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Right-left orientation and spatial abilities in patients with right and left hemispheric lesions and controls

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Abstract

Primary Objective: To study whether deficits in right-left orientation (rlo) exist on a larger scale in patients with right or left hemispheric brain injury compared to healthy controls, and to study the connections between rlo and spatial abilities.

Research Design: A matched groups design was adopted to examine differences in the applied measures.
Methods and Procedures A new measure of rlo was applied. Further tests were used covering visual memory, mental rotation, handedness, and visuo-construction. 69 healthy controls and 82 patients suffering from right (n=51) or left (n=31) hemispheric brain lesions were examined and tested individually during one hour periods.

Main Outcomes and Results: There were no significant differences in the performance of the rlo task. A significant difference was found in the visuo-constructive task between both patient groups and the controls. Patients with left hemispheric lesions scored lower than the controls in mental rotation. The prevalence of massive deficits in rlo was twice as high in the combined patient groups than in the controls.

Conclusions: Theories of lateralization of rlo and spatial abilities were not supported. The groups did show differing patterns of intercorrelations. This gave rise to the idea of different compensatory strategies for solving spatial tasks resulting in comparable outcomes which was not confirmed in further analyses.

Introduction

The ability to discriminate right from left plays an important role in everyday life. For example, it is of vital importance to find one's way in an unknown place according to descriptions like "turn right at the third junction." Importantly, there is a significant percentage of people having difficulties in differentiating right from left. Optometrists find in 6% of their patients a permutation of the right and left contact lenses (McMonnies, [1]). Driving instructors also complain about the fact that some of their students are not able to reliably tell right from left in stressful situations (Besuden, [2]).

According to clinical observations, patients with brain injuries often have difficulties with this basic decision. This group is especially likely to be affected in coping with a new environment and in daily life activities, such as clothing oneself. It is therefore important to identify such deficits as early as possible and integrate this cognitive ability into neuropsychological interventions. However, few studies have been done on this matter.

Definition of right-left orientation

By exploring literature regarding right-left orientation (rlo), it appears that right-left orientation itself can be understood as a more global term comprising various abilities of different complexity (Benton and Sivan, [3]). Furthermore, similar words such as 'right-left discrimination' or 'right-left differentiation' are used – often with the same word being used by various authors but meaning something different.

In Rigal's [4;5] opinion, rlo consists of three complementary aspects. The first, right-left discrimination (rld) refers to the ability to discriminate two simultaneously shown symmetrical stimuli (mirror images). The second is recognition, which requires memory. It builds upon rld and means the ability to decide whether a particular stimulus is identical to a previous one. Only the third aspect of rlo demands the appearance of the labels 'right' and 'left', either as the stimulus in a question, or in the answer 'Lift your right arm!'. The correct usage of those two words can be regarded as the most developed (third) aspect of rlo.

In cognitive abilities no single process or cause is sufficient for the result of a task. Therefore, it is unlikely that rlo is based on a single factor. Depending on the task, it is probable that perceptual, memory, visual-spatial-cognitive, and linguistic capacities are challenged. The author's understanding of the rlo concept also needs to be taken into consideration. Similar terms are often used as analogies whose differences are not clearly stated. An explanation of which of the above defined aspects used to embrace their chosen term may also not be available. Depending on the researcher, rlo combines perception, memory, spatial orientation, mental imagery, and language. The characteristics of the stimulus material are also said to influence the ability to discriminate.

Rlo and laterality

Numerous studies have investigated rlo in connection with laterality. Rogers [6] found that male students did not have a better right-left discrimination than female students (n=30). This did not support the assumption of males being more lateralized. A significant correlation was found between right-left discrimination and recognition of spatial relations.

Bakan and Putnam [7] found right-handed males to be significantly better than right-handed females in the Culver Lateral Discrimination Test. This test requires identifying shown body parts as belonging to the right or left side of a body. A non-significant trend was shown for left-handed males to be better than left-handed females. According to Bakan and Putnam right-left discrimination is a spatial ability in which males also scored higher in other studies.

Another approach taken to interpret these results takes into consideration that female brains are less functionally asymmetrical than males (Kolb and Whishaw, [8]). This explains females' greater difficulties distinguishing between right and left.

Similar heterogeneous results can also be found in further studies, such as Manga and Ballesteros [9] and Hannay, Leli, Falgout, Katholi and Halsey [10]. Some results were contradictory, as there are indications for and against a smaller lateralization in women. Furthermore, in some studies, bilateral activity during tasks of rlo was found in both genders.

