = .152$, $F(1, 55) = 9.823$, $p = .003$. The JLO significantly predicted ROCF performance, $\beta = .568$, $t(56) = 6.003$, $p < .0001$, and accounted for an additional 32.9% of the variance, $\Delta R^2 = 0.329$, ΔF (1, 54) = 34.231, $p < .0001$. In addition, the Digit Span significantly predicted ROCF performance, $\beta = .263$, $t(56) = 2.842$, $p = .006$, accounting for an additional 7%, $\Delta R^2 = 0.069$, ΔF (1, 53) = 8.078, $p = .006$. The regression coefficients are specified in table 7.

Table 7. *Unstandardized (B), standard errors (SE B) and standardized (β) regression coefficients for each predictor in the stepwise multiple regression models for visuoconstuction in stroke patients.*

	B	**SE B**	**β**
Step 1			
Constant	35.90	2.34	
Lateralisation	-4.567	1.457	-.389*
Step 2			
Constant	21.682	3.053	
Lateralisation	-3.089	1.178	-.263**
JLO corrected score	0.557	0.095	.587*
Step 3			
Constant	18.09	3.136	
Lateralisation	-3.319	1.11	-.283*
JLO corrected score	0.538	0.09	.568*
Digit Span scaled score	0.535	0.188	.263*

*$p < .01$, **$p < .05$

LGG

It was found that the JLO explains a significant amount of the variance in the performance on the ROCF in LGG patients, F (2, 32) = 3.487, $p = .043$, adjusted $R^2 = 0.128$, after controlling for lateralisation. Lateralisation did not significantly account for variance in the ROCF, $\beta = .211$, $t(34) = 1.314$, $p = .198$. The JLO significantly predicted ROCF performance, $\beta = .373$, $t(34) = 2.328$, $p = .026$, and accounted for 13.9% of the variance, $\Delta R^2 = 0.139$, ΔF (1, 32) = 5.418, $p = .026$. The regression coefficients are specified in table 8.

Table 8. *Unstandardized (B), standard errors (SE B) and standardized (β) regression coefficients for each predictor in the stepwise multiple regression models for visuoconstruction in LGG patients.*

	B	**SE B**	**β**
Step 1			
Constant	30.155	1.204	
Lateralisation	1.035	0.883	.200
Step 2			
Constant	20.171	4.436	
Lateralisation	1.091	.830	.211
JLO corrected score	0.350	0.150	.373*

$^*p < .01$, $^{**}p < .05$

HGG

It was found that the Letter Fluency explains a significant amount of the variance in the performance on the ROCF in HGG patients, F (2, 53) = 4.861, p = .012, adjusted R^2 = 0.123, after controlling for lateralisation. Lateralisation significantly accounted for variance in the ROCF when combined with Letter Fluency, β = -.310, t(55) = -2.371, p = .021; on its own, however, it was not a significant predictor of ROCF performance, β = -.221, t(55) = -1.669, p = .101. The Letter Fluency significantly predicted ROCF performance, β = .337, t(55) = 2.578, p = .013 and accounted for 10.6% of the variance, ΔR^2 = 0.106, ΔF (1, 53) = 6.645, p = .013. The regression coefficients are specified in table 9.

Table 9. *Unstandardized (B), standard errors (SE B) and standardized (β) regression coefficients for each predictor in the stepwise multiple regression models for visuoconstruction in HGG patients.*

	B	**SE B**	**β**
Step 1			
Constant	33.576	1.316	
Lateralisation	-1.742	1.044	-.221
Step 2			
Constant	35.573	1.473	
Lateralisation	-2.442	1.030	-.310**
Letter Fluency z-score	.978	0.379	.337**

$^*p < .01$, $^{**}p < .05$

Discussion

The aim of this study was to evaluate the differences and similarities between stroke and tumor patients in visuoconstruction, in order to discover the potential of adding tumor patients to study samples in neuropsychological lesion studies studying visuoconstruction. First, the frequency of visuoconstructive, visuoperceptive and executive impairment and performance on these tasks was evaluated. Secondly, it was tested whether visuoconstruction was lateralised in our study populations. Thirdly, the role that different components play in visuoconstruction was evaluated per patient group.