Clinical studies of rlo

In 1940 Josef Gerstmann reported a frequent association of finger agnosia (deficit in naming the fingers), right-left disorientation, dyscalculia and dysgraphia. This later became known as the "Gerstmann Syndrome."

This phenomenon was first associated with lesions of the left parietal lobe, but has also been observed in diffuse brain lesions. In one study Benton [11] addresses the question of whether the Gerstmann Syndrome should be understood as a diagnostic category. One hundred patients with and 100 without cerebral brain lesions completed a test battery covering rlo, finger localization, calculating, writing, reading, and praxia. The correlations between the 4 postulated symptoms believed to account for the syndrome are not higher than the correlations between other combinations of the tests used. In a subgroup of 12 patients with left parietal lesions, similar results were found. Looking at these results, the theoretical speculations about the anatomical substrates of the Syndrome appear not to be supported..

Benton considers the Gerstman Syndrome to be fictional and to be a result of distorted observations. Benton [12] asserts that neither broader examinations nor detailed single case studies provided indications of the Gerstmann Syndrome being anything more than a random group of deficits lacking neuropsychological significance. In Benton's review of studies of this phenomenon a large overlap between the assumed symptoms and aphasia is especially prevalent.

In a similar way, Critchley [13] made critical comments in his analysis of the literature about the Gerstmann Syndrome. Benke´s [14] opinion is that the Gerstmann Syndrome is a concept already falsified, but which is still important from a theoretical perspective because it points out the importance of a critical empirical usage of the term 'syndrome'.

There are very few studies with neurological patients that concern themselves with rlo. Fischer, Marterer and Danielczyk [15], Kálmán, Magloczky and Zoltan [16], and Rainville, Marchand and Passini [17] conducted studies with demented patients. With positron emission tomography (PET), Fischer et al. [15] discovered that dementia of the Alzheimer type (DAT), which exists twice as often as dementia of the multi infarct type (MID), leads to abnormal temporal parietal occipital structures. Disturbed rlo was the consequence in DAT when this region was lesioned, regardless of which hemisphere the region is located. DAT patients only showed deficits in rlo regarding their own body if they suffered from severe dementia. They also showed significant symptoms of aphasia. The authors assume a primary degenerative dementia causing a gradual decrease of cognitive abilities. This goes along with a breakdown of the right-left concept. The MID patients showed correlations with language and visuo-spatial functions depending on the location of the lesion. The authors conclude that a strong linkage between a global inability in rlo and aphasia should exist. More recent studies aiming at patients with brain lesions were not found, so our study should be one of the first in this area.

The aim of the current study was to clarify whether difficulties in rlo were more common in people after brain injury and if there was a difference in rlo between right and left hemispheric lesions. Furthermore the question was addressed whether rlo has significant associations with spatial abilities and if these associations differ in people with brain injuries and healthy controls.

Method

Participants

The healthy control group consisted of 69 people with 35 men (50.7%) and 34 women (49.3%). At the time of investigation, the mean age was 62.93 years (SD=10.04; Range: 45-85 years). Sixty three people (91.3%) called themselves right-handed, five (7.2%) left-handed, and one person (1.4%) stated that he is able to use both hands equally. Six people (8.7%) said they prefered to use the left hand when they were children but were trained to use the right hand. Difficulties in discriminating right and left were denied by 60 people (87.0%), admitted by six (8.7%), and three people (4.3%) said they ‘sometimes’ had difficulties.

Participants in this research were patients at the Odebornklinik Bad Berleburg and referred by the treating psychologist and physician and also by reviewing patients’ files. Patients with other physical problems, such as visual or auditory problems that could not be treated by eyeglasses or hearing aids, as well as those having significant deficits in memory or concentration, and significant motor restrictions of both hands and arms were excluded. If there were any doubts about their suitability for the study, the Syndrom-Kurz-Test (SKT) by Erzigkeit [18] was administered to screen for memory or attention deficits. Patients who then showed to have severe cognitive deficits were excluded.

Tables 1 and 2 list the main diagnoses separated for right and left hemispheric brain lesions.

Table 1: Main diagnoses of patients with right hemispheric brain lesions (n=51).

main diagnosis	number of patients	percentage
arteria cerebri media infarction	20	39.2%
brain stem infarction	8	15.7%
right hemispheric infarction without further localization	5	9.8%
subarachnoidal bleeding (SAB)	3	5.9%
basal ganglia infarction	3	5.9%
basal ganglia bleeding	2	3.9%
closed head injury	2	3.9%
cerebellar infarction	2	3.9%
capsula interna infarction	1	2.0%
medulla oblongata infarction	1	2.0%
arteria posterior infarction	1	2.0%
cerebellar bleeding	1	2.0%
basal ganglia ischaemia	1	2.0%
brain tumor	1	2.0%

The group of patients with right hemispheric brain lesions consisted of 30 men (58.8%) and 21 women (41.2%). At the time of examination the mean age for women was 63.3 years (SD 9.5; Range: 45-76 years) and 61.7 years (SD 9.8; Range: 40-80 years) for men. Omitting gender created a mean age of 62.4 years (SD 9.6; Range: 40-80).

Table 2: Main diagnoses of patients with left hemispheric brain lesions (n=31).

main diagnosis	number of patients	percentage
arteria cerebri media infarction	9	29.0%
brain stem infarction	5	16.1%
left hemispheric infarction without further localization	4	12.9%
cerebellar infarction	3	9.7%
subdural haematoma	3	9.7%
medulla oblangata infarction	1	3.2%
arteria cerebri posterior infarction	1	3.2%
subarachnoidal bleeding (SAB)	1	3.2%
basal ganglia bleeding	1	3.2%
persistent reversible ischaemic neurological deficit (PRIND)	1	3.2%
transitory ischaemic attack (TIA)	1	3.2%
meningeoma	1	3.2%

The group of patients with left hemispheric brain lesions consisted of 22 men (71.0%) and 9 women (29.0%). At the time of examination, the mean age for women was 66.2 years (SD 10.7; Range: 50-79 years) and 64.0 years (SD 8.4; Range: 47-82 years) for men. Omitting gender created a mean age of 64.7 years (SD 9.0; Range: 47-82). The main diagnosis in both patient groups is infarction of the arteria cerebri media (right: 39.2%; left: 29.0%), followed by brain stem infarction (right: 15.7%; left: 16.1%). Both patient groups were heterogeneous as is typical in clinical neurology, but this must be taken into consideration when interpreting the results. For further analyses the control group was matched with the clinical groups regarding number, age, gender, education, and socioeconomic status.

Procedure and instruments

To assess the rlo, we modified the second version (2003) of the card game ‘Rinks & Lechts – Links ist da, wo der Daumen rechts ist, oder?’ (‘Reft & light – left is where the thumb is right, isn't it?’), which was developed by Staupe and Freudenreich in 2000. Photographs of the game can be seen at www.amigo-spiele.de/upload/rinks_und_lechts_1089.pdf. This game consists of cards with police officers and cards with task instructions. Both sets of cards show one out of seven symbols (e.g. house) which marks the beginning symbol. On each police card, either a policeman or policewoman is shown from the front or back view. The cards with task instructions have three orders (e.g. 3 right, 2 left, 2 right).

The police cards are placed in a circle on a table creating the testing area. Here tasks need to be accomplished by following one order after the other. The rule ‘right’ = clockwise and ‘left’ = counter clockwise does not apply for the tasks. Instead, for each task card, the decision of left and right has to be recognized from each police officer’s point of view three times. This can be a challenge to some participants because the direction of the police cards is up or down while others appear to lie on their side because of the circular arrangement.

The card game in the 2003 version consists of 43 task cards. Twenty one task cards were used that are identical to the ones of the original game (first version 2000) and all seven police cards. Additionally, two other task cards served as training examples. The standardized order of the police cards placed in a circle resulted from experimental variation of the police cards combined with the task cards. This was determined before the first examination. In this way, each police card was utilized almost equally as a starting and finishing point.

Before the examination began, participants were asked to name the symbol they saw on the edge of each of the police cards in order to check their recognition and correct naming. Participants were also shown two example cards to learn the mode of the tasks. For each task card three orders need to be followed, one after the other. The symbol on the task card indicates where the beginning is (the police officer card with matching symbol). From this point, the first order (e.g., 3 left) needs to be followed from the perspective of the police officer. Ofte [19] asserts this requires the ability to switch perspectives. From this position the participant counts three cards to the left, leaving out the starting card. The card where the participant ends up after the first order is now the starting point for the second order, continuing in the same manner with the third order. After the third order, the symbol on the police card where the participant ends up is named or pointed at; therefore the instrument can be considered as a measurement of performance. Feedback discussing the results or steps before was not allowed.