The first analysis revealed that there were no significant differences in the amount of patients with impairments in visuoconstruction between stroke, LGG and HGG patients, nor in the amount of patients that were impaired on the tasks measuring executive functions. The patient groups did differ in the amount of visuoperceptive impairments, with stroke containing the highest amount of impaired patients, and the LGG group the lowest amount. When the mean scores on the tasks were assessed, the patient groups differed significantly on all tasks. Stroke patients performed significantly worse than the tumor patients on visuoconstruction and -perception. In both executive tasks, stroke patients performed worse than the LGG patients, but not than HGG patients. There was no difference between the LGG and HGG patients on visuoconstruction and -perception, but there was a difference on executive functioning. The second analysis revealed hemispheric dominance only in stroke patients. In this patient group, significantly more right hemisphere patients were impaired on visuoconstruction. The third analysis revealed that in stroke patients, visuoperception and "updating" or working memory/attention played a role in visuoconstruction. In LGG patients, only visuoperception played a role in visuoconstruction. In HGG patients, only "shifting" contributed to visuoconstruction. In the following sections the results of these analyses will be discussed.

Firstly, the analysis of the patterns of impairments and functioning in stroke, LGG and HGG patients will be discussed. The fact that there were no differences between the groups in visuoconstruction at an impairment level, suggests that stroke and tumor can be combined in studying visuoconstruction. When assessed in more detail, on a performance level, however, it was found that stroke patients performed worse than tumor patients on most tasks. This is in line with research suggesting that cognitive impairments due to stroke are more severe than due to tumor (Anderson et al., 1990). The fact that stroke and HGG showed no difference in performance on executive functioning is in line with the notion that both in stroke and HGG executive dysfunctioning is commonly observed (stroke: Gottesman & Hillis, 2010; Kruijt et al., 2008; Lésniak, Bak, Czepiel, Seniów & Czlonkowska, 2008; Nys et al., 2005; Nys et al., 2007; HGG: Klein et al., 2001; Meyers, Weitzner, Valentine & Levin, 1998; Price, Goetz & Lovell, 2002). Despite the fact that in both LGG and HGG patient groups a relatively high amount of patients suffered frontal lesions (see table 2), LGG patients were less impaired on executive functioning. This is in line with the general belief that LGG are less impaired in cognitive functioning than HGG patients (DeAngelis, 2001; Hahn et al., 2003; Hom & Reitan, 1984; Talacchi, Santini, Savazzi & Gerosa, 2011), specifically in executive functioning (Miotto et al, 2011). It contrasts other studies that argue that LGG patients show more cognitive impairment than is traditionally believed (Reijneveld, Sitskoorn, Klein, Nuyen, & Taphoorn, 2001; Teixidor et al., 2007). Despite the fact that stroke patients performed worst on most tasks, it must be pointed out that the tumor groups did show specific deficits in the current study (see table 5), especially the HGG patients. This contradicts research claiming tumors show more global deficits than stroke (Taphoorn & Klein, 2004) and strengthens the argumentation that tumor patients can form complementary study subjects (Shallice et al., 2010). Especially in studying executive functioning, it seems stroke and HGG patients can be combined.

The findings that there was a significant difference between the stroke, LGG and HGG patients, are not in line with a recent study that showed that stroke, LGG and HGG did not differ in executive functioning (Cipolotti et al., 2015). The discordance between the conclusions of this study and our findings might partly be explained by the fact that Cipolotti et al. (2015) used *only* frontal patients, whereas our study included several lesion locations. Thus, even though there was a high prevalence of frontal lesions in the tumor groups, other lesion locations were taken into account as well in the present study. As executive processes are said to be mediated by networks incorporating multiple cortical regions (posterior as well as prefrontal regions) (Goldman-Rakic, 1998; Mesulam, 1998), other lesion regions than the frontal lobe should be included as well when assessing executive functioning. Furthermore, Cipolotti et al. (2015) assessed patients post-operatively, whereas the current study assessed patients pre-operatively. As surgery can have effects on cognitive functioning, both positively and negatively (Habets et al., 2014; Satoer, Visch-Brink, Dirven & Vincent, 2016; Talacchi et al., 2011), this might confound their results.