The instructor presents all 21 task cards in their numbered order, which was fixed in advance through the presentation mode. Depending on the working speed of the participant, the total duration was between 10 to 25 minutes. There is no time limit for each task. One point can be scored for each card if the answer after the third order is correct. A total score of 21 points is possible.

Further information about ‘Rinks & Lechts’, as well as detailed instructions and a scoring sheet are available from the first author. A basic examination of the test regarding quality criteria is covered elsewhere (Hirsch, Schlötterer, Gesewsky, Ferlings and Röhrle, [20]).

Further instruments used were:

- Pattern Recognition (PE) [Subtest 4 of the Berlin Amnesia Test (BAT; Metzler, Voshage and Rösler, [21]]. A pattern is shown for five seconds and then has to be recognized out of four shown patterns. The maximum score is 10 points.

- Mental Rotations Test (MRT-A) by Peters, Laeng, Latham, Jackson, Zaiyouna und Richardson [22] with a maximum score of 24 points.

- Block Design (BD) of the German version of the Wechsler Adult Intelligence Scale-III (von Aster, Neubauer, and Horn, [23]). Age-corrected norms were used for this subtest.

- Hand Dominance Test (HDT; Steingrüber and Lienert, [24]). The HDT consists of three subtests: tracing a track, pointing circles and pointing squares with a pen. The dominance of one hand over the other is calculated manually and theoretical scores from –100 (extreme sinistry) to +100 (extreme dexterity) can occur.

- Edinburgh Handedness Inventory (EHI). The EHI was only applied in the patient groups as a substitute for the HDT because some of them were not able to do the necessary finger movements due to paresis.

Spearman correlations were calculated to document associations between the different measurements because of non-normality. Multivariate analyses of variance (MANOVAs) were performed to compare the different groups.

Results

Controls

Table 3 shows the Spearman correlations between the applied neuropsychological measures in the control group (n=69).

Table 3: Intercorrelations of all applied tests in the control group (n=69).

		pattern recognition (BAT)	**mental rotations test (MRT-A)**	**hand-dominance-test (HDT)**	**block design (BD)**
‚Rinks & Lechts‘ total score	r	.13	.29	.09	.33
	sgn	.279	.016	.454	.006
pattern recognition (BAT)	r		.20	-.20	**.39**
	sgn		.094	.120	**.001**
mental rotations test (MRT-A)	r			.20	.20
	sgn			.103	.094
hand-dominance-test (HDT)	r				-.20
	sgn				.120

sgn = significance (2-tailed)

After Bonferroni-correction (p=0.05/10=0.005) there was only one significant correlation between pattern recognition (BAT) and block design (BD) (r=0.39). There were non-significant correlations between the total score of ‘Rinks & Lechts’ and the mental rotations test (r=0.29) and with block design (BD) (r=0.33).

Table 4 shows the means of the neuropsychological tests by gender. From the univariate inspection of the data, one can see a large difference in the mental rotations test (MRT-A) in favour of the men. The effect size d=0.71 can be considered as quite high (Cohen, [25]).

Table 4: Comparisons of means between males and females in the control group (n=69).

	group	n	Mean	sd	d
‚Rinks & Lechts‘ total score	men	35	17.17	4.92	0.19
	women	34	16.26	4.88	
	total	69	16.72	4.89	
pattern recognition (BAT)	men	35	7.14	1.70	-0.37
	women	34	7.74	1.56	
	total	69	7.43	1.65	
mental rotations test (MRT-A)	men	35	10.00	6.70	0.71
	women	34	6.24	3.85	
	total	69	8.14	5.77	
hand-dominance-test (HDT)	men	35	32.81	18.70	0.28
	women	34	27.62	18.86	
	total	69	30.25	18.82	
block design (BD)	men	35	9.89	2.70	-0.04
	women	34	10.00	2.67	
	total	69	9.94	2.67	

d= univariate effect size

Table 5: Results of ANOVA with factor ‘gender’ in the control group (n=69).

	F	P	partial eta^2
‚Rinks & Lechts’ total score	.590	.445	.009
pattern recognition (BAT)	2.267	.137	.033
mental rotations test (MRT-A)	**8.115**	**.006**	.108
hand-dominance-test (HDT)	1.322	.254	.019
block design (BD)	.031	.860	.000

Table 5 shows the only significant difference between men and women was found in the total score of the MRT-A, which was an effect of middle size referring to Tabachnik and Fidell [26] and to Cohen [25]. In the total score of ‘Rinks & Lechts’, a significant gender difference could not be found.

Controls versus patients with right hemispheric lesions

The controls and the patients with right hemispheric lesions were matched according to number, gender, age, and socioeconomic status. Each resulting group consisted of 51 participants. Table 6 shows the Spearman correlations between the neuropsychological measures in patients with right hemispheric lesions. Measures of handedness are excluded because a performance test could only be applied in the controls.

Table 6: Intercorrelations of applied tests in patients with right hemispheric brain lesions (n=51).

		pattern recognition (BAT)	mental rotations test (MRT-A)	hand-dominance-test (HDT)
‚Rinks & Lechts‘ total score	r	**.58**	**.56**	.36
	sgn	**.000**	**.000**	.009
pattern recognition (BAT)	r		**.60**	**.50**
	sgn		**.000**	**.000**
mental rotations test (MRT-A)	r			**.45**
	sgn			**.001**

sgn = significance (2-tailed)

After Bonferroni correction (p=0.05/6=0.008), five of the six correlations in Table 6 are significant. Right-left orientation has high associations with visual memory and mental rotation. Comparable strong associations can be found between visual memory, mental rotation, and visuoconstruction.

All correlations were tested for group differences between controls and patients with right hemispheric damage (rh) (Bortz, [27]). The rh group had a significantly (p=0.03) higher correlation (r=0.58) between the total score of 'Rinks & Lechts' and pattern recognition (BAT) than the controls (r=0.11). A further correlation just failed to reach significance (p=0.09) and can therefore only be interpreted as a trend, with the rh group having a higher correlation (r=0.60) than controls (r=0.28) between BAT and MRT-A.

Table 7 shows the means of the neuropsychological tests by group membership. From the univariate inspection of the data, one can see a large difference in block design (BD) in favour of the controls. The effect size d=0.80 can be considered as high (Cohen, [25]).

Table 7: Mean comparisons between the control group and the patients with right hemispheric brain lesions (rh) (n=51 each).

	group	mean	sd	d
‚Rinks & Lechts' total score	controls	16.35	5.09	0.31
	rh	14.63	5.99	
pattern recognition (BAT)	controls	7.39	1.71	0.46
	rh	6.49	2.17	
mental rotations test (MRT-A)	controls	8.55	6.39	0.37
	rh	6.51	4.77	
block design (BD)	controls	9.88	2.84	0.80
	rh	7.71	2.58	

d= univariate effect size

MANOVA was significant [Pillai´s trace 0.15, F(4,97)=4.10, p=0.004] with an effect size of η^2=.145 (partial eta-square) to be of middle size (Tabachnik and Fidell, [26]). Since MANOVA showed differences between the controls and the rh group, ANOVA was calculated to find out in which variables these differences existed.

Table 8: Results of ANOVA between the control group and patients with right hemispheric brain lesions (n=51 each).

	F	p	partial eta^2
‚Rinks & Lechts' total score	2.459	.120	.024
pattern recognition (BAT)	**5.446***	**.022**	.052
mental rotations test (MRT-A)	3.335	.071	.032
block design (BD)	**16.415****	**<.001**	.141

As can be seen in table 8, two differences became significant. These are the scores in BAT (p=0.022) and BD (p<0.001), which are to be understood as small (BAT) and middle (BD) effects, according to Tabachnik and Fidell [26], and small (BAT) and big (BD) effects according to Cohen [25]. No significant difference was found between the healthy controls and the rh group for the total score in 'Rinks & Lechts'.

Controls versus patients with left hemispheric lesions

The controls and the patients with left hemispheric lesions (lh) were matched according to number, gender, age, and socioeconomic status. Each resulting group consisted of 31 participants. Table 9 shows the Spearman correlations between the neuropsychological measures in the patients with left hemispheric lesions. Measures of handedness are excluded because a performance test could only be applied in the controls.

Table 9: Intercorrelations of applied tests in patients with left hemispheric brain lesions (n=31).

		pattern recognition (BAT)	mental rotations test (MRT-A)	block design (BD)
‚Rinks & Lechts' total score	r	.08	-.01	.36
	sgn	.685	.956	.044
pattern recognition (BAT)	r		.30	.25
	sgn		.103	.171
mental rotations test (MRT-A)	r			.23
	sgn			.225

sgn = significance (2-tailed)

After Bonferroni correction (p=0.05/6=0.008), none of the six correlations in table 9 are significant. This is a striking difference to the correlational pattern in patients with right hemispheric lesions.