Secondly, the analysis of lateralisation will be discussed. The fact that stroke patients showed lateralisation was in line with our expectations, as Biesbroek et al. (2014) found right hemispheric neuroanatomical correlates for visuoconstruction in this population of stroke patients. Nevertheless, it must be noted that not *all* visuoconstructively impaired patients in our study had right hemispheric damage; a small 15.8% had left hemispheric damage. Thus, left hemispheric involvement in visuoconstruction cannot fully be ruled out in this group (Biesbroek et al., 2014). The fact that tumor patients did not show lateralisation is in line with the current consensus in the literature (Guérin et al., 1999; King, 1981; Trojano, De Cicco & Grossi, 1993, Trojano et al., 2004; Trojano & Conson, 2008). However, these results must be interpreted with caution, as the distribution of left and right hemispheric patients is not equal in the groups. In the stroke group, there is a relatively low amount of left hemispheric patients. This might be explained by the fact that neuropsychological assessment was not always possible in patients with aphasia. In addition, left hemispheric damage is overrepresented in the tumor group. This may be due to the fact that language abilities are easily tested during awake craniotomy, leading to more neuropsychological assessment of left hemispheric glioma patients. Future research should carefully match left and right brain damaged patients throughout the different aetiologies when assessing lateralisation.

Thirdly, the analysis of the underlying components of visuoconstruction will be discussed. This analysis led to divergent findings. In stroke patients, both a visuoperceptional and an executive functioning component, "updating" or working memory/attention, play a role. Working memory deficits have been reported repeatedly following stroke (Hommel et al., 2009; Philipose, Alphs, Prabhakaran & Hillis, 2007; Van Geldorp, Kessels & Hendriks, 2013). The fact that this function forms a central component of visuoconstruction in stroke might be surprising, as verbal working memory is said to be mediated by the left hemisphere (Langel, Hakun, Zhu & Ravizza, 2014; Nagel, Herting, Maxwell, Bruno & Fair, 2013; Walter et al., 2003) and right sided lateralisation of visuoconstruction in the stroke group was found. However, as lateralisation was controlled for in the analysis, the effect of working memory is robust. The involvement of this component underlines the importance of executive functioning in this patient group, which is in line with the findings from our previous analyses (see third alinea) and literature (Nys et al., 2007). Furthermore, the fact that both visuoperception and executive functioning play a role in visuoconstruction in stroke patients is in line with the literature on visuoconstruction (see Trojano & Conson, 2008).

In LGG patients, only visuoperception was found to play a role in visuoconstruction. The fact that no executive component was found is in line with our previous results that LGG patients showed relatively little executive problems (see third alinea) and literature suggesting LGG patients show less executive impairment than HGG patients (Miotto et al., 2011). However, the fact that only visuoperception was found, is not in line with literature suggesting both visuoperception and executive functioning play a role in visuoconstruction (see Trojano & Conson, 2008). In HGG patients, only "shifting" was found to play a role in visuoconstruction. Impairments in mental flexibility and nominal verbal fluency have been reported in HGG patients previously (Miotto et al., 2011) and word fluency is among the most frequently affected functions in glioma patients (Talacchi, Santini, Savazzi & Gerosa, 2011). However, the fact that no visuoperceptive component was found, is not consistent with the literature. The fact that different components play a role in visuoconstruction in the stroke, LGG and HGG patient groups shows that including different aetiologies can lead to divergent findings about visuoconstruction. As visuoperception played a role in LGG patients and executive functioning in HGG patients, adding these patient groups to the stroke population could lead to convergent findings on the underlying mechanisms of visuoconstruction.

There were some limitations to this study. First of all, some methodological matters regarding the study sample were suboptimal. For example, the current study did not control for handedness, as information was missing in many patients on their handedness. As handedness is strongly related to hemispheric specialization of language functions in the left hemisphere (Berker, Berker & Smith, 1986; Harris, 1991; Knecht et al., 2000) and the right hemisphere is involved in spatial processing (Joseph, 1988), this might influence the lateralisation analysis in this study. In addition, there was a heterogeneous study group with regards to lesion location. Lesion location was not taken into account in analyses, whereas lesions in different lobes can result in different cognitive impairments due to their functional specialization. As Anderson et al. (1990) did carefully match patients based on lesion location, a direct comparison with this study should be made with caution. Thus, future research should include a sample with an equal distribution of lesion locations or control for lesion location in the analyses. Furthermore, the range of days between the onset of stroke and neuropsychological assessment in stroke patients was quite large (see table 1). Thus some patients were assessed in the acute phase (1 day – one week), others in the subacute phase (1 week – 1 month) or the chronic phase (>1 month). As cognitive outcome can vary between these groups (Gottesman & Hillis, 2010), this can influence the results of the current study. Moreover, it would be interesting to take into account the time between the diagnosis and neuropsychological assessment in tumor patients, which can provide an insight into how much time the brain has had to compensate the brain damage functionally. This is informative, as it is known that low and high grade tumors recruit different mechanisms of neural plasticity when compensating for different lesion growth patterns pre-operatively (Van Dellen et al., 2012).

Moreover, in the stroke group, subcortical lesions were included, whereas the tumor patients suffered from mainly cortical lesions. An exploratory, 'quick and dirty analysis' was conducted to study the effects of excluding the subcortical stroke patients from the study sample (see appendix 1). Results revealed slight changes; there were less impairments on all tasks, the mean performance decreased on all tasks but the Letter Fluency and the JLO was the only significant factor in visuoconstruction. These results lead to an overall different representation of visuoconstructional functioning in stroke patients. As subcortical lesions following stroke can lead to substantial neuropsychological disorders (Hochstenbach, van Spaendonck, Cools, Horstink & Mulder, 1998), it is beneficial to include these in neuropsychological analyses. It has been reported, for instance, that strokes in the basal ganglia can result in memory, attention, visuospatial and language dysfunction (Hochstenbach et al., 1998) and that strokes in the thalamus can result in deficits in long-term memory, executive functioning and attention (van der Werf et al., 2003). Future research should aim to include subcortical lesions in the tumor group as well, as cognitive deficits have been reported in subcortical tumor as well (Friedman, Meyers, & Sawaya, 2003). The fact that the deep location of subcortical tumors makes surgical removal difficult (Kelly, 1986) might explain why no subcortical lesions were present in the current study. Modern techniques such as stereotactic techniques increasingly enable surgeons to successfully remove deeper structures (Kelly, 1986), possibly increasing the amount of subcortical tumor patients being treated surgically and consequently undergoing pre-operative neuropsychological assessment.

Secondly, methodological remarks can be made regarding the study design. As the weak lateralisation hypothesis (Laeng, 2006; Trojano & Conson, 2008) states that left hemispheric visuoconstructional impaired patients are characterized by executive disorders and right hemispheric patients by visuo-spatial deficits, ideally the patient groups should be divided into left and right hemispheric brain damaged patients per group. This way, this lateralisation hypothesis can be tested in stroke and tumor patients, potentially shedding new light on this hypothesis. In the current study, the sample size was not large enough to enable this study design. Future research should aim to include more patients in order to make this division.

Thirdly, some methodological matters regarding the neuropsychological assessment were suboptimal. For instance, executive functioning was not assessed holistically; only the "shifting" and "updating" components of the model described by Miyake et al. (2000) were measured. Future research should take the third component, "inhibition", into account as well. In addition, the executive tasks were *verbal* tasks. As the performance on the ROCF requires non-verbal, spatial executive functions, ideally, non-verbal measures are used in studying executive functions in relation to the ROCF. It is, for instance, possible that the executive dysfunctioning that was observed in the stroke group is influenced by the high prevalence of temporal lesions in this group, which commonly affect language functions. Future studies could for example use the Corsi Block Tapping Task (Corsi, 1972) to assess spatial working memory and the Brixton Spatial Anticipation Test (Burgess & Shallice, 1997) or the Wisconsin Card Sorting Test (Berg, 1948) to assess spatial shifting.

However, these tasks are quite global measures of executive functioning. Ideally, when assessing executive deficits in copying the ROCF, a detailed rating system is used to assess the strategies used in copying the complex figure, such as the Boston Qualitative Scoring System (BQSS; Stern et al., 1999). This way, executive processes that play a role in copying the figure, like organizational and planning abilities (Somerville, Tremont, & Stern, 2000), can be assessed more specifically. Although Miyake et al. (2000) argue that planning is generally less suitable for operationalization than their latent variables, in the case of visuoconstruction, planning is operationalized adequately by rating systems like the BQSS (Somerville et al., 2000). However, the current study lacked such a detailed rating system, as the neuropsychological assessment was part of standard clinical care and therefore left little possibilities for manipulation of the tasks. Future research should aim to include such a system in assessing executive functioning in visuoconstruction.

Besides these limitations, the current study has several strengths. Firstly, this study is one of the few studies that directly compared stroke and tumor groups neuropsychologically, and to our knowledge the only study that compared them on visuoconstruction. Secondly, the fact that the tumor group was subdivided into LGG and HGG patients allows more detailed analysis of the tumor group. Thirdly, the tumor patients were assessed pre-operatively. As surgery can change cognitive functioning (Habets et al., 2014; Satoer et al., 2016; Talacchi et al., 2011), this ensures that the results represent the damage that was caused by the tumors. Finally, it should be mentioned that despite the relatively low amount of patients in the separate groups, the power is not affected, because we focused on a small amount of predictors.