It was confirmed that the correlations did not differ significantly between the controls and the lh group (Bortz, [27]). Only a few trends were found. For example, the controls showed a trend (p=0.13) of having a higher correlation (r=0.29) between 'Rinks & Lechts' and MRT-A than the lh group (r=-0.01). This means controls and the lh group do not show any different patterns of correlations.

Table 10 shows the means of the neuropsychological tests by group membership. From the univariate inspection of the data, one can see a large difference in block design (BD) in favour of the controls. The effect size d=0.91 can be considered as high (Cohen, [25]). Medium effect sizes in favour of the controls can be seen in mental rotation and right-left orientation.

Table 10: Mean comparisons between the control group and patients with left hemispheric lesions (lh) (n=31 each).

	group	mean	sd	d
‚Rinks & Lechts' total score	controls	17.29	4.41	0.48
	lh	14.77	6.06	
pattern recognition (BAT)	controls	7.16	1.92	0.29
	lh	6.61	1.84	
mental rotations test (MRT-A)	controls	8.90	6.31	0.59
	lh	5.97	3.71	
block design (BD)	controls	10.10	2.47	0.91
	lh	7.97	2.21	

d= univariate effect size

MANOVA was significant [Pillai´s trace 0.20, F(4,57)=3.59, p=0.011] with an effect size of η^2=.20 (partial eta-square) to be of middle size (Tabachnik and Fidell, [26]). Since MANOVA showed differences between the controls and the lh group, ANOVA was calculated to find out in which variables these differences existed.

Table 11: Results of ANOVA between the control group and patients with left hemispheric brain lesions (n=31 each).

	F	p	partial eta^2
‚Rinks & Lechts' total score	3.493	.067	.055
pattern recognition (BAT)	1.322	.255	.022
mental rotations test (MRT-A)	**4.991**	**.029**	.077
block design (BD)	**12.787**	**.001**	.176

Table 11 shows two significant differences between the controls and the lh group in MRT-A (p=0.029) and in BD (p=0.001). The effects are small (MRT-A) and middle (BD) according to Tabachnik and Fidell [26] or middle (MRT) and big (BD) according to Cohen [25]. The total score of 'Rinks & Lechts' was not significantly different between the controls and the lh group.

Patients with right hemispheric lesions versus patients with left hemispheric lesions

The patients with right and left hemispheric lesions were matched according to number, gender, age, and socioeconomic status. Each resulting group consisted of 31 participants. Tables 12 and 13 show the Spearman correlations between the neuropsychological measures in the two groups. A Bonferroni correction of p=0.05/6=0.008 was applied. The Edinburgh Handedness Inventory was excluded because of a ceiling effect and restriction of range.

Table 12: Intercorrelations of applied tests in patients with right hemispheric brain lesions (n=31).

		pattern recognition (BAT)	mental rotations test (MRT-A)	block design (BD)
‚Rinks & Lechts' total score	r	**.56**	**.55**	.21
	sgn	**.001**	**.001**	.263
pattern recognition (BAT)	r		**.57**	.35
	sgn		**.001**	.055
mental rotations test (MRT-A)	r			.39
	sgn			.029

sgn = significance (2-tailed)

Table 13: Intercorrelations of applied tests in patients with left hemispheric lesions (n=31).

		pattern recognition (BAT)	mental rotations test (MRT-A)	block design (BD)
‚Rinks & Lechts' total score	r	.08	-.01	.36
	sgn	.685	.956	.044
pattern recognition (BAT)	r		.30	.25
	sgn		.103	.171
mental rotations test (MRT-A)	r			.23
	sgn			.225

sgn = significance (2-tailed)

In the right hemispheric group there are quite strong associations between right-left orientation, visual memory, and mental rotation. In contrast, no correlation was significant in the left hemispheric group.

We checked for significant differences between the groups (Bortz, [27]) and found two to be significant: The rh group showed a significantly (p=0.02) higher correlation (r=0.56) between 'Rinks & Lechts' and pattern recognition (BAT) than the lh group (r=0.08). The rh group also showed a higher (p=0.01) correlation between 'Rinks & Lechts' and MRT-A (r=0.55) than the lh group (r=-0.01) and a trend (p=0.11) of a higher correlation (r=0.57) between BAT and MRT-A than the lh group (r=0.30).

In summary, in a third of the comparisons of correlations, significantly higher relations in the rh group were shown and, in one comparison, at least one trend in the same direction was significant. This confirms the assumption of different correlations between the patient groups.

Table 14: Mean comparisons between patients with right (rh) and left (lh) hemispheric brain lesions (n=31 each).

	group	mean	sd	d
‚Rinks & Lechts' total score	rh	14.94	6.32	0.03
	lh	14.77	6.06	
pattern recognition (BAT)	rh	6.71	2.13	0.05
	lh	6.61	1.84	
mental rotations test (MRT-A)	rh	7.19	4.69	0.29
	lh	5.97	3.71	
block design (BD)	rh	8.16	2.28	0.08
	lh	7.97	2.21	

d= univariate effect size

Table 14 displays the means of the two groups in the applied neuropsychological measures. MANOVA was not significant [Pillai´s trace 0.02, F(5,56)=0.27, p=0.93]. Both patient groups did not differ in their abilities, neither in 'Rinks & Lechts', nor in any other spatial test.

Prevalence of rlo in controls and patients

An analysis of extreme groups was performed. People were chosen from the controls and the combined patient groups who had less than 50% correct answers in 'Rinks & Lechts' (see table 15). In this respect there was no significant difference between the patient groups, therefore they were combined. Since the card game shows a ceiling effect in the way it was used and even the mean score varied only between 14-18 correct answers depending on the group, it seems justifiable to define an ability of less than half of the potential score as being very low.

Table 15: Categorical performance of the control group (n=69) and the total patient group (n=82) in 'Rinks & Lechts'.

	< 10 points		≥ 10 points	
	N	**%**	**n**	**%**
patients (n=82)	18	22	64	78
controls (n=69)	8	11,6	61	88,4
total (n=151)	26	17,2	125	82,8

The Chi²-Test was not significant (Chi²=2,82, p=,093, df=1) but the number of people scoring significantly low is almost twice as high in the patient group (22%) than in the control group (11,6%).

Discussion

This study examined patients with right and left hemispheric brain injuries and a healthy control group. The aim was to clarify whether difficulties in rlo are more common in people after brain injury and if there is a difference in rlo between right and left hemispheric lesions. Furthermore the question was addressed whether rlo has significant associations with spatial abilities and if these associations differ in people with brain injuries and healthy controls.

In the control group the largest association of our applied test of rlo was seen with block design (BD) (r=0.33). This correlation was not as high as expected and the correlations with the other spatial tasks showed that our rlo task is a heterogeneous mixture of different cognitive abilities.

There were no significant differences in rlo between men and women in our control group. Our results confirmed one aspect of the research showing very different outcomes regarding rlo. No gender differences in rlo were found by Ofte [19;28], Ofte and Hugdahl [29], Rigal [4;5], Rogers [6], Bakan and Putnam [7] (only left-handers), Hannay et al. [9] and also by McMonnies [1]. The higher frequency of reporting rlo difficulty by women may be a result of self-report bias, potentially caused by a more critical self-concept.

The only gender difference was found in mental rotation, as it was frequently replicated in several other studies. There was only a moderate correlation between our rlo task and the mental rotations test (r= 0.29). This could in part explain the lack of gender differences in the rlo task because it obviously does not depend heavily on mental rotation.

The patients with right hemispheric lesions (rh) showed a significantly higher correlation between our rlo task and visual spatial memory than the controls. The intercorrelations in the rh group between the applied tasks were much more homogenous than in the control group. This patient group had high associations between the rlo task and visual spatial memory and mental rotation. No significant difference was found in the rlo task, but the controls were significantly better in visual spatial memory and visuo-construction than the rh group.

It seems that the lesions in the rh group did not have an overall effect on the spatial functions relevant in this study. Right-left orientation was obviously not greatly affected by right hemispheric brain injury. In solving the rlo task, rh patients relied heavily on visual spatial memory and mental rotation. This was surprising because the right hemisphere is said to play an important role in the latter task (Kolb and Whishaw, [8]). Therefore, we could not replicate the results of Hécaen, De Agostini and Monzon-Montes [30] who found the right hemisphere to be of importance for tactile and visual spatial perception in patients with brain lesions and controls.

There were no significant differences in the correlational patterns between the patients with left hemispheric brain injury (lh) and the control group. In this patient group mental rotation and visual spatial memory were unrelated to our rlo task. There was only a slight association with visuo-construction.

The control group scored significantly higher in mental rotation and visuo-construction than the lh group. This was counterintuitive because the lh patients had functioning right brains and so should not be worse than the rh patients compared to the control group, especially in mental rotation. The left hemisphere could be of greater importance in spatial abilities than is currently thought.