To conclude, the current study reveals many similarities and differences between stroke and tumor groups in studying visuoconstruction. It shows that although there is no difference in amount of visuoconstructively *impaired* patients between the groups, stroke patients generally perform worse compared to tumor patients. In addition, it shows that tumors can result in specific deficits, and HGG patients are more impaired than LGG patients on executive tasks only. Furthermore it shows that stroke and tumor patients cannot be grouped together when studying *performance* on visuoconstruction or –perception, but stroke and HGG patients can be grouped together when studying performance on executive functioning. In addition it reveals differences in lateralisation and demonstrates different components that contribute to visuoconstruction between the groups. Thus, studying the different patient groups separately can lead to different conclusions about visuoconstruction. This demonstrates the importance of studying more than one aetiology with regards to visuoconstruction. Nevertheless, the fact that visuoperception played a role in LGG patients and executive functioning in HGG patients and both played a role in stroke patients, means that adding the tumor patient groups to the stroke population leads to convergent findings on the underlying mechanisms of visuoconstruction. In addition, tumor patients showed specific lesions and did not differ in amount of visuoconstructive impairments. Therefore we argue that including both aetiologies is a pragmatic procedure for studying visuoconstruction. This enables the use of large sample sizes, which increases the robustness of neuropsychological findings (Wallenstein, Zucker & Fleiss, 1980). It should be noted however, that this does not mean that the findings can be generalized over the different aetiologies. Future research should assess the influence of handedness and lesion location on these analyses, improve the methods of testing executive functioning and assess the influence of the different components in left and right brain damaged patients by analyzing these hemispheres separately per group. Furthermore, it would be interesting to investigate the influence of including subcortical tumor lesions in the analyses. These recommendations could help further discover whether stroke and tumor patients can be studied together in light of visuoconstruction. The current study, however, provides promising indications for combining the two aetiologies.

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Appendix 1:

Results of a 'quick and dirty' analysis of excluding subcortical stroke patients from the study sample in the current study

Demographic information

Table 1. *Demographic information of the study population*

	Stroke (n = 42)	**LGG (n = 35)**	**HGG (n = 56)**
Age in years (SD)	57.4 (15.7)	39.4 (11.3)	57.4 (12.6)
Gender (%)			
Female	20 (47.6)	13 (37.1)	14 (25.0)
Male	22 (52.4)	22 (62.9)	42 (75.0)
Education level (%) *			
Low (1-5)	27 (64.3)	13 (37.1)	32 (57.1)
High (6-7)	15 (35.7)	22 (62.9)	24 (42.9)
Dominant hand (%)			
Right	36 (85.7)	19 (54.3)	32 (57.1)
Left	4 (9.5)	2 (5.7)	7 (12.5)
Ambidexter	1 (2.4)	0 (0)	2 (3.6)
Missing	1 (2.4)	14 (40.0)	15 (26.8)
Time in days between symptom onset and assessment (median)	6.0 (M = 8.4, SD = 7.1), range = 2 – 34		

Table 2. *Location of the lesion per lobe in the stroke, LGG and HGG groups (n, %)*

	Stroke (n = 42)	**LGG (n = 35)**	**HGG (n = 56)**
Frontal	7 (16.7)	13 (37.1)	22 (39.3)
Temporal	12 (28.6)	8 (22.9)	10 (17.9)
Parietal	2 (4.8)	8 (22.9)	12 (21.4)
Occipital	7 (16.7)	0 (0)	0 (0)
Insular	5 (11.9)	5 (14.3)	7 (12.5)
Central	9 (21.4)	1 (2.9)	5 (8.9)

Table 3. *Left and right hemisphere distribution in the stroke, LGG and HGG groups (n, %)*

	Stroke (n = 42)	**LGG (n = 35)**	**HGG (n = 56)**
Left hemisphere	17 (40.5)	25 (71.4)	45 (80.4)
Right hemisphere	25 (59.5)	10 (28.6)	11 (19.6)

Patterns of impairments and functioning in stroke, LGG and HGG patients

Table 5. *Amount and percentage of impaired patients on the ROCF, JLO, Letter Fluency and Digit Span test per patient group (n, %)*