The correlational patterns in both patient groups were very different. The rh group had significantly greater associations between the rlo task and visual spatial memory and mental rotation than the lh group. Depending on the side of the lesion, it seemed that totally different strategies to solve the rlo task were applied. Surprisingly, both groups did not differ significantly in the rlo task or in any other test in this study.

Thus, our results did not replicate the results of Hécaen et al. [30] or those of Ditunno and Mann [31]. The last two authors proposed a relative specialization of the right hemisphere for tasks similar to our mental rotation task. The results of Rogers [6] and Serrati et al. [32] were replicated who did not find differences in an rlo task between the right and the left hemisphere. The rh group probably had damage in less important modules, or in the lh group other important modules are affected, which could be the reason why the lh group does not score better. However, there are also studies that consider the importance of the left hemisphere for spatial functions (McGlone and Davidson, [33]), in particular for rlo (McFie and Zangwill, [34]). If that is the case, patients with left hemispheric lesions should show smaller intercorrelations. Serrati et al. [32] used transcranial doppler sonography while having healthy right handed people solve mental rotation tasks and right-left-discrimination tasks. Both hemispheres were activated equally. These results correspond to our results in the aspect of not having found differences between the rh group and the lh group in any spatial test, neither in mental rotation, nor in rlo among others.Our results regarding mental rotation are also supported by those of Vingerhoets, Lannoo and Bauwens [35].

Referring to Margolin´s [36] model of multiple representations, according to Schneider and Detweiler [37], our results of different associations in the investigated subpopulations give rise to the idea that different lesions in various areas lead to different compensation strategies. The results of further analyses did not support this idea. The time between brain lesion and testing in both patient groups was dichotomized by the median and Mann-Whitney U-tests were calculated in both groups. In the rh group there was no significant difference in rlo ($z=-.31$, $p=0.76$, $d=0.17$) between patients with earlier compared to later onset. A comparable result was observed in the lh group ($z=-.58$, $p=0.57$, $d=0.11$). Thus, there seems to be little evidence for compensation strategies in either patient group.

It is concluded that lesions in the right hemisphere do lead to the fact that, in relation to rlo, other tests are of more importance than is the case in healthy people and in people with left hemispheric lesions. Nevertheless, the cause of these differing correlations, especially their slopes, remains unclear. Furthermore, the correlations in the lh group showed neither significant improvements nor differences to those of the controls.

Conclusions and Implications

According to our results, rlo is not a lateralized cognitive function. Rogers [6] and Serrati et al. [32] similarly did not find any hemispheric preference for rlo. An interhemispheric exchange could be responsible for this finding, in that the left hemisphere might play an important role as an ‘organisator’or ‘moderator’ for spatial functions processed in the right hemisphere (Hugdahl and Davidson, [38]). Another possible explanation could be the way information is organized in neural networks. If that is the case, a separation in right versus left hemisphere would not necessarily evoke varying patterns of correlations, nor would it show any different results in right versus left hemispheric patients because all information would be processed in a less lateralized way as assumed.

Why are there no significant differences in rlo between the patient groups and the controls? Ofte [19] says that children and adolescents get more correct answers the more concrete the stimuli. Perhaps the cards of the game ‘Rinks & Lechts’, which was constructed for children age six and up, are too easy to be used for differential diagnosis in adults – whether healthy or brain injured. So far it can be used just as a screening instrument for more severe deficits in rlo. Since our analysis of extreme groups revealed that the prevalence of massive difficulties in rlo is almost twice as high in the combined patient groups compared to the control group, it is recommended to integrate this area into routine neuropsychological evaluations after serious brain injury.

To our knowledge this is the first study which examined rlo in clinical groups in a more detailed fashion. Further studies could apply several measures of rlo in different clinical groups and examine their interrelationships and their associations with several aspects of spatial abilities.

Another interesting point for future studies might be to explicitly conceptualize rlo as a decision making process. Attempts to link this phenomenon with research in the area of decision making have been scarce. Participants who have difficulties in discriminating right from left face a decision under uncertainty [39]. If they are aware of their difficulties they are in a situation of expected uncertainty, if not, they may find themselves in unexpected uncertainty [40]. This might have differential influences on the decision making process. It is also not clear how laboratory research in rlo might be transferred into real life scenarios. When the reaction times of right-handed subjects to the word “right” are faster than to the word “left” [41] and when above-below decisions are faster than front-back decisions and front-back decisions are faster than right-left decisions [42] they are isolated from the goals, contingencies, and consequences of everyday life [39]. Consequently it would be very interesting to establish a closer link between neuroscience and real life decision making.

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