	Stroke (n = 42)	**LGG (n = 35)**	**HGG (n = 56)**	**p-value**
ROCF	16 (38.1)	5 (14.3)	10 (17.9)	.022
JLO	14 (33.3)	0 (0)	5 (8.9)	< .0001
Letter Fluency	13 (31.0)	5 (14.3)	17 (30.4)	.170
Digit Span	6 (14.3)	0 (0)	7 (12.5)	.073

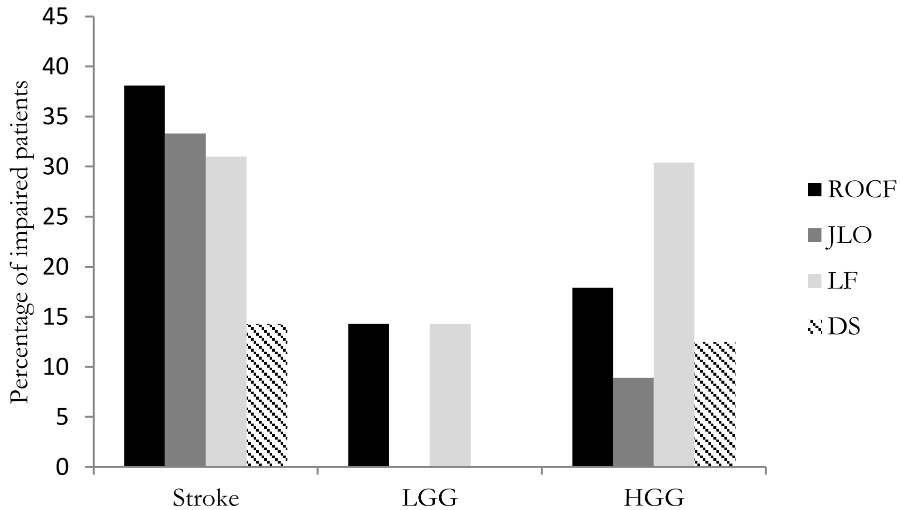

Figure 1. Percentage of patients that are impaired on the ROCF, JLO, Letter Fluency and Digit Span per patient group.

Table 6. *Mean performance on the ROCF, JLO, Letter Fluency and Digit Span test per patient group*

	Stroke (n = 42)	**LGG (n = 35)**	**HGG (n=56)**
Corrected ROCF score (M, SD)	27.9 (6.2)[a, b]	31.5 (2.4)	31.5 (3.2)
Corrected JLO score (M, SD)	20.8 (6.6)[a, b]	28.3 (2.5)	26.6 (4.8)
Letter Fluency z-scores (M, SD)	-1.3 (1.1)[a]	-0.6 (1.1)[b]	-1.2 (1.1)
Digit Span scaled scores (M, SD)	7.9 (2.8)[a]	10.8 (3.1)[b]	8.9 (2.9)

a = differs significantly from LGG, *b* = differs significantly from HGG

Lateralisation of visuoconstruction

Stroke

There was a significant difference in the amount of left and right hemisphere patients that were impaired on visuoconstructive tasks in the stroke group χ^2 (1) = 8.396, p = .004, with 87.5% of the impaired patients on visuoconstruction having right hemisphere damage, and 12.5% of the impaired patients suffering left hemispheric damage.

The role that visuoperception and executive functioning play in visuoconstruction

Stroke

It was found that the JLO explained a significant amount of the variance in the performance on the ROCF in stroke patients, F (2,39) = 20.625, p < .0001, adjusted R^2 = 0.489, after controlling for lateralisation. Lateralisation accounted significantly for variance in the ROCF, β = -.255, t(41) = -2.238, p = .031, and explained a significant 14.1% of the variance, R^2 = .141, F(1, 40) = 6.571, p = .014. The JLO significantly predicted ROCF performance, β = .623, t(41) = 5.471, p < .0001, and accounted for an additional 37.3% of the variance, ΔR^2 = 0.373, ΔF (1, 39) = 29.93, p < .0001. The regression coefficients are specified in table 7.

Table 7. *Unstandardized (B), standard errors (SE B) and standardized (β) regression coefficients for each predictor in the stepwise multiple regression models for visuoconstuction in stroke patients.*

	B	**SE B**	**β**
Step 1			
Constant	35.461	3.077	
Lateralisation	-4.725	1.843	-.376*
Step 2			
Constant	20.758	3.566	
Lateralisation	-3.203	1.432	-.255**
JLO corrected score	0.591	0.108	.623*

*p <.01, **p <.